CABINET OFFICE

performance and innovation unit

The Energy Review

A PERFORMANCE AND INNOVATION UNIT REPORT – FEBRUARY 2002

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FOREWORD BY THE PRIME MINISTER

Energy underpins our daily lives: it lights our streets, heats our homes, powers our industry, and fuels our vehicles. That's why securing cheap, reliable and sustainable sources of energy supply has long been a major concern for governments.

However, the energy sector is constantly changing.

The last few decades have witnessed the development of North Sea oil and gas reserves; privatisation and liberalisation in the energy sector; a shift towards gas for electricity generation; and the emergence of new renewable technologies. Electricity prices are now cheaper, and carbon dioxide emissions are lower, than 10 years ago.

There is no reason to expect that the pace of change will slow. And there are added challenges – climate change and, for the UK, resource depletion in particular – to which our energy policy needs to respond. That is why I asked the Performance and Innovation Unit to examine the long-term challenges for energy policy in the UK, and to set out how energy policy can ensure competitiveness, security and affordability in the future.

Their report looks to 2020 and beyond to 2050, sets out the key trends, and explains the choices that we face. It is difficult to predict the technological, economic and geopolitical changes that will take place during that time – and the report does not try to do so. But it makes clear how important it is to keep our options open, so that we can respond positively to changing circumstances.

Three issues stand out from the analysis:

- Diversity and security of supply are no longer only a matter of ensuring a balance of energy sources within the UK. Increased reliance on imports from Europe and elsewhere underlines the need to integrate our energy concerns into our foreign policy.
- Alongside low prices and secure supplies, climate change has become a central aspect of energy policy. Achieving global emission reductions will need major technological innovation, and I am convinced that the UK would benefit from being ahead of the game in moving to clean and low carbon technologies and in sharply improving our performance on energy efficiency.
- It is striking that both security of supply and climate change issues are truly international. The UK cannot therefore only act through domestic policies, but must address these issues via international policies and

agreement, particularly through EU market liberalisation and the Kyoto agreements.

This report is being published as a report to government, and as such is not a statement of government policy. However, I believe the report raises many of the issues we need to discuss as we develop our energy policy.

I hope that this report will launch a thorough debate. The Government will consult shortly on the issues raised in the report and will set out its detailed response in an Energy White Paper later in the year.

Tony Blair

EXECUTIVE SUMMARY

Key points

Trends in energy markets have been comparatively benign over the past 10–15 years: the UK has been self-sufficient in energy; commercial decisions have resulted in changes in the fuel mix that have reduced UK emissions of greenhouse gases; and trends in world markets and domestic liberalisation have reduced most fuel prices.

The future context for energy policy will be different. The UK will be increasingly dependent on imported oil and gas. The Californian crisis has highlighted the importance of putting in place the right incentives for investment in energy infrastructure. And the UK is likely to face increasingly demanding greenhouse gas reduction targets as a result of international action, which will not be achieved through commercial decisions alone.

The introduction of liberalised and competitive energy markets in the UK has been a success, and this should provide a cornerstone of future policy.

But new challenges require new policies. The policy framework should address all three objectives of sustainable development – economic, environmental and social – as well as energy security. Climate change objectives must largely be achieved through the energy system. Where energy policy decisions involve trade-offs between environmental and other objectives, then environmental objectives will tend to take preference.

Key policy principles should be: to create and to keep open options to meet future challenges; to avoid locking prematurely into options that may prove costly; and to maintain flexibility in the face of uncertainty. Increasingly policy towards energy security, technological innovation and climate change will be pursued in a global arena, as part of an international effort.

Within the UK, the overall aim should be the pursuit of secure and competitively priced means of meeting our energy needs, subject to the achievement of an environmentally sustainable energy system.

The UK's future energy strategy should have the following elements:

(i) energy security should be addressed by a variety of means, including enhanced international activity and continued monitoring. However, there appear to be no pressing problems connected with increased dependence on gas, including gas imported from overseas. The liberalisation of European gas markets will make an important contribution to security;

(ii) continued attention to long-term incentives is needed, though recent levels of investment in the energy industries have been healthy;

(iii) there is a strong likelihood that the UK will need to make very large carbon emission reductions over the next century. However, it would make no sense for the UK to incur large abatement costs, harming its international competitiveness, if other countries were not doing the same;

(iv) keeping options open will require support and encouragement for innovation in a broad range of energy technologies. The focus of UK policy should be to establish new sources of energy which are, or can be, low cost and low carbon;

(v) the immediate priorities of energy policy are likely to be most cost-effectively served by promoting energy efficiency and expanding the role of renewables. However, the options of new investment in nuclear power and in clean coal (through carbon sequestration) need to be kept open, and practical measures taken to do this;

(vi) the Government should use economic instruments to bring home the cost of carbon emissions to all energy users and enable UK firms to participate in international carbon trading. Achieving deep cuts in carbon would require action well beyond the electricity sector where cuts have been concentrated in recent years;

(vii) step changes in energy efficiency and vehicle efficiency are needed, with new targets for both. In the domestic sector, the Government should target a 20% improvement in energy efficiency by 2010 and a further 20% in the following decade;

(viii) the target for the proportion of electricity generated from renewable sources should be increased to 20% by 2020;

(ix) institutional barriers to renewable and combined heat and power investments should be addressed urgently; and

(x) the Government should create a new cross-cutting Sustainable Energy Policy Unit to draw together all dimensions of energy policy in the UK.

In the light of this review, the Government should initiate a national public debate about sustainable energy, including the roles of nuclear power and renewables.

Recent trends in energy markets have been benign for policy

In recent decades, the context for energy policy in the UK has been remarkably benign. The UK is currently one of just two G7 countries which is self-sufficient in energy. Energy prices have generally been falling in real terms, partly because world oil prices have fallen and partly because of the successful liberalisation of UK gas and electricity markets. UK industry and consumers, including the fuel poor, have gained. And the UK has found it easier than many other countries to achieve greenhouse gas reductions – the “dash for gas” in particular (which was driven by commercial decisions) reduced carbon emissions from electricity generation.

But the future context will be much more challenging

The future for energy policy seems likely to be much less benign for two reasons:

- issues of energy security are likely to become more important. The UK will become increasingly dependent on imported oil and gas. And the Californian energy crisis has highlighted the importance of getting incentives for new investment in energy right;
- the UK is likely to face increasingly demanding carbon reduction targets. A low carbon future, if it were to be adopted, could not be achieved on the basis of spontaneous changes within the energy system, especially when at present, one low carbon source,

nuclear power, faces a progressive run-down as existing plant reach the end of their lives and are decommissioned.

In addition, although good progress is being made towards the elimination of fuel poverty, many people continue to spend a substantial proportion of their income on fuel, largely as a result of the age and energy inefficiency of the housing stock.

New challenges require new policies

The introduction of liberalised and competitive energy markets in the UK has been a success, and competitive markets should continue to form the cornerstone of energy policy. But new challenges require new approaches. The future framework for energy policy needs to address all three objectives of sustainable development – environmental, economic and social – as well as energy security. But climate change objectives must largely be achieved through the energy system.

Consistent with this, the future aim of energy policy should be the pursuit of secure and competitively priced means of meeting the UK's energy needs, subject to the achievement of an environmentally sustainable energy system.

The strategy articulated in this review thus has three main dimensions:

- measures to address the security of the energy system;
- measures to ensure the energy system is environmentally sustainable – these are intended in particular to create options to put the UK on a path to a low carbon economy; and
- approaches which take full account of the potential costs of achieving the objectives of policy, in terms of higher energy bills.

Concerns about security need to be addressed

There are a number of reasons why security is on the agenda. These include:

- the Californian experience of electricity blackouts;
- concerns resulting from the terrorist attacks in the USA of September 11; and
- the sensitivity to the UK's future need to import gas, possibly across long pipelines and from trading partners who seem to offer less security than we are used to.

There is general agreement that a diverse energy system – both in terms of types of energy and their sources – can benefit security. Some people argue that self-sufficiency is needed for security. But this is not necessarily so. As in other markets, imports can be a valuable means of increasing diversity and reducing risks – most other G7 countries already rely substantially on imported energy. Some submissions to the review have suggested that the Government should decide the fuel mix to be used for electricity generation. This review has rejected these proposals on the grounds that they would seriously distort the efficient functioning of energy markets.

Instead, the approach taken is to view issues of security in risk management terms. Some risks are essentially international, others domestic.

There are three main ways to safeguard security:

- to make maximum use of competitive markets to meet customers' needs. A key conclusion of the review is that the liberalisation of EU gas and electricity markets is important for energy security. Liberalisation would add flexibility and depth to European energy markets, increasing substantially the resilience of the energy system;
- to create a more resilient and flexible energy system. The review considers various options for enhancing the resilience of the UK energy

system, including increased gas storage; greater use of liquid natural gas (LNG); and greater ability to use coal than would otherwise be the case. In the first instance, these are matters for market participants to address. The role of government should be to monitor the actions of market participants; to remove any barriers due to policies, such as the planning system; and to intervene directly, as a last resort, where there is clear evidence of market failure and where the benefits of intervention are likely to outweigh the costs; and

- to use international action to address global threats to energy security. On just about any scenario the UK will become more dependent on imports both for both its gas and its oil. There is little risk of there being insufficient gas available internationally: there is plenty, and 70% of the world supplies can be accessed from Europe. But the UK cannot be sanguine about the path that the gas will take from its source to the European market and the risks it may encounter *en route*. Particular concerns are:
  - the level of investment in the exporting countries;
  - investment in the transit countries; and
  - facility failure overseas.

These risks need to be monitored. They are outside the direct control of UK purchasers or the UK Government. The key is to develop strong links with trading partners, so that the UK can ensure that the benefits associated with trade are mutually recognised and delivered.

Making sure suppliers face the right investment incentives is essential

The other main area of risk to energy security is the set of issues which arise as a result of the Californian experience. Supplies of electricity were interrupted because insufficient investment had been made both in the network and in electricity generation. The Californian problems were very specific to that state and were due in considerable measure to failures in regulation, which have no parallels in the UK.

Present levels of capacity in the UK in both electricity and gas networks and in electricity generation are healthy. The processes of privatisation and liberalisation seem to have succeeded well. Even so, the situation needs to be monitored since future investment might be constrained if the wrong signals and incentives come through the regulatory structures. But there is no reason for immediate concern. Care is also needed to ensure that the anticipation of public intervention does not lead the private sector to hold back its own investment plans.

Moving to a low carbon economy poses a major potential challenge

Looking to the longer-term, the central question for energy policy is the weight to be given to environmental and other objectives. The strong likelihood of a stringent greenhouse gas target being adopted in the future is sufficient to justify giving the environmental objective a strong priority within future energy policy – especially since the energy system is the source of 80% of UK greenhouse gases and 95% of CO_2. Low carbon options also have the merit that, particularly where they are local and dispersed, they generally contribute to the security of the energy system.

This review has not considered the scientific case for carbon reductions – this was the task of the Royal Commission on Environmental Pollution (RCEP), and of bodies such as the Intergovernmental Panel on Climate Change (IPCC). Neither has the review conducted a cost-benefit analysis of the different ways of responding to the challenge: this is a matter for the international community as a whole. There is a lot of work on the possible overall costs to the economy of meeting a substantial carbon reduction target. Most estimates suggest that the impacts on GDP are likely to be small – though precise costs will depend on the methods chosen to reduce carbon, the rate of technical progress, and the scope for trading reductions elsewhere in the world.

Possible future energy worlds in 2020 and 2050 have been analysed using scenarios. Credible scenarios for 2050 can deliver a 60% cut in CO_2 emissions, but large changes would be needed both in the energy system and in society. Two opportunities stand out. Substantial improvements in domestic and business energy efficiency could be made, and there are prospects for significant improvements in energy efficiency in the transport system. Yet even if these improvements can be achieved, and even if the electricity system was to produce no carbon whatsoever, a 60% cut in CO_2 emissions could only be met if we were also to go on to make very large reductions in the use of fossil fuels as the main means of powering future vehicles. This shows the scale of the challenge.

The Government will need to make decisions about its longer-term approach to carbon reducing policies in the light of the UK's international commitments. The RCEP has proposed that the UK should adopt a strategy which puts the UK on a path to reducing CO_2 emissions by 60% from current levels by 2050. This would be in line with a global agreement which set an upper limit for the CO_2 concentration in the atmosphere of some 550 ppmv. It would be unwise for the UK now to take a unilateral decision to meet the RCEP target, in advance of international negotiations on longer term targets. Greenhouse gases are global pollutants, and it would make no sense to incur abatement costs in the UK and thereby harm our international competitiveness, if others were not contributing.

Given the strong chance that future, legally binding, international targets will become more stringent beyond 2012, a precautionary approach suggests that the UK should be setting about creating a range of future options by which low carbon futures could be delivered, as, and when, the time comes. The focus of this review is on ways of creating new options, and building upon the options we already have. Attention has been given to the cost-effectiveness of different options, both immediately and in the longer term.

There is a central role for market-based instruments and for support for innovation and R&D

A centrepiece of any long-term carbon-reducing policy should be the use of market-based instruments to put a price on carbon emissions and to help determine the most cost-effective opportunities. This need not happen immediately, but decisions about long-term approaches are needed soon, since early commitment will start to influence decisions in many markets. A central aim should be to enable the UK to participate in international carbon trading.

A vital means of increasing the range of options for the future is innovation. This is a theme that needs to pervade all areas of energy policy and a range of policies should be directed towards it. The encouragement of renewables is one means of increasing innovation and new technologies.

Central to that process will be a stronger research and development (R&D) base. A group convened by the Government's Chief Scientific Adviser (CSA) has undertaken a review of energy research to inform this review. The findings of this group suggest there is a need for much greater investment in R&D if the cutting-edge technologies for a low carbon future are to be developed. R&D will not only facilitate the achievement of environmental goals but should create valuable export opportunities for British industry. A healthy R&D base is also necessary to attract and foster the scientific expertise needed by the new industries which will arise from the innovation it stimulates. The CSA's group suggested that a national Energy Research Centre should be established to provide the focus for such scientific activity.

A step change in energy efficiency is needed

Increased energy efficiency is obviously worthwhile if it saves money. There is no point in wasting energy that can easily be saved. The scope for cost-effective energy efficiency improvement is large and new potential will continue to be created by innovation. Major energy users have the incentive to save energy, but where energy is a small part of an individual's or firm's budget the opportunities are often ignored, partly because there are risks and bother involved in making the necessary investments.

This review puts forward a programme to produce a step change in the nation's energy efficiency. At the centre would be a new target – to ensure that domestic consumers' energy efficiency improves by 20% between now and 2010, and again by a further 20% between 2010 and 2020. This would approximately double the existing rate of improvement. It is a challenging proposition. The gains in terms of energy savings in a year could reach about 0.25% of GDP by 2020, over and above the cost of the investment needed to unlock these savings.

Combined Heat and Power (CHP) – which is sometimes viewed as a form of energy efficiency – is a low cost option for carbon abatement, but not zero carbon. In the long term, it will benefit from policies that put a price on carbon. Industrial CHP is a mature technology. It does not need support to encourage "learning by doing" cost reduction, in the same way as new renewable technologies do. Yet it is important that current market and institutional barriers to CHP are removed – many of these barriers are similar to the ones confronting renewable investments. The scope for CHP will be increased substantially by micro-CHP suitable for use in homes.

An expanded role for renewables should be a key plank of future strategy

Renewables are not just a single technology but a highly flexible set of options. Some of these options will be developed under the existing Renewables Obligation. At the moment, the use of renewables nearly always costs more than the use of fossil fuels. Government support is justified for two reasons:

- use of renewables will help the UK to obtain carbon savings in the short term which helps in meeting international obligations; and
- support for renewables will induce innovation and "learning", bringing down the longer-term unit costs of the various technologies as volumes increase and experience is gained. In this way, today's investment buys the option of a much cheaper technology tomorrow. Although learning will be international, some of the new technologies – notably the marine technologies – may have particularly British applications and require UK based technological development.

In order to bring down the cost of new renewables and to establish new options, an expanded renewables target of 20% of electricity supplied should be set for 2020. The review estimates that meeting the whole of this 20% target could produce domestic electricity prices in 2020 around 5-6% higher than otherwise. The longer-term assurance which an extended target would give to the industry could, however, help to bring down the costs of supporting renewables over the next decade. The review has not come to a conclusion about the means by which the 2020 target should be delivered. This should wait upon the review of the working of the Renewables Obligation in 2006/07.

Achieving the existing target that 10% of electricity should be supplied by renewable energy by 2010 is by no means guaranteed. The renewables industry faces three institutional barriers that must be removed if it is to succeed. These are:

- the excessive discount which, following the introduction of the New Electricity Trading Arrangements, is currently imposed on the prices paid to small and intermittent generators;
- the urgent need to change the way in which local distribution networks are organised and financed; and
- the working of the planning system, which at present fails to place local concerns within a wider framework of national and regional need.

Recommendations are made to address all of these barriers.

Measures are needed to keep the nuclear option open . . .

Nuclear power offers a zero carbon source of electricity on a scale, which, for each plant, is larger than that of any other option. If existing approaches both to low carbon electricity generation and energy security prove difficult to pursue cheaply, then the case for using nuclear would be strengthened.

Nuclear power seems likely to remain more expensive than fossil fuelled generation, though current development work could produce a new generation of reactors in 15–20 years that are more competitive than those available today. Because nuclear is a mature technology within a well established global industry, there is no current case for further government support.

The decision whether to bring forward proposals for new nuclear build is a matter for the private sector. Nowhere in the world have new nuclear stations yet been financed within a liberalised electricity market. But, given that the Government sets the framework within which commercial choices are made, it could, as with renewables, make it more likely that a private sector scheme would succeed.

The desire for flexibility points to a preference for supporting a range of possibilities, and not a large and relatively inflexible programme of investment such as would be implied by the 10GW programme currently proposed by the nuclear industry. If the UK does not support nuclear power today, the option will still be open in later years, since the nuclear industry is an international one, using designs that have been developed to meet circumstances in many countries. The desire for new options points to the need to develop new, low waste, modular designs of nuclear reactors, and the UK should continue to participate in international research aimed in this direction.

The nuclear skill base needs to be kept up-to-date. In particular the Government should ensure that the regulators are adequately staffed to assess any new investment proposals. Action is also required to allow a shorter lead-time to commissioning, should new nuclear power be chosen in future. Finally, within a new framework for encouraging a low carbon economy, the Government should ensure that, as methods to value carbon in the market are developed, additional nuclear output is able to benefit from them.

The main focus of public concern about nuclear power is on the unsolved problem of long-term nuclear waste disposal, coupled with perceptions about the vulnerability of nuclear power plants to accidents and attack. Any move by government to advance the use of nuclear power as a means of providing a low carbon and indigenous source of electricity would need to carry widespread public acceptance, which would be more likely if progress could be made in dealing with the problem of waste.

. . . and to create future options for coal by carbon sequestration

In the medium-term, coal has a continuing role to play in the energy mix. Its longer-term contribution depends on there being a practical way of handling the CO_2 that it produces. CO_2 capture and sequestration – whereby carbon is taken out of fossil fuels and stored:

- could be a means to preserve diversity of fuel sources, while meeting the need for deep cuts in CO_2 emissions;
- has the potential to allow fossil fuels to be a source of hydrogen for transport and other applications without large-scale carbon release into the atmosphere; and
- seems to be well suited to UK circumstances, since the UK has potential repositories in the Continental Shelf, and the carbon could possibly be used to get more oil from existing wells.

At the moment uncertainties surrounding costs, safety, environmental impacts and public and investor acceptability are large. Steps should be taken to reduce these uncertainties – as discussed more fully in the DTI Clean Coal Review. As part of this work, the legal status of disposing of CO_2 in sub-sea strata needs to be clarified, in the light of possible conflicts with the London and OSPAR Conventions.

Increased vehicle efficiency and investment in new options for transport fuels is required in the longer-term

The transport sector is likely to remain primarily oil-based until at least 2020. Access to oil supplies is not a current concern. Nevertheless, the economy's dependence on transport, coupled with increased imports as UKCS production declines, reinforces the need to improve the energy efficiency of oil-driven vehicles. Prospective advances in vehicle technology hold out the possibility of significant reductions in fuel use.

The potential long-term requirement for significant CO_2 emissions reductions from the transport sector combined with the possibility that oil will become scarcer, raise the need to develop alternative fuels. There is the long-term prospect that the technology for powering vehicles by fuel cells fed on hydrogen will fulfil its current promise, and so ultimately provide a substitute for oil. Other options, such as liquid biofuels may also have a role. International efforts are needed to develop these technologies.

Handling the projected growth in aviation energy use and CO_2 emissions must become a priority. Taxation and other measures to manage aviation demand should be prioritised for discussion in EU and other international forums.

Institutional changes, including to the planning system, need to be made to deliver the strategy.

The approach adopted in this review suggests that in the long-term the Government should be aiming to bring together the three interlinked themes in this review – energy policy, climate change policy and transport policy – in one department of state. In the shorter-term, consideration should be given to locating responsibility for energy efficiency and CHP policy with other aspects of energy policy.

As an immediate response to the challenge, the Government should set up a Sustainable Energy Policy Unit. This would be a cross-cutting unit staffed by civil servants from all the departments with an interest in sustainable energy, as well as staff from the Devolved Administrations, external experts and people from the private sector. The Unit would focus on providing ministers with cross-cutting analytical capability to ensure that key developments in energy use and supply were monitored and assessed. It would lead on the development of strategic policy issues, adapting quickly to changing circumstances.

The different responsibilities of the DTI and the regulators, most notably Ofgem, should continue. The DTI and DEFRA should do more to set out their priorities in guidance to Ofgem, so that Ofgem can further consider the impacts of its proposals for non-economic objectives. But it is Ministers who should take responsibility for intervention in markets, if economic objectives conflict with environmental and social goals.

In many parts of the energy industries, investors have found that their projects have difficulty in gaining planning permission. The attitude of local communities to proposals for new energy developments is important. They must continue to have their say in the planning process, which is one reason why it is important to engage the public in the energy policy debate. But national planning guidance needs to make it clear where there is a national case for new investment in energy-related facilities by establishing the relevant national and regional context for each type of development.

Next steps: a national public debate is now needed

The review develops a radical agenda – to enable the UK to put itself on the path to a low carbon economy, while maintaining competitively priced and secure energy. Precautionary action is needed in advance of further international agreement. Tasks that should be undertaken within the next five years include:

- Government should move towards a clear rationale for the balance of policy instruments – taxes, permits and regulation – to create powerful incentives for long-term carbon reduction; and
- immediate action is needed to assist innovation and to create new options, and also to manage risk.

But these are not matters for the UK alone. Increasingly, policy towards energy security, technological innovation and climate change will be pursued in a global arena, as part of an international effort.

The implementation of an ambitious low carbon policy would be a demanding task. Change of this kind takes a long time. It would be wrong to imagine that everything can be "win-win": there will be some hard choices, and there will be losers as well as winners. For this reason the Government needs to take the issues to the public soon. During the review, proposals were made to the PIU for an extensive process of public involvement. There was insufficient time for this, but it should constitute a central part of the implementation of the findings of the review.

The nation must not be lulled into inaction by the focus of much of the expert debate on long timescales and on energy systems in a future which will belong mainly to our grandchildren: the time for action is now and all players in the energy system have a role to play. Given that there is considerable inertia in the system, and that the low carbon technologies are not part of the conventional energy system, a change of direction will be difficult to achieve. It will require clarity of purpose in all parts of Government.

1. INTRODUCTION

Introduction

1.1 Energy use is central to our lives, whether to provide light or warmth, to drive our cars or to fuel our services and industries. Fortunately, the energy markets supplying UK consumers exhibit many signs of health and there is no energy crisis in the UK. However, debate has been increasing about the ways in which energy policy balances economic, environmental and social objectives. Blackouts and price hikes in California in late 2000 and early 2001 raised concerns about regulatory frameworks and investment in energy infrastructure. The fuel protests in October 2000 illuminated how affordability and accessibility of energy are vital to maintain a secure and equitable society. Human induced climate change is now being seen as a reality, with energy use being the major contributor, raising the question of how best to achieve a sustainable future.

1.2 A number of countries and international organisations have considered it timely to review their approach to energy: for example, the USA[1] and the European Commission[2] published papers in 2001, and the Council of Australian Governments has set up a review to identify strategic issues for Australian energy markets.

1.3 A prudent government must be sure that long-term concerns have been addressed and varied objectives are being balanced. In June 2001 the Prime Minister, Tony Blair, asked the Performance and Innovation Unit (PIU) to carry out a review of the strategic issues surrounding energy policy for Great Britain.

Review objectives and scope

1.4 The review had three main objectives:

- to set out the objectives of energy policy, including the UK contribution to global policy initiatives, to 2050;
- to develop a framework for reconciling the trade-offs among the different objectives of energy policy; and
- to develop a vision and strategy for achieving these objectives and to identify the practical steps that need to be taken in the short-and medium-term, as well as the longer-term.

1.5 A further objective of the review was to inform the Government's response to the Royal Commission on Environmental Pollution's (RCEP) report on *Energy – The Changing Climate*[3]; and in particular the recommendation that: "The Government should now adopt a strategy which puts the UK on a path to reducing carbon dioxide emission by some 60% from current levels by about 2050".

1.6 The scope of the review was to cover energy policy in Great Britain with a time horizon of 2050. While the review analysed the implications for fuel poverty of possible policy changes, the review did not cover policy towards fuel poverty. Fuel poverty has recently been addressed by the consultation on, and final publication of, the UK Fuel Poverty Strategy.[4] In addition, while the review covered

[1] US National Energy Policy Development Group (2001).

[2] Commission for the European Union (2001d).

[3] Royal Commission on Environmental Pollution (2000).

[4] DTI, DEFRA (2001).

the role of the transport sector in future scenarios and considered potential technical developments, the review did not cover transport policy instruments.

1.7 The review is being presented to the Government. It is a consultative document and not a statement of Government policy.

1.8 Energy policy in England, Scotland and Wales is the responsibility of UK Government, but responsibility is devolved in Northern Ireland. However, there are areas within energy policy in Scotland and Wales that are devolved: these are detailed in Box 1.1 below. The review's formal recommendations should be interpreted as applying only to UK Government responsibilities; it is for the devolved administrations to determine policy in relation to devolved matters. Given their range of responsibilities, the Scottish Executive and National Assembly for Wales must remain fully involved in the development of energy policy.

Review process

1.9 The review team, a multi-disciplinary mix of civil servants and secondees from outside Whitehall, was assembled in June 2001. Annex 2 lists the team members and their home organisations.

1.10 There were five phases to the review:

- posting scoping notes on various issues on the PIU website to stimulate discussion;
- taking evidence from interested parties. Around 400 submissions were received, and many were placed on the PIU website;

Box 1.1 Devolved powers and energy

While responsibility for energy policy in Great Britain is reserved to the DTI, a number of areas relating to energy policy are devolved to Scotland and Wales. Listed below are the key areas that impact on energy policy that are devolved in Scotland and Wales.

Area	Devolved in Scotland	Devolved in Wales
Environment policy	✓	✓
Promotion of renewable energy	✓	✘
Promotion of energy efficiency	✓	✘*
Support for innovation	✓	✓
Housing	✓	✓
Building Regulations	✓	✘
Planning (apart from the energy consents listed below)	✓	✓
Power station consents (over 50MW)	✓	✘
Overhead electricity line and gas pipeline consents	✓	✘

The National Assembly for Wales also has a cross-cutting duty under the Government of Wales Act to promote sustainable development across all of its activities. The Scottish Executive's Ministerial Group on Sustainable Scotland undertakes a similar role in Scotland.

* The NAW controls the budget and/or funds certain energy efficiency schemes in Wales, e.g. the Home Energy Efficiency Scheme, the Energy Efficiency Best Practice Programme, and part of the activities of the Carbon Trust Wales.

- establishing important times and dates within the energy industry, and creating scenarios for possible energy systems in 2020 and 2050. These three sources of information highlight key issues for energy policy in the short-, medium- and long-term;
- formulating a framework for Government on how to make choices among different policies and how to reconcile competing objectives; and
- setting out key Government actions in the short-term while exposing fundamental policy decisions for the medium- and long-term.

1.11 In carrying out the review, the PIU team has drawn on the expertise of the review's Advisory Group, made up of representatives and stakeholders inside and outside Government. (Annex 2 lists the membership of the Advisory Group.) Brian Wilson, the Minister of State (Industry and Energy), Department of Trade and Industry, acted as the review's Sponsor Minister and chair to the Advisory Group. The input and assistance of the Advisory Group was a crucial part of the review. The group was, however, advisory; the report does not necessarily represent the views of all group members.

1.12 In keeping with other PIU projects, the review team adopted an open and consultative approach, involving discussions with a wide range of outside stakeholders. Several workshops were held in England, Scotland and Wales and the team participated in several conferences and undertook numerous bilateral meetings. In addition, Whitehall departments provided invaluable support and assistance. We are grateful to all those who have spent time talking to us, organising and taking part in workshops, and referring us to relevant literature and research findings.

Review outline

1.13 The rest of the review is structured as follows:

- Chapter 2 briefly describes the current state of play in the energy system and challenges faced;
- Chapter 3 sets out the objectives for energy policy, a framework for future decision making and a discussion of different policy instruments;
- Chapter 4 considers the issue of security in the energy system;
- Chapter 5 presents the lessons from four scenarios created for 2050 and 2020;
- Chapter 6 discusses low carbon options;
- Chapter 7 presents policies and a programme for a low carbon future;
- Chapter 8 considers the institutional changes required to achieve a secure, low carbon future;
- Chapter 9 summarises the review's main conclusions and policy recommendations; and
- Chapter 10 looks at implementation of the recommendations.

1.14 Annexes then follow:

- Annex 1 sets out the role of the Performance and Innovation Unit;
- Annex 2 gives details of the Project Team, Sponsor Minister and Advisory Group;
- Annex 3 lists the organisations consulted and submissions received;
- Annex 4 presents an analysis of the potential impact of recommendations on fuel poverty;
- Annex 5 presents the basis for government intervention in the improvement of energy efficiency;
- Annex 6 provides details of low carbon technologies discussed in Chapter 6;

- Annex 7 discusses key future events and sets out timelines affecting decisions;
- Annex 8 presents a summary and recommendations from the Chief Scientific Adviser's Energy Research Review;
- Annex 9 is a glossary; and
- Annex 10 lists references.

1.15 A series of working papers was commissioned or prepared by the review team to underpin the review's analysis and conclusions. These are referred to in the text and listed in Annex 10.

2. THE CHALLENGE AHEAD

Summary

The energy system would face a serious challenge if the UK were to try to achieve large carbon reductions, while maintaining energy security and affordable and competitive energy prices.

- **The UK is currently one of only two G7 countries that are net exporters of energy, but it will almost certainly be increasingly reliant on imported energy over the next 10-20 years.**
- **Energy prices in the UK seem to be at, or even slightly below, the OECD average.**
- **There is the prospect of rapid technological change in the energy industries. Substantial change may be in prospect, but it would need to be accommodated.**
- **UK carbon emissions have been falling steadily over the last 30 years. Future emission reductions will be harder to achieve than past reductions.**
- **Energy use and emissions from transport have been growing broadly in line with GDP, until recently.**
- **There is a continued need to protect the fuel poor from the impact of higher energy costs. Similarly concerns relating to industrial competitiveness need to be addressed.**

Introduction

2.1 The energy system would face a serious challenge if the UK were to try to achieve large carbon reductions, while maintaining energy security and affordable and competitive energy prices. The purpose of this chapter is to introduce and explain those challenges, largely by showing how the energy system has developed. Since this review has the task of looking ahead for 50 years, this chapter takes some glances back over the past 50 or more years, but most of the information relates to the last 30 years. After a brief historical review, the chapter gathers together some facts relating to the major themes of this review: energy security, energy prices, fuel poverty, UK competitiveness and trends in carbon emissions. It finishes by looking at some of the options opened by recent change in energy technologies.

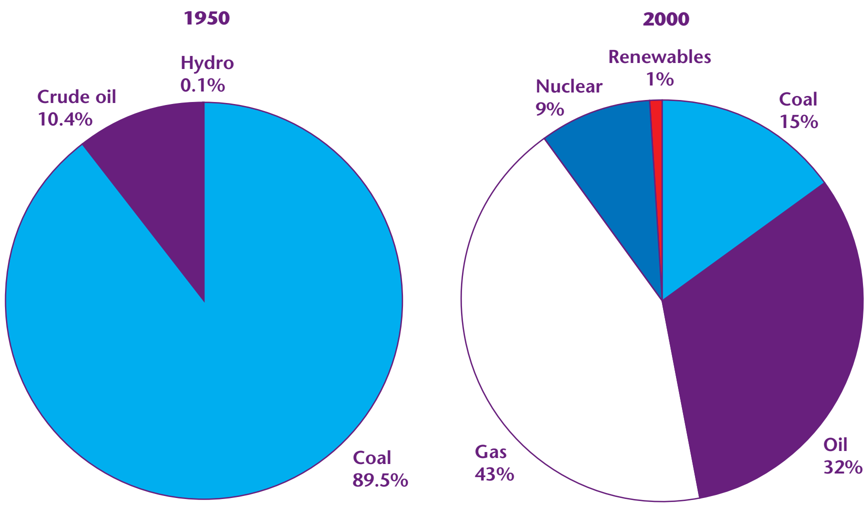
2.2 An examination of past trends demonstrates that huge changes in energy systems can be made. The energy system is made up of a series of physical assets, for example power plants, gas and electricity network infrastructure, and oil refineries. These take time to build and, once in place, last for years, often decades, into the future. It is therefore difficult to transfer out of an energy system quickly without creating stranded assets, and efficient policy should try to minimise this waste. Annex 7 gives details of some of these "timelines", whose importance is one of the themes of this review.

2.3 These long time horizons create a need to try to look into the future. Yet the history of energy reviews is littered with failed attempts to project or forecast the production and/or use of energy resources. This review is unlikely to prove an exception. The important thing is to reflect this uncertainty in policy-making, so that it is flexible in the face of new information. It would be wrong to try to plan the energy system, but equally, given the often long lead times within the energy system, a long-term vision is sometimes needed if we are to avoid commitments which may be found wanting as policy needs change.

The UK Energy System in the Twentieth Century

2.4 The UK's energy system has changed dramatically over the last century. Similar changes in technologies, fuel supplies, infrastructure, management and operation of the industry and customer relationships can be expected over the next century. In 1950, as Figure 2.1 shows, the energy system for both industry and domestic demand was fuelled by coal. Fifty years later that energy system looks

Figure 2.1: Change in the UK primary fuel mix from 1950 to 2000 (%)



Source: Darmstadt et al (1971) and DTI (2001a).

very different. In 1965, it was not clear whether the UK would find natural gas in the North Sea.[1] Today domestic natural gas is our largest source of energy.

2.5 A thumbnail sketch of the history is as follows:

2.6 **Before World War 2:**

- coal was the dominant fuel in industry and electricity power plants, and in houses and businesses;
- town-gas networks existed in larger towns, with the gas derived from coal; and
- vertically integrated, independent companies distributed electricity to customers via distribution networks with limited interconnection between them.

2.7 The structure of the energy system and the diversity of energy supplies altered considerably **in the second half of the twentieth century:**

- coal continued to be of central importance for electricity generation, although its importance elsewhere fell substantially;
- nuclear power plants began to be commissioned from the mid-1950s;
- the electricity industry was combined into state-owned monopolies, during the 1950s;
- the high voltage electricity transmission network was created in order to transport electricity over long distances from big power plants;
- electricity distribution networks shrank in importance and activity;
- during the 1960s and 1970s there was a move to an extensive natural gas network for heating (industry, commerce and domestic);
- demand for transport fuel increased dramatically;
- gas fired central heating largely replaced open coal fires in homes; and
- the use of electrical appliances in commerce and the domestic sector increased hugely.

2.8 **During the 1990s**, the GB energy sector was transformed by market liberalisation. The privatisation of the gas and electricity supply industries, combined with the introduction of competitive markets, gave consumers choice between alternative providers of gas and electricity. These changes, which were largely pioneered in GB, are now being adopted in many other countries.

2.9 A longer-term shift from coal to gas was already underway but liberalisation accelerated it, with beneficial environmental effects. The switch from coal to gas in electricity generation was the result of:

- the availability of cheap gas;
- pressure on coal generators to reduce acid rain emissions;
- the wholesale electricity market; and
- the availability of combined cycle gas turbine technology.

2.10 The changes during the 1990s in the energy system had a number of beneficial impacts, both economic and environmental. Some of the environmental improvements in respect of carbon were incidental, although there were direct policy measures intended to improve efficiency. The beneficial impacts were:

- privatisation and liberalisation helped to reduce the costs of production and transportation;
- reductions in costs, partly also due to falling world fossil fuel prices, have been translated into retail fuel price reductions;
- falling real prices have helped to reduce fuel poverty while maintaining the competitiveness of UK industry;

[1] Ministry of Fuel and Power (1965) said that "… gas may be found under the British part of the Continental shelf".

- the switch from coal to gas reduced environmental emissions, not only of acid gases, but also of greenhouse gases; and
- the switch from coal to gas increased the diversity and security of electricity generation – at the start of the 1990s, coal accounted for about two-thirds of the fuel used for electricity generation, but it now accounts for only one-third.

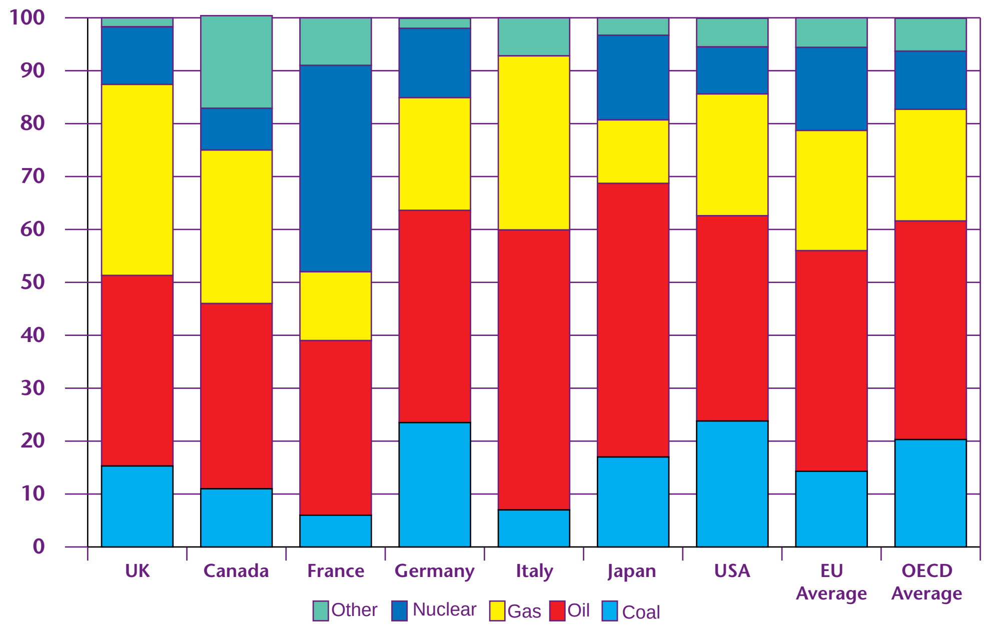
Security

2.11 Security of the energy system is a central concern and is examined in detail in Chapter 4. One facet of security has always been taken to be the diversity of fuels in use in the energy system. Countries vary widely in their energy supply mix. Figure 2.2 shows the different mix of primary fuels in the G7 countries. There are considerable differences among countries, especially in the shares of nuclear and coal. All countries use roughly the same proportion of oil, reflecting its dominance in transport uses and its phasing out in most other markets. The differences in each country's fuel mix largely reflect historical circumstances, resource endowments and different political and market choices. A variety of very different approaches have been adopted.

2.12 In the UK, one aspect of security concern has been the imminent peaking of oil and gas production from the UKCS. As Figure 2.3 shows, the UK is one of only two G7 countries that is a net total exporter of energy. Table 2.1 shows that the UK is projected still to be a net exporter of oil in 2010. But then total net exports are projected to fall rapidly, so that the UK becomes a net importer shortly after 2010.

2.13 The UK is expected to become a net importer of gas sooner than for oil, indeed the UK already imports natural gas during periods

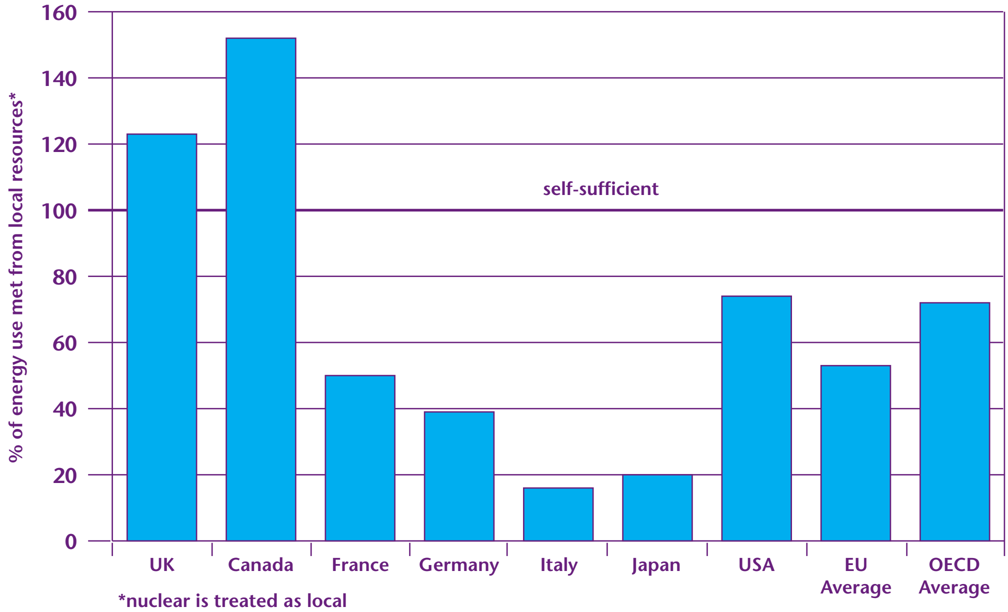
Figure 2.2: Primary energy use in G7 countries and in the EU and OECD, 2000



Note: "Other" includes renewables and net imports of electricity. Electricity trade is less than 1% of total energy in all cases except France, which exports 2% and Italy, which imports 2%

Source: IEA (2001a).

Figure 2.3: Energy self-sufficiency in G7 countries and in the EU and OECD, 1999



*nuclear is treated as local

Source: IEA (2001a).

Table 2.1: UK oil production and trade, 1973-2010 (mtoe)

	1973	1990	1998	2005	2010
Production	0.6	95.3	138.9	150.0	126.0
Exports	20.9	76.5	113.1	123.3	95.5
Imports	136.9	65.4	61.3	70.0	70.0
Bunker use	5.4	2.5	3.1	2.0	2.0
Net imports	110.6	–13.6	–54.9	–55.3	–27.5

Source: IEA (2000a).

of peak demand. Based on the current level of reserves and prices, the Department of Trade and Industry (DTI) forecasts that the UK will become a net importer of gas on an annual basis from 2005.

2.14 Other changes which may impact on energy security are expected by 2020:

- many of the existing nuclear power stations will have ceased production; and
- coal is likely to play a smaller role in the energy mix, and at least some UK coal mines will have exhausted their reserves.

2.15 This means that the UK is heading towards a situation where it becomes a net importer of oil and gas and where the two leading electricity generating technologies of the past century – nuclear and coal – are, on current plans, running down. Whether this much increased import requirement represents a problem is discussed in Chapter 4.

2.16 In the 1970s the energy problem was largely defined in terms of potential world-wide shortages of resources. Energy policy was seen by some people as a process of finding new options to replace depleting reserves. Since the

Table 2.2: Trends in real industrial energy prices by fuel, UK, 1970–2000

	1970	1980	1990	2000
Coal	108.1	154.5	100.0	60.27
Heavy fuel oil	91.1	245.4	100.0	122.99
Gas	158.9	166.8	100.0	58.76
Electricity	117.1	127.0	100.0	67.95

Source: DTI (2001a).

Table 2.3: Trends in real domestic energy prices by fuel, UK, 1970–2000

	1970	1980	1990	2000
Coal and smokeless fuels	89.2	109.0	100.0	94.9
Electricity	84.9	104.0	100.0	78.3
Gas	129.0	86.4	100.0	77.4
Petrol and oil	97.1	107.3	100.0	116.7

Source: DTI (2001a).

1970s, views have changed and there is no longer a sense of urgency about future world-wide energy resources. In large measure this is because there has been a more systematic search for major energy resources, and many have been found. While in the 1970s the world reserve to production ratio for gas was around 40 years; it is now close to 60 years, despite substantial and rising gas use in the meantime.[2] World coal reserves now stand at 200 years or more.[3] The position for oil is slightly different. While world reserves have remained roughly constant at around 35 years, oil has been searched for intensively for many years, and few large new discoveries have been made for some time.[4] This means that for the 50-year period of the current energy review, it is possible to be confident about world-wide coal reserves, and reasonably confident about gas availability, but oil might become scarcer by mid-century.

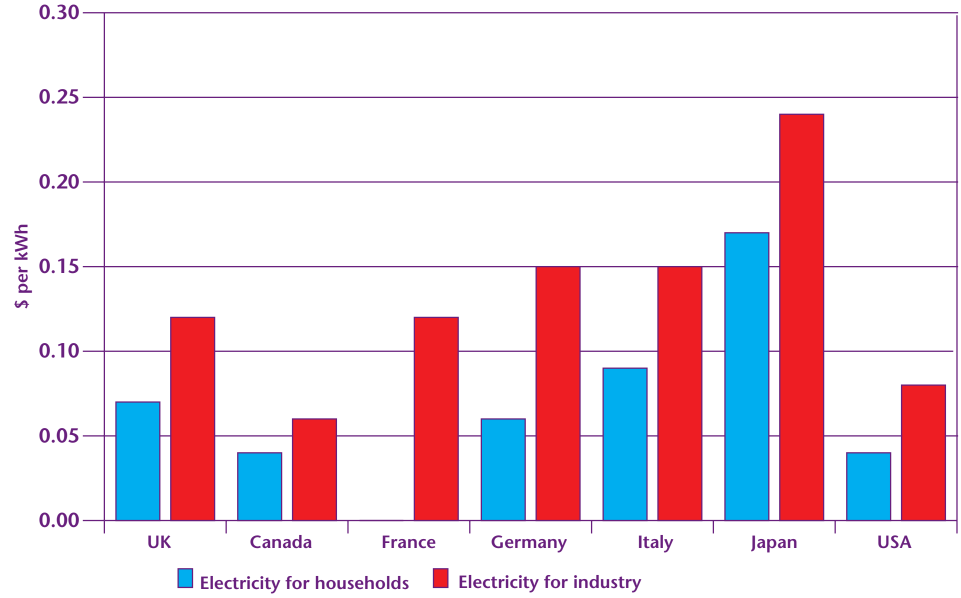
Energy Prices

2.17 Table 2.2 shows that industrial energy prices have been on a downward trend since the early 1980s. The exception is the price of heavy fuel oil which has fluctuated, and where the price in 2000 was above the price in 1990 (and indeed 1970). This is a reflection of changes in oil prices. Table 2.3 shows that, with the exception of petrol prices, domestic energy prices have fallen over the last decade: the falls in gas and electricity prices have been particularly marked.

2.18 Figure 2.4 shows that if UK average industrial and domestic electricity prices are compared with prices in other European and G7 countries, the UK is slightly below average. But average industrial prices conceal a wide range of terms, and it can be misleading to apply them to particular sectors. Figure 2.5

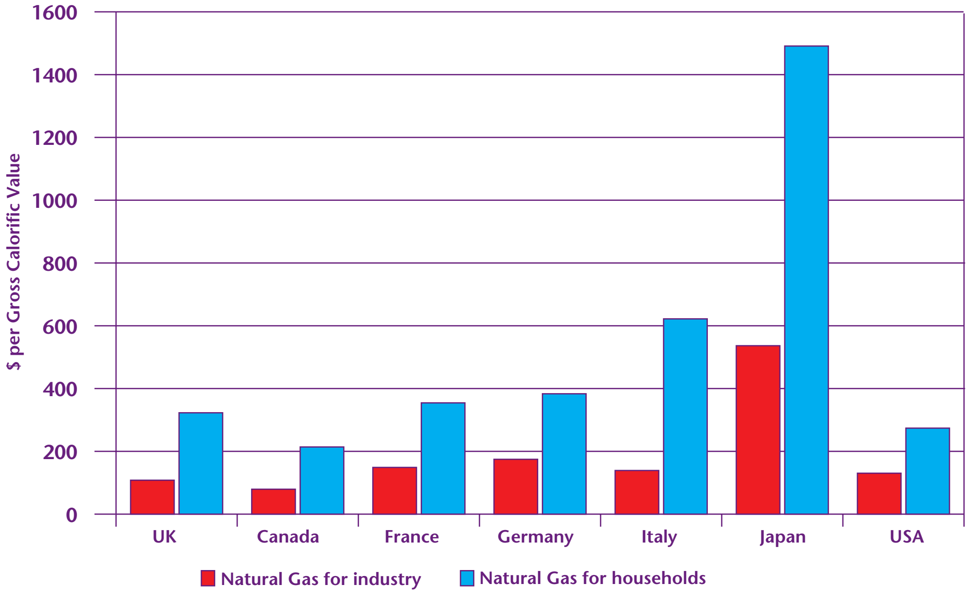
[2] BP (2001).
[3] UNDP and WEC (2000).
[4] BP (2001).

Figure 2.4: The price of electricity in G7 countries, 1999



Source: DTI (2001f).

Figure 2.5: The price of gas in G7 countries, 1999



Source: DTI (2001f).

shows that in 1999, UK gas prices seemed similarly to be somewhat below the average. The prices shown in Figures 2.4 and 2.5 include taxes: in the UK, domestic energy taxes are low, relative to other European and G7 countries.[5]

Carbon emissions

2.19 An objective of the review was to inform the Government's response to the Royal Commission on Environmental Pollution 2000

[5] DTI (2001).

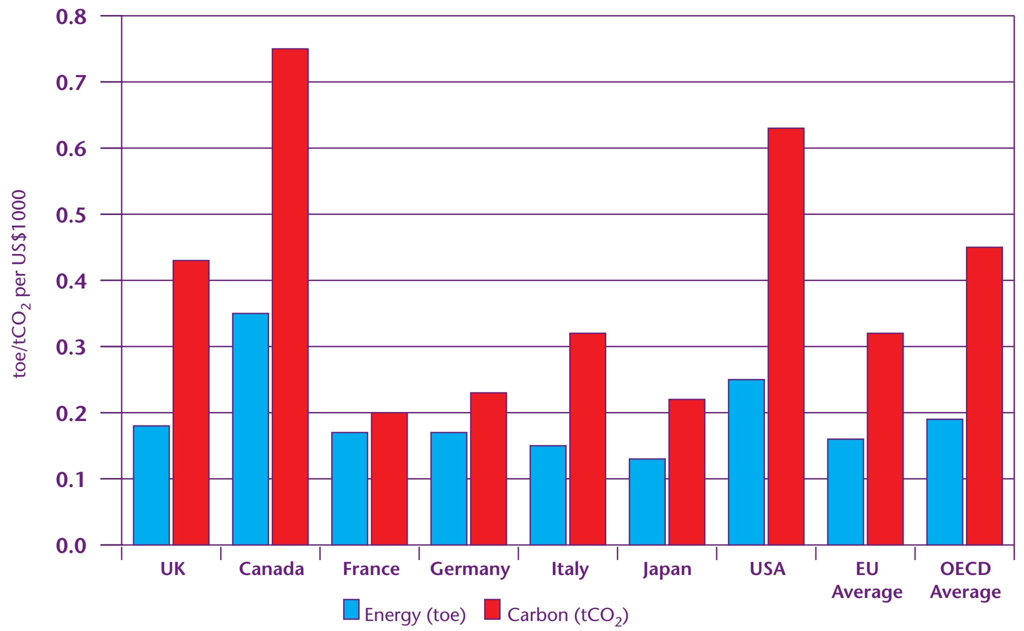
report on *Energy – The Changing Climate*.[6] And in particular, the recommendation that: "The Government should now adopt a strategy which puts the UK on a path to reducing carbon dioxide emission by some 60% from current levels by about 2050".

2.20 Because 95%[7] of UK carbon dioxide emissions result directly from fuel combustion, the energy system will be key to any action to reduce carbon emissions. Yet the UK contributes only around 2%[8] to global carbon dioxide emissions. Any major move to reduce carbon dioxide emissions would have to be in the context of widespread international action. Figure 2.6 shows energy consumption and carbon emissions per unit of GDP for the UK and other OECD countries. The UK carbon emissions per unit GDP are roughly equal to the OECD average, though some countries, such as France and Japan, have much lower carbon emissions per unit of GDP. Figures for emissions per capita show broadly the same picture.

2.21 Figure 2.7 shows UK fossil fuel use by sector, and the resulting carbon emissions. The main sources of carbon dioxide emissions are power stations (28%), industry and business[9] (32%), transport (25%), and the domestic heating sector (17%).[10]

2.22 Figure 2.8 illustrates the links between GDP, energy use and carbon emissions since 1970. Despite rising energy consumption, carbon emissions have fallen. The main reasons are that the energy ratio has fallen due to improvements in energy efficiency, changes in industrial structure and saturation in demand for some important energy needs; and that the carbon ratio has fallen because of switching to lower carbon fuels.

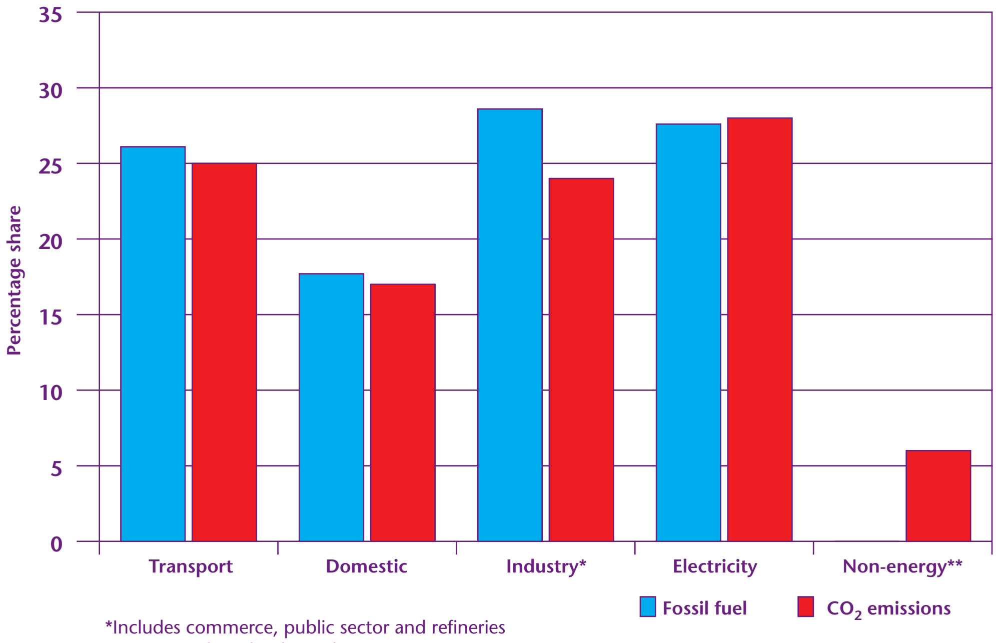
Figure 2.6: Energy consumption and CO_2 emissions in the EU and OECD, 1999



Source: IEA (2001a).

[6] RCEP (2000).
[7] DEFRA (2001b).
[8] DETR (2000).
[9] Includes all business and public sector activity and oil refineries.
[10] DTI (2001).

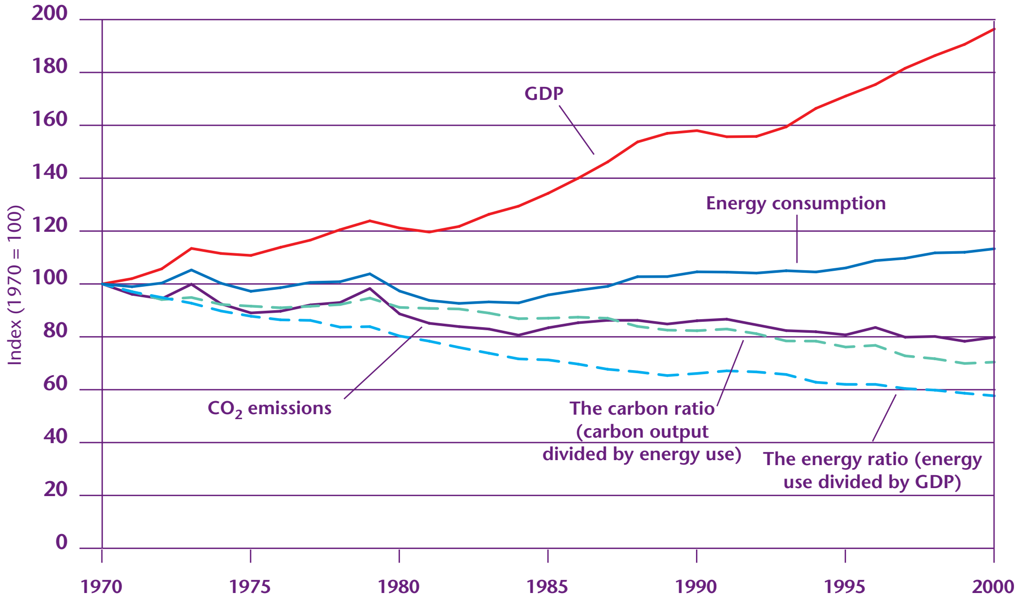
Figure 2.7: UK fossil use and CO_2 emissions by sector, 2000(%)



*Includes commerce, public sector and refineries
**emissions from land use changes

Source: DTI (2001d).

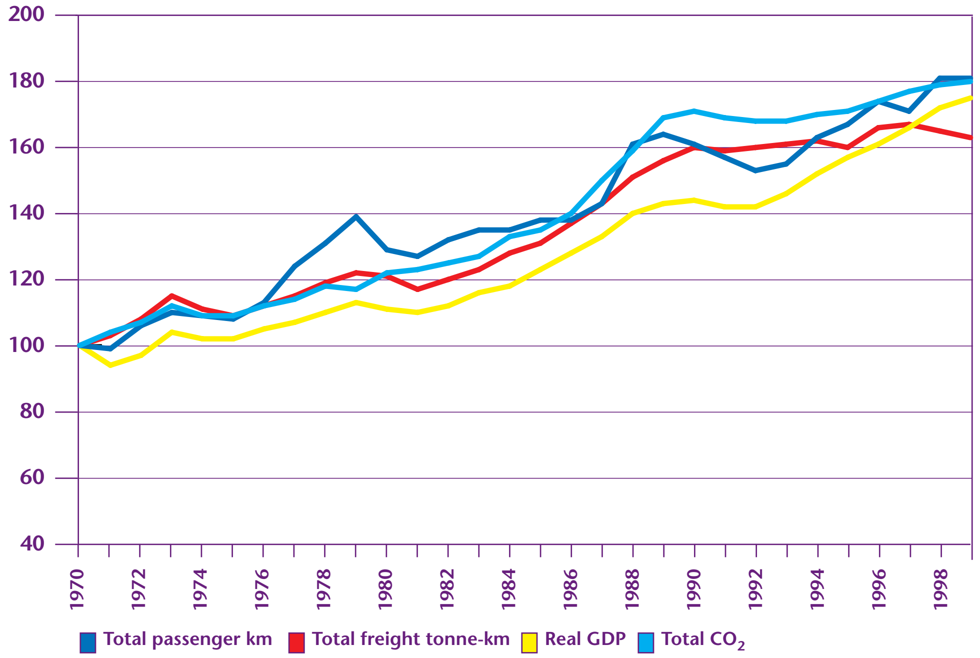
Figure 2.8: UK GDP, energy consumption and CO_2 emissions, 1970-2000



Source: DTI (2001a), ONS (2001), DEFRA (2001b).

2.23 Figure 2.9 illustrates how transport growth, measured in terms of both passenger kilometres and freight tonnes travelled, has nearly doubled over the last thirty years. Unlike Figure 2.8, which shows that GDP and carbon dioxide emissions from energy use are diverging, Figure 2.9 shows that carbon dioxide emissions, transport growth and GDP continue

Figure 2.9: UK GDP, transport growth and CO_2 emissions, 1970-1999



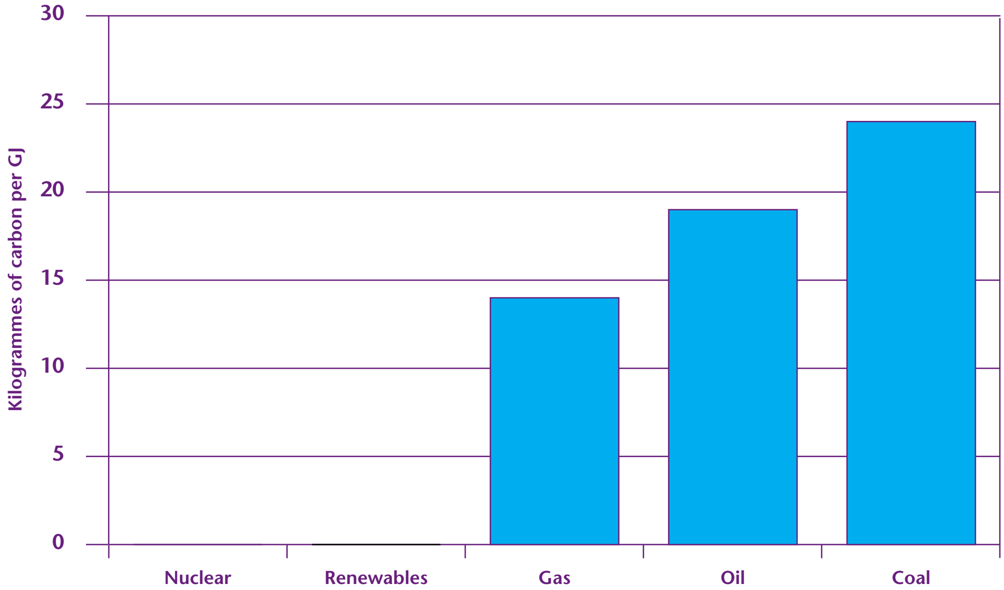
Source: DTLR (2000), DEFRA (2001b).

to be in step with one another, except very recently when CO_2 seems to have stabilised.

2.24 Figure 2.10 illustrates the variation among the amounts of carbon dioxide that are released through the use of different fuels. Natural gas has lower emissions than coal or oil, while nuclear and renewable energy have almost zero emissions.

2.25 Different parts of the economy use different types of energy: for example, the

Figure 2.10: The carbon content of fuels



Source: DTI (2000a).

transport sector primarily uses oil, while the domestic heating sector primarily uses natural gas. There are obvious technological constraints on the extent to which each sector is able to switch to a lower carbon fuel supply, in the short term. The implication is that it is harder to move those sectors towards a lower carbon ratio than the sectors which use a lot of electricity.

2.26 Past trends in the carbon ratio should not lead us to be complacent about future emissions from the energy system. As shown in Figure 2.8, between 1970 and 2000 the average rate of reduction in the carbon ratio was 0.75% a year. To deliver 60% CO_2 cuts, as envisaged by the Royal Commission on Environmental Pollution, would require an average rate of reduction of 2% between 2000 and 2050.

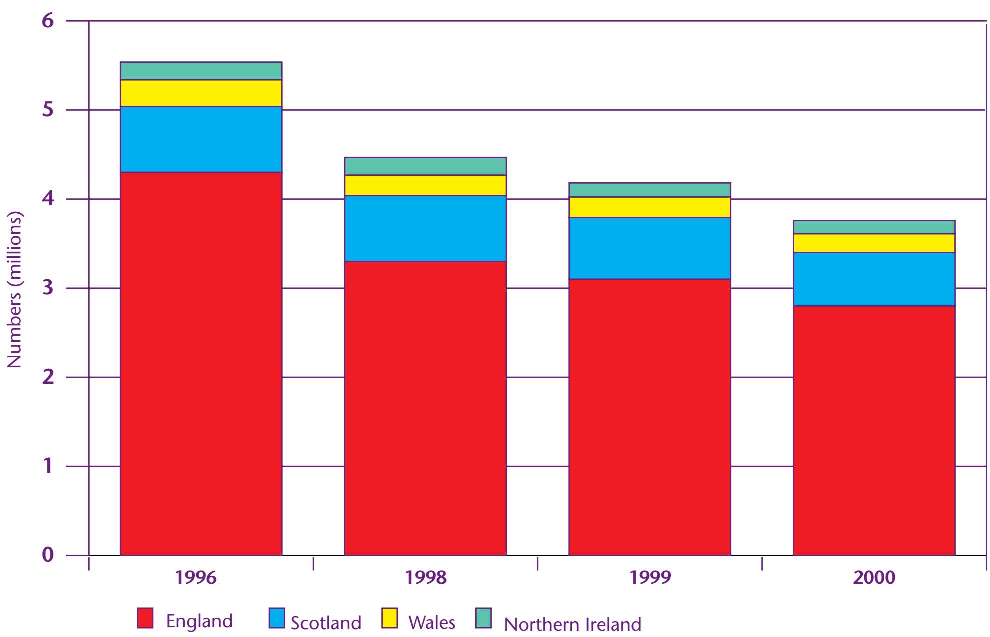
2.27 Moreover, the combination of favourable circumstances that arose in the 1990s is unlikely to be repeated:

- opportunities for carbon emissions reductions through fossil fuel-switching by end-users are almost over, with most heat demand already being met by gas; and
- the output from existing nuclear power stations will start to decline as they reach the end of their commercial lives, putting upward pressure on greenhouse gas emissions.

Fuel Poverty

2.28 Any move towards a low-carbon future would need to take account of the impacts of any changes in prices on those in fuel poverty. The most widely accepted definition of a fuel-poor household is that it is one which needs to spend more than 10% of its income on fuel use and to heat its home to an adequate standard of warmth. The number of households in fuel poverty in the UK has fallen over the last decade (see Figure 2.11). The improvement has

Figure 2.11: Number of households in fuel poverty in the UK, 1996-2000



Source: DEFRA, DTI (2001).
Note: chart based on definition of fuel poverty including housing benefit and income support for mortgage interest as income.

largely been a result of reduced fuel prices, improved energy efficiency and increased incomes. In more recent years, the new Home Energy Efficiency Scheme (HEES) and winter fuel payments, now standing at £200 per annum, have helped. Annex 4 gives more details.

New Opportunities

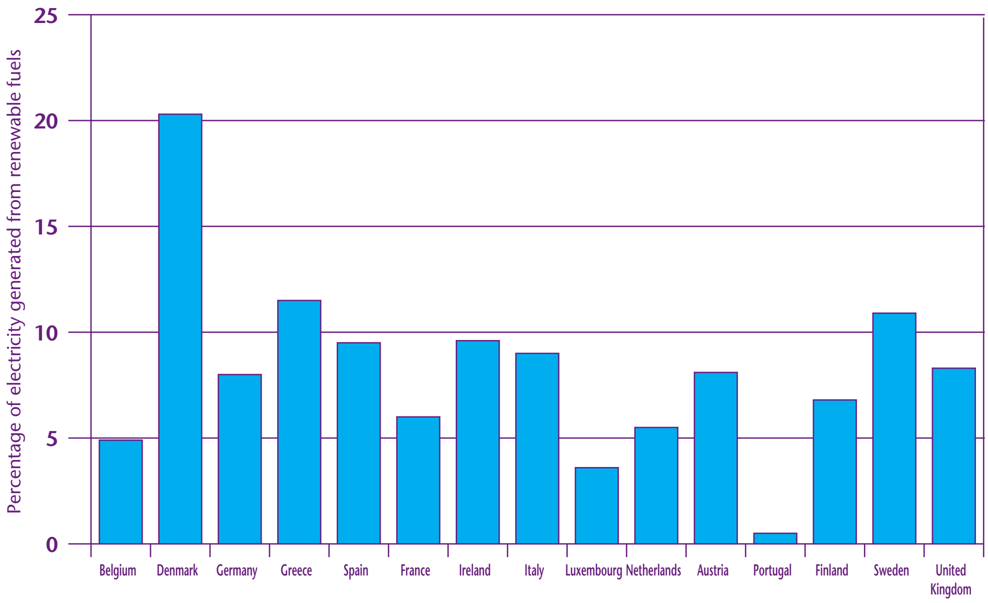
2.29 The energy system in 2050 will be very different from that in place today. It would be wrong to try to design a policy that applied unchanged over the long term. The uncertainties – both technological and commercial – are too great. The guiding principle should be to design policy in such a way that it allows maximum flexibility, if and when circumstances change.

2.30 Legislative requirements impose an important set of boundaries or constraints. The UK is bound by the provisions of relevant European Directives[11] and international treaties, for example the Kyoto Protocol, which establish certain required outcomes by certain times. While the means of achieving those outcomes are left to individual governments, the outcomes are legally binding.

2.31 The 1990s saw a number of developments which opened up new options for future energy systems:

- a number of new renewable energy technologies emerged on the world energy scene for the first time (some renewable technologies such as large-scale hydro have been established for many years). The UK is very well endowed with renewable resources, yet it uses less renewable energy than most EU countries (though many countries achieve their higher ranking by extensive use of large hydro and conventional biomass plants, rather than by using new renewables). Looking at different countries' plans for new investment in renewables to meet the EU

Figure 2.12: Increase in the share of renewable electricity required by 2010 to meet EU target



Source: Official Journal of the European Communities (2001).

[11] For example, the Common Rules for the Internal Market in Electricity; the Common Rules for the Internal Market in Gas; the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market; a Community Strategy to Limit Carbon Dioxide Emissions by Improving Energy Efficiency; see http://europa.eu.int/eur.lex for full list.

renewable energy target, the increase to which the UK is committed is broadly similar to that in many other countries (Figure 2.12);

- network information and control technologies, as well as metering technologies, have opened up the possibility of designing and operating energy networks in new ways;
- new demands, for example from Internet server farms for high quality power secure against network disruptions, are driving changes to the energy system. As a result there will perhaps be more on-site power, different service offers or new network quality standards;
- new technologies, such as fuel cells, micro turbines, and new market structures have opened up the possibility of energy systems based on clean and efficient, decentralised units;
- the major car makers have made progress in the production of low emissions vehicles, such as hybrid electric engines. There have also been major advances in research into genuinely zero emission vehicles, based upon fuel cells.

Conclusions

2.32 This brief survey suggests the following three main conclusions:

- UK carbon emissions have been falling steadily over the last 30 years, mainly as a result of commercial decisions in the light of government policy. Future emission reductions will be harder to achieve than past reductions. Until recently, emissions from transport have been growing broadly in line with GDP;
- the UK is currently only one of two G7 countries that are net exporters of energy, but it will be increasingly reliant on imported energy over the next 10-20 years; and
- if instruments which raise energy prices are used to reduce carbon emissions, there would be a continued need to protect the fuel poor from the impact. Similarly concerns relating to industrial competitiveness will need to be addressed.

3. FRAMEWORK

Summary

This Chapter looks at the justification for government involvement in energy markets and proposes a framework on which future energy policy should be based.

- **Government intervention in energy markets may be justified where there are market failures or equity-related objectives, such as fuel poverty, that market outcomes may not serve. But competitive energy markets should continue to be encouraged.**

- **The guiding principle should be sustainable development, requiring achievement of economic, environmental and social objectives. It is also vital to maintain adequate levels of energy security at all points in time.**

There will be trade-offs and synergies between these objectives.

- **Because greenhouse gas abatement can only be delivered through the energy system, energy policy is likely to give preference to this objective.**

- **An overarching statement of energy policy could be "the pursuit of secure and competitively priced means of meeting our energy needs, subject to the achievement of an environnmentally sustainable energy system".**

- **We should prepare for the greater use of economic instruments that enable the wider environmental costs of carbon to be incorporated into market prices. Such instruments are likely to be cost-effective and to be used in international carbon trading.**

- **This will tend to raise energy prices. If energy is used more efficiently energy bills will not necessarily rise. And action to reduce fuel poverty will also help to remove constraints.**

- **Good policy will normally require a mix of different instruments including actions that directly tackle market failures. Targets can be useful for signalling long-term Government intentions to the market, even if not backed up by specific measures from the outset.**

- **A unilateral commitment to large cuts in carbon emissions beyond those already agreed would damage the competitiveness of UK industry without corresponding global environmental gain.**

- **In the short- to medium-term, the key priorities of energy policy are to maintain energy security, to ensure compliance with existing carbon abatement targets, and to develop a range of low carbon options to be used to meet possible post-Kyoto targets. The UK should also be pursuing innovation to permit deep cuts in carbon in the longer-term. The Government has an important role in stimulating innovation.**

The rationale for having an energy policy

3.1 The general objective of Government energy policy at present is "to ensure secure, diverse and sustainable supplies of energy at competitive prices".[1] The UK energy market is now almost wholly in private ownership; there is more competition than ever before and an independent economic regulator is in place to control the activities of the natural monopolies in the energy sector – the gas pipelines and electricity wires – and to police competition. Why then have a Government energy policy?

3.2 Government intervention in private markets may be justified on the following grounds

- **market failures** which lead to economic inefficiencies;
- **equity issues**, so that even where markets work well, the outcomes are considered socially undesirable; and
- **other reasons** including strategic and political ones.

It does not follow that the existence of potential grounds for government intervention means that actual intervention is necessarily justified. Governments do not have perfect knowledge, and interventions may be poorly structured and have unanticipated consequences. Government intervention may sometimes make matters worse.

[1] DTI (2000c), page 4 paragraph 1.1.

Efficiency reasons

3.3 There are four main market failures associated with the energy markets:

- there are market failures arising in part from the fact that electricity and gas networks are **natural monopolies**. Even with regulation of those monopolies, their existence inhibits the ability of suppliers to tailor products to meet the needs of individual consumers and for consumers to communicate their wishes to suppliers. These issues are discussed further in Chapter 4;
- there are very large **"environmental externalities"** associated with energy production and use: the costs of environmental damage are not visited on those people who are responsible; externalities can be "internalised" by measures that enable the wider social costs of pollution to be factored into commercial decision-making;
- there are **information failures** (or "asymmetries"), especially in the household and small business sector, where consumers have much less information (for example about energy saving possibilities) than suppliers. Another way of looking at this is to say that there are very substantial economies of scale in making decisions about efficient energy use; and
- there is the **public good aspect of innovation** which may result in the private market tending to under-supply innovation, especially in a liberalised market, because it cannot privately capture all the benefits that result.

Equity reasons

3.4 In the right conditions – such as competition among a large number of buyers or sellers – markets will often provide the most efficient outcome. But efficient markets are not necessarily equitable. Governments and societies may have preferences for distributions of incomes and products which are different from those that markets produce, and in such cases intervention for social reasons may be justifiable.

3.5 Equity considerations are affected by the fact that energy is a necessity of life. Everyone needs warmth and light to survive. And in a modern society access to electricity is also essential in order to maintain a range of household needs. For example refrigerators and televisions and (increasingly) access to the Internet are no longer regarded as luxuries and their absence is liable to increase social exclusion. The Government is concerned that many of the poorer and more vulnerable members of society cannot afford adequate supplies of energy and for that reason has set out a strategy to tackle fuel poverty.[2]

3.6 It should also be recalled that equity concerns can be addressed by means other than intervention in energy markets, for example through special payments to those thought to be in need through the social security system.

Other reasons

3.7 But there are other reasons why governments tend to intervene in energy markets which are essentially strategic and political. Energy is essential, not only to households but also to businesses. The non-transport part of our energy system places heavy reliance on two fuels, gas and electricity, for which energy storage is very difficult. Electricity cannot currently be stored in significant quantities[3] and gas is also difficult and costly to store except in large specialised

[2] DTI, DEFRA (2001).
[3] Consumer could meet small needs using batteries and fuel-cell technologies are becoming developed for larger applications.

facilities.[4] The difficulties with storing these fuels mean that security of supply is extremely important. Significant supply interruptions can very quickly become a matter of major political concern. This is reinforced historically: until recently Government owned the UK gas and electricity industries. Consumers have become accustomed to seeing Government playing a major role in energy markets. The continued existence of "emergency arrangements" for most forms of energy, under which Government can suspend market operations, is also evidence of this continuing political/strategic concern.

3.8 These are the reasons why Government may choose to intervene, but what principles should govern its intervention? These must be established in relation to the Government's objectives.

Objectives of energy policy

3.9 Sustainable development is an overarching goal of Government policy. The notion of sustainability originally stems from environmental concerns, but sustainable development is now defined in terms of trying to balance progress in high level economic, environmental and social objectives, rather than just environmental goals:

- **Economic objectives:** Economic policy is concerned mainly with promoting economic growth and efficiency via trade liberalisation and competitive markets. Within energy policy, this translates into the promotion of efficiency, both in the sense of achieving the lowest possible costs, and of allocating resources to where they are of greatest social benefit. Greater economic efficiency or growth releases or creates resources which can then be devoted to other goals, such as environmental protection. The economic implications of a country pursuing a *unilateral* carbon abatement policy, particularly in terms of its competitive position in international trade, are considered later in this chapter.
- **Environmental objectives:** Effective protection of the environment is a major high-level Government objective. Tackling climate change is currently the most prominent, but there are many others including safeguarding individuals against poor air quality and toxic chemicals, improving water quality and providing solutions to nuclear waste problems. The environmental impact of the energy system is probably greater than that of any other industrial activity.
- **Social objectives:** The key social issues specific to the provision and use of energy are: tackling fuel poverty; maximising access to services that need electricity (e.g. the Internet); maximising access to transport, particularly in rural communities; minimising transitional employment shocks due to changes in the energy industry; and ensuring fair siting of energy infrastructure through the planning system.

Security: a cross-cutting objective

3.10 Energy security does not fit easily into any of the categories of economic, environmental or social objectives of policy, but the importance of achieving adequate levels of energy security has already been noted and is discussed more fully in Chapter 4 which focuses on energy security issues. Achievement of adequate levels of energy security can be thought of in risk terms: the objective of policy is to achieve an appropriately low level of the various risks of interruption and stress that face the energy

[4] The capacity of the gas holders found in most towns is very limited – they are used mainly to help smooth the difference between daytime and night-time gas use.

system and to develop means of managing the residual risk. The risk analogy suggests that security policy will often involve the payment of a premium as an insurance against an adverse outcome. A more secure system is likely to be a more costly one.

3.11 The energy system faces a range of (often linked) risks in relation to the continuity of energy supply:

- there are risks to both the quantity of energy supplied and the price of energy;
- the risks may be long-term: for example increasing use of imported fossil fuels may expose the UK to greater risks of supply interruption or high prices due to either political difficulties or the exercise of market power;
- risks could equally be medium-term: for example inadequate network investment now could lead to a shortage of capacity in the network in a few years' time; and
- risks may be very short-term: for example if a large power station suddenly fails, other generating capacity needs to be ready to make up the shortfall in a matter of minutes.[5]

3.12 The achievement of adequate levels of security can therefore be seen as an objective that has to be satisfied at all points in time if other objectives are to be satisfied. Recent Government statements on energy policy have laid particular stress on security, and on diversity as one means of promoting security. Whatever the relative priorities given to economic, environmental and social objectives, security needs to be maintained. However, the need for Government intervention to establish an adequate level of security is likely to vary over time as circumstances in world energy markets change. This could be characterised as the price of security (the "insurance premium") varying over time.

3.13 A secure energy system is also likely to have elements of both diversity and flexibility. Both these characteristics will enable it to respond more easily to changing circumstances without undue problems for final energy consumers and are discussed further in Chapter 4.

3.14 One of the problems with security as an objective is the difficulty of quantifying it. By contrast, carbon emissions are relatively simple to measure. It is fairly easy to look at out-turn security in terms of actual interruptions and price volatility. However, because of the time lags in the energy system, current policy is concerned with *future* security. Estimates of future interruptions depend on a huge range of judgements about the likelihood of various events, ranging from the relatively frequent and predictable (e.g. how often a coal-fired plant might break down) to the very infrequent and highly unpredictable (e.g. an explosion at a major gas terminal).

3.15 The importance of energy security is emphasised by the fact that both Ofgem and the Secretary of State for Trade and Industry have legal duties in relation to the provision of secure supplies of gas and electricity.

The energy system

3.16 Consideration of energy security draws attention to the links between different energy markets of which one of the most obvious is the use of gas for electricity generation. But there are other good reasons for thinking in terms of energy systems. In particular, carbon emissions come from all aspects of energy use and there may be little value in driving down emissions from one part of the energy system (e.g. power generation) if that is being offset by rising emissions elsewhere (e.g. transport). Alternatively, if carbon emissions are very costly to abate in one sector, there may be good

[5] The shortfall could also be managed if some consumers were ready, at a price, to lose their supplies at very short notice.

grounds for strong abatement measures elsewhere.

3.17 An aspect of the approach taken to this review has been to try to consider the energy system as a whole, rather than focussing on individual fuels or sub-markets. The structure of this review reflects that approach and it is recommended that future analysis of energy issues also tries to consider the implications of particular measures for the energy system as a whole.

Trade-offs, synergies and constraints

3.18 In some circumstances, actions that promote one objective will also promote another. Reducing energy consumption, for example, should both enhance energy security and reduce environmental impacts. It will be important in future to maximise such **synergies**. But there will also be **trade-offs** and these may be more frequent than the synergies. Security considerations are a necessary underpinning, but how should trade-offs between the three constituent objectives of sustainable development – economic, environmental and social – be assessed?

3.19 Government intervention to address market failures or internalise externalities would, if successful, increase efficiency and should thus enable at least one objective to be improved without harm to others. However, these improvements may not always be readily apparent, especially when they lead to changes in income distribution, as most individual interventions do. For example, government intervention to address environmental externalities could take the form of energy taxes, leading to higher energy prices and reduced pollution. This may at first appear to conflict with the economic objective of cost minimisation, but if a wider view is taken of "costs" so as to include environmental costs, or damage, then this intervention can be viewed as in accordance with economic objectives. However, unless otherwise addressed, the higher prices would adversely affect those in fuel poverty. If the environmental issue was global but was being tackled unilaterally, there would also be adverse economic impacts on a country's international competitiveness.

3.20 Some of the strongest synergies might come about where measures to promote environmental objectives (such as more renewable energy, less energy use, higher energy prices) also have beneficial effects on security (such as less need for imported energy and less reliance on fossil fuels). But it is most unlikely that synergy will ever be complete between two sets of objectives. For example, if greater use of coal were thought to increase security, there would be adverse environmental effects. In fact, the greater need for trade-offs in future is a general theme of this report. It is unlikely that the cheapest energy options will always be best for the environment, security and wider social objectives.

3.21 Where potential trade-offs exist it is important to establish whether one or more of the objectives constitutes a "constraint", that is an objective where there is no scope for compromise or trade-off within the UK political process.[6] If all the objectives are seen as constraints in this sense then the only way to proceed is to use additional measures outside energy policy to offset adverse impacts. However, this may just be shifting the trade-offs from one policy domain to another.

3.22 **Security** has some of the characteristics of a constraint – something that should be met at all times. However, because security is inherently hard to quantify, it may be difficult to identify the degree to which it is damaged by a particular policy and thus the extent of compensating action required. It is also likely

[6] In practice, almost all "constraints" will be flexible in some circumstances – like "force majeure" provisions in contracts.

that small changes to the level of security could be tolerated if the alternative was the introduction of completely new measures to achieve just a small impact.

3.23 Aside from security, the main constraints on UK energy policy are likely to come from **international agreements** of one sort or another.

3.24 The main area in which international agreements constrain UK energy policy is in the environmental field. The main areas of agreement at present cover emissions of the gases that cause acid rain (mainly oxides of sulphur and nitrogen) and emissions of greenhouse gases. Current commitments for greenhouse gases, under the Kyoto Protocol cover the period 2008-2012. The constraint on greenhouse gases, under the Kyoto Protocol, currently operates only until 2012. The parties have agreed to establish additional commitments beyond 2012, but the timing and scale of these remains very uncertain.

3.25 Of course, international agreements are not simply imposed on countries, but arise from a process of negotiation. At the negotiation stage, each country is likely to emphasise the difficulties it would face in meeting particular targets. To the extent that such difficulties are accepted as real, or well presented, the draft of the agreement may be adjusted accordingly. However, future agreements on climate change will involve many countries, and the ability of any one country to influence the agreement to its advantage will be correspondingly small.

3.26 International agreements on carbon abatement are expected to permit trading of emissions among participants. The Kyoto Protocol already makes provision for such trading through the Kyoto flexibility mechanisms.[7] If the UK is able to meet future international targets by trading rather than domestic action, it could be argued that environmental considerations no longer represent a constraint on energy policy. To a limited degree, this may be true. Were the Government to reach the view that domestic compliance with emission limits would have unacceptable implications for energy security (in practice, this seems unlikely) then compliance could be achieved by buying permits from abroad whilst keeping domestic emissions higher in order to safeguard security. In this sense, the potential for trade-offs between environmental and security objectives remains. However, the permits purchased would have a cost for the nation and it seems very probable that this cost would be placed on energy consumers by one means or another. This means that the potential for sacrificing environmental objectives in favour of economic or social ones would remain constrained.

3.27 International constraints also exist in the areas of other policy objectives. However, these are generally of a partial nature or are constraints on instruments, rather than objectives. An example of a partial constraint is the UK's obligation, as a member of the International Energy Agency, to hold specified levels of oil stocks. These contribute to energy security but the IEA does not attempt to place general constraints on the energy security of members – indeed, in view of the difficulties of measuring security as a whole, it is hard to see how it could do so. An example of a constraint on instruments is the EU limit on the minimum rate of VAT (5%) on domestic energy.[8]

3.28 In broad terms, international agreements place some restrictions on UK energy policy but do not prevent UK ministers making decisions about the trade-offs among the economic, social and security objectives of energy policy. International agreements are more likely to constrain UK ministers' ability to trade environmental benefits for benefits in other areas.

[7] DETR (2000), page 18.
[8] European Commission 6th VAT Directive 77/388 Articles 12(3)(a) and 28(2)(b).

What can energy policy achieve?

3.29 In seeking principles to guide the resolution of trade-offs, it is useful to look at what energy policy can realistically deliver across economic, environmental and social objectives. This recognises that policy in a wide range of other areas (such as education, the general tax and benefits system, employment and trade) can have a significant impact on these objectives.

3.30 Starting from environmental policy objectives, the expectations about what energy policy can deliver are necessarily large. Taking first the issue of climate change, some 80% of all greenhouse gases are directly the result of energy use (including energy use in transport). Reducing these emissions by significant amounts will therefore inevitably require action within the energy system. There are other policy areas (e.g. building regulations) which influence levels of greenhouse gas emissions.[9] But the level of emissions finally depends on energy use, and energy use is squarely within the domain of energy policy. If reduction of greenhouse gas emissions is important, energy policy must be the main delivery vehicle.

3.31 Energy policy is also crucial to other elements of environmental objectives. For example, almost all emissions of oxides of sulphur and nitrogen and (non-military) arisings of radioactive waste come from the energy system.

3.32 Turning to economic objectives, the energy system again plays a crucial role – the continuing need which businesses and households alike have for secure and efficiently provided energy supplies has already been discussed. Energy accounts for about 4% of UK GDP.[10] Total expenditure on energy by households is about 5% of total consumer spending, with about half of this being spending on motor fuels. For most companies, energy costs amount to only 1-2% of total costs, but some industries have a much greater dependence on energy than this. The internalisation of environmental externalities in energy prices (as discussed in Paragraph 3.19) can be viewed as serving broad economic objectives, but would inevitably worsen the economic prospects of energy-intensive producers of traded goods.

3.33 The extent to which energy policy can deliver social objectives is quite limited. If policies to promote security or environmental protection led to higher energy prices, there could be a significant effect on those suffering fuel poverty. Here, however, there is a very high degree of policy substitutability – increased fuel poverty can be addressed quite directly either by income supplements (outside energy policy) or by improved energy efficiency measures within the homes of those who experience fuel poverty. In the area of citizen involvement with local decision-making – where, say, an implication of environmental objectives was the expansion of certain kinds of decentralised energy – the degree of policy substitution is less clear cut. However, it is still reasonable to suppose that some accommodation between environmentally motivated local energy development and citizen participation might be reached without sacrificing environmental objectives to any great extent.

3.34 The most important starting point for a framework to resolve trade-offs between objectives in energy policy-making is therefore that Government *must* use the energy system to deliver most environmental objectives, especially climate change objectives. And the environmental objectives which energy policy is

[9] It is also the case that adaptation approaches to climate change involve a much wider policy-making arena. At present emission reduction is at the heart of international approaches to climate change although individual governments, including that of the UK, are also considering ways of adapting, not least because some measure of climate change now appears unavoidable.

[10] DTI (2000d), page 16.

best placed to deliver are the ones most likely to be subject to binding international constraints.

3.35 As the achievement of environmental objectives, especially climate change, can only be achieved through the energy system, and since some environmental objectives may effectively be constraints, this suggests that **where energy policy decisions involve trade-offs between environmental and other objectives, then environmental objectives will tend to take preference over economic and social objectives**. The actual balance will, of course, depend on costs: a minor environmental improvement would not be worth having at the expense of major economic cost. But given the unavoidable need to take action in the energy system for environmental ends, there is a strong likelihood that, where major actions are needed, the value of the environmental gains will outweigh the costs in other areas. The wider impacts of environmentally-motivated decisions must always be carefully monitored, so that policies which can mitigate the more serious impacts on fuel poverty and competitiveness can be considered.

3.36 There is a constant need to check the extent to which given policy approaches affect security objectives – in extreme cases the pursuit of security may, over short periods of time, need to over-ride environmental considerations.[11]

3.37 **Recommendation: The DTI should re-define its general energy policy objective. The new objective could be "the pursuit of secure and competitively priced means of meeting our energy needs, subject to the achievement of an environmentally sustainable energy system".**

Resolving trade-offs

3.38 The previous analysis suggests that in the longer-term a good deal of energy policy may be devoted to resolution of environmental issues where the scope for trade-off against other objectives is very limited. Nonetheless, trade-offs between other objectives will remain and there may be some scope for trade-off with environmental objectives.

3.39 There is no easy way to make these trade-offs. Each will need to be considered separately in the context of its particular circumstances. In the last resort, such trade-offs are political decisions and political priorities can, and do, alter.

3.40 There are tools that can assist with these decisions. Two examples that are widely used are cost-benefit analysis (CBA) and multi-criteria analysis (MCA). A key aspect of CBA is that it attempts to reduce all aspects of the decision to monetary values. This can involve placing values on things that are not traded and hence do not have a market value that can be observed. And it can also involve deliberately reducing or increasing certain market values in an attempt to allow for equity concerns. This process is known as "shadow pricing". In order to assist policy evaluation, Government should determine shadow prices for any important environmental externalities as well as for the value of a reduction in fuel poverty and the value of more or less energy security. It is accepted that there are no easy means to establish appropriate values for these shadow prices and that uncertainties associated with them are likely to be large. This is a good reason for keeping them under regular review and may also justify using a range of shadow prices to assess the robustness of a policy to uncertainty. The shadow prices could then be used in policy analysis by Government departments and by independent regulatory

[11] For example, if the impact of temporary shortage of gas on the electricity sector could only be offset by a higher level of coal use, then exceeding emission targets or limits might be the only way to maintain supplies.

bodies. In the longer-term, the need for some shadow prices could fall away, for example if environmental externalities were internalised through economic instruments and thus came to be reflected in market prices.

3.41 MCA does not try to reduce all aspects of a decision to monetary values, but ranks alternatives according to a range of criteria of which monetary value is just one. Others might include public acceptability, environmental impact or transparency. Different weights can be placed on the criteria to determine an overall ranking.

3.42 A key element in any evaluation of trade-offs is to consider them against a range of future scenarios. Options that appear relatively attractive in some global scenarios will be less so in other, perhaps equally likely, scenarios. An objective of any assessment would therefore be to seek policies or choose options that are robust against a wide range of future scenarios and may also be flexible enough to adapt to changing circumstances.

3.43 In Chapters 6 and 7 a simplified form of MCA is used to assess the relative attractions for the UK of a range of low carbon options. The analysis is then translated into broad policy recommendations in relation to each option. The form of the analysis reflects the purpose for which it is intended – i.e. to recommend broad strategic guidance and directions for more detailed analysis rather than to make firm decisions between clear-cut alternatives.

3.44 **There is no simple way to resolve residual trade-offs. Each case will demand separate analysis. It is recommended that to assist this process HM Treasury should establish, and keep under regular review, shadow prices for key environmental externalities and other non-economic policy objectives.**

When should Government intervene?

3.45 Compared to the era when Government owned large swathes of the energy industries, Government now has fewer policy levers or instruments than it had, and there is much greater recognition of the effectiveness of markets in choosing between energy options and allocating energy resources.

3.46 The existence of Government policy objectives, and of considerations that might in principle justify intervention in pursuit of those objectives, does not in itself mean that there needs, at any particular time, to be active or major policy intervention. If an existing system, based on market operations, produces outcomes that deliver policy objectives, active policy intervention will not be needed. For example, from the mid-1980s to the late-1990s, UK policies mainly aimed at promoting energy markets and at curtailing acid gas emissions, in conjunction with developments in international energy markets, kept energy security at acceptable levels and also led to reductions in carbon emissions, without the need for major new policy intervention on either account. Establishing the importance of a policy objective does not therefore always require policy activity. And it must always be remembered that Government may lack detailed knowledge of market conditions or better foresight than the market, and that Government intervention, particularly in the form of "picking winners", may be misjudged. Only when events threaten the boundaries surrounding the achievement of an objective will it be necessary to intervene. The corollary is that achievement of energy policy objectives needs to be kept under continuous review.

3.47 Government intervention needs, so far as possible, to provide transparent, consistent and long lasting signals to all participants in energy markets. The provision of long-lasting signals is of particular importance since many energy investments are capital intensive, of long duration, and once built are relatively inflexible. Without long-term signals, these investments will not be influenced in the directions desired and changes that may need to happen over many years will not come about. Short-run interventions in pursuit of immediate political or economic gains should be avoided. Some elements in the preferred energy policy mix may take time to establish – there may need to be a transitional period, allowing for existing commitments to be met. If long-term objectives need to be sacrificed for the sake of protecting existing commitments, then this should be clearly recognised.

3.48 The converse of providing long-lasting signals is that when, for whatever reason, Government feels unable to provide clear indications of its longer-term policies, it should attempt to ensure that the absence of such signals, or of instruments supporting them, does not lead to investment being made in long-lived energy assets which are very likely to be incompatible with those policies. This would limit resources being wasted on stranded assets due to lack of clarity over Government policy, and also reduce the risk of energy systems being "locked-into" inappropriate assets. Sometimes it is easier to say what is not wanted than what is wanted.

3.49 **Where possible, Government should adopt long-lasting energy policy signals in order to affect energy investments and ensure long-term change. Where short-term policy adjustments are required, in response to particular events, these should be recognised as such and should not undermine the long-term signals.**

How should Government intervene?

3.50 There are three main types of instrument available for Government intervention:

- **direct regulation**, in which Government or regulators can set the physical or economic rules under which energy system participants can act. This can take the form, for example, of licensing firms to supply retail energy, controlling the emissions from an industrial plant, or setting building regulations to ensure a minimum level of energy efficiency;
- **economic (or market-based) instruments**, where Government or regulators can encourage particular outcomes without in any way specifying how those outcomes might be delivered. An example might be a tax on a particular form of energy, which encourages all consumers to reduce its use, but does not attempt to say by how much or which sort of consumers should make the reductions; and
- **policies of other kinds**. This is a catch-all category that includes direct government spending (for example on energy R&D), decisions on how Government will procure energy services and energy-using equipment for its own use, and voluntary agreements between Government and groups of market participants.

3.51 Whatever instruments are used, and in whatever combination, their use should meet two broad criteria: they should be efficient or cost-effective and they should promote equity.

3.52 The criterion of efficiency covers effectiveness – in other words, it needs to help move the energy system clearly towards the desired goal – and costs, not only to government (public sector costs) but to the economy as a whole (resource costs). The comparison of effectiveness and resource costs gives a cost-benefit or cost-effectiveness criterion that is fundamental to the assessment of policy instruments.

3.53 The two most important considerations in terms of equity are distribution – how the instrument affects the distribution of goods between different members of society, and transparency – how clear and comprehensible is the instrument.

3.54 The relative merits of the different approaches are explored in the following paragraphs using carbon abatement as an example of the final objective.

Direct regulation

3.55 Regulation is of particular importance for the natural monopolies where competition cannot be relied upon to set appropriate prices or levels of output. However, regulation is often used in competitive markets as well. For example, producers of a particular energy-using product might be required to ensure that it meets specified criteria for energy use per unit of output in order to reduce the carbon emissions associated with its use. Regulation has the advantage of considerable flexibility and, depending on the detail, it can deliver a high degree of cost-effectiveness, especially in circumstances where a wide range of market participants face very similar costs (e.g. costs of finding information) or have similar preferences. But there are risks of regulation not being cost-effective if, through ignorance on the part of the regulator, market participants are compelled to specified actions when other, less costly actions could deliver the same results. In general, such distortions will be minimised when regulation specifies the result to be achieved, rather than the means of achieving it.

3.56 In most circumstances direct regulation is transparent to those immediately affected and it can be structured in such a way as to avoid some adverse distributional outcomes. On the other hand, the costs (e.g. raised product prices) or benefits (e.g. reduced energy consumption) are not always obvious to the buyer.

Economic instruments

3.57 The key property of an economic instrument is that it is designed to achieve one particular objective, usually by placing a value on a cost or benefit that, for whatever reason, is not valued by the market. By doing so, these instruments affect market prices – for example, a tax on carbon emissions would increase the prices of fossil fuels. Another example is a system of tradable carbon permits for the control of carbon emissions. Such permits could be traded between all participants in the market to ensure that the overall emission target (which would fix the number of permits) was met in the most cost-effective manner. Those who could reduce emissions most cheaply would sell permits to those whose emission reduction costs were higher. There would also be good incentives to find new and innovative ways of reducing emissions in ways that regulators may not have considered at the outset. Such instruments can be particularly useful in addressing environmental externalities but can also be applied to other objectives.

3.58 For economic instruments to be efficient, market participants need to know *well in advance* how many permits, for example, are to be issued for any particular period. It is also important to ensure that there are no other market or institutional failures that prevent participants reacting to the incentive.[12] Economic instruments are generally transparent, even to those not directly affected, but are not structured to address distributional issues because they affect market prices which in turn affect all types of consumer or producer. However, distributional issues can be addressed by other, parallel, measures. A large majority of

[12] An example of such a failure might be the inability to obtain planning permission for a low carbon technology. Such failures would need to be addressed directly.

those consulted in the course of the energy review (of those who expressed opinions on instruments) believed that economic instruments have efficiency and transparency advantages over other instruments and should be used more in the future.

3.59 The impact of tax instruments could be enhanced by agreements such as those negotiated in respect of the Climate Change Levy. In return for a lower tax rate, the taxpayer agrees to abate energy (or carbon) use more than had it faced the full tax rate. This is profitable for the taxpayer since the reduction in tax on residual energy (emissions) can more than offset the extra abatement costs. This approach is sometimes known as "conditional taxation". Its disadvantages are greater complexity, the need for regulators to reach judgements about the amount of abatement that is reasonable in return for a given tax reduction, a potential distortion of incentives between those with agreements and those without, and the possibility of taxpayers subsidising very high-cost carbon abatement at the margin.

Other instruments

3.60 The general characteristic of this group of instruments is that they "pick winners" with Government giving support of one sort or another to a particular technology or type of activity that it believes will be able to achieve its objectives efficiently. Because Governments may be poorly informed of the relative carbon abatement costs of different options, they may pick winners that turn out to be losers. Instruments of this sort do have the advantage, however, of considerable flexibility and can be used in circumstances where, for whatever reason, it may not be appropriate to give long-term general incentives or introduce new regulations. These instruments can also be quite carefully crafted to minimise adverse distributional consequences, although the price might be some lack of transparency.

Comparison of instruments

3.61 It is clear that different instruments have different advantages and disadvantages. Most past policy approaches to environmental and other energy policy problems have used a combination of instruments – there has been a policy package, rather than a single instrument. It is very likely that such an approach will continue to be needed in the future. Economic instruments have very important potential advantages in terms of their ability to involve all market participants in addressing an issue and thereby delivering the most cost-effective solution, but unless or until certain market failures can be resolved, and international agreement reached on longer-term carbon abatement, economic instruments alone cannot be relied on for the purpose of carbon abatement. The use of a range of instruments is also more likely to deliver an overall policy stance that is flexible to changes in circumstances and distributional considerations, while still giving significant messages about future policy to the markets. The overall conclusion is that in many instances delivering energy policy objectives will need an effective and pragmatic blend of instruments, although in the longer term a greater role for economic instruments should be sought.

The role of targets

3.62 An important element of environmental and energy policy-making has been the establishment of targets for the achievement of given outcomes by a specified dates. Targets do not, of course, determine means (which, if any, of the instruments discussed above might be used to deliver them), but they do give a clear indication of ends. How far should targets continue to be used?

3.63 The case for continuing to set targets is strong. They provide an obvious means of focusing both policy makers' and market participants' attention on areas where new policy measures may be required or existing ones adjusted. In doing so, they also provide a focus for innovation at a time when clearer market support (perhaps in the form of economic instruments) is premature, and they may of themselves help to stimulate a modest amount of investment, especially in R&D, by firms anxious to anticipate future developments.

3.64 At the same time, a target does not of itself have much impact on market investment patterns, unless backed by instruments and measures to ensure its achievement (or unless it would have been achieved anyway). It leaves room for back-tracking in the event that circumstances turn out to be different from what was expected, while still making back-tracking sufficiently sensitive politically so that it would not be undertaken lightly. This sensitivity contributes a lot to the confidence-enhancing quality of targets, which is necessary if they are to have any impact at all on behaviour.

The centrality of carbon and the climate change issue

3.65 The issue of climate change has been identified as a key challenge for our future energy system. Under the Kyoto Protocol the UK faces internationally agreed targets for carbon emissions covering the period up to 2012. The Government has set out a range of policies to meet those targets in its Climate Change Programme.[13] This section considers what might come next against the background of widespread agreement that the developed countries will need to make very large reductions in carbon emissions in the longer-term if the climate is to be stabilised.[14]

3.66 In broad terms there are three possible national policy approaches to climate change:

- **unilateral:** proceeding with significant long-term reductions in carbon without any guarantee that other countries will do likewise. Since the benefits of carbon reductions are global, rather than accruing to those reducing the emissions, it seems very unlikely that individual countries, including the UK, would be prepared to accept the risks of this strategy. If a country moves ahead unilaterally on abatement of pollutants with global effect, its competitive position is likely to be undermined and economic growth restricted. Depending how the costs of that abatement are met, companies in that country producing internationally traded goods with energy intensive processes (such as steel) may be particularly threatened. On the other hand, if other countries then follow, the country starting the process could have gained "first-mover" advantages, perhaps by developing low carbon technologies it can then export;
- **reactive:** only taking action to address carbon reduction once bound by internationally agreed targets and not going beyond those targets. This approach carries different risks, including being unprepared and ill-equipped, relative to other countries, to pursue emissions reduction. For this reason it is also likely to be unattractive to the UK; and
- **leading:** aiming to promote international agreement and taking precautions that would minimise the risks of failing to meet existing targets, while also facilitating achievement of possible future targets and promoting a degree of first-mover advantage. This is the approach already adopted in the UK Climate Change Programme[15] and is well suited to framing longer-term policy in this area.

3.67 A further important consideration is that international agreements to reduce carbon are very likely to feature international trade in

[13] DETR (2000).
[14] Further details can be found in PIU (2001g).
[15] DETR (2000), page 6, paragraph 8.

Box 3.1: Carbon Valuation:

There are two major alternatives for producing a market value of carbon (i.e. a general incentive for carbon abatement). One is carbon taxes and the other is tradable carbon emission permits (TCEPs). There are two key differences between these approaches:

- taxes fix the value of carbon but leave the quantity undetermined whilst permits fix the quantum and leave the value to be determined; and
- the distributional consequences can vary depending how the permits are allocated.

In both cases, the mechanisms would need to be phased in over long future time periods in order for future tax levels, or future permit availability, to affect current investment decisions. If introduced suddenly, either mechanism could produce very high taxes or permit prices, given the difficulties of substituting for energy in the short term.

Carbon taxes could be applied to producers of fossil fuels. The taxes would be passed on to buyers in the form of higher prices, all the way down to the final purchaser. The tax would be set at the level thought necessary to deliver the total level of carbon abatement required.

TCEPs might be required for all sales of fossil fuel to final consumers. The total volume of permits issued would equal the quantity of emissions allowed and their value would be determined by trading between permit holders. For example, a petrol company might need to surrender a permit for each unit it sold to motorists and the cost of that permit would be reflected in the price paid by the motorist. Large consumers might buy their own permits to cover their energy needs and pass these to their energy supplier to surrender.

The key issue with permits is their initial allocation. One approach is to auction all permits to the highest bidder. In this case, the distributional consequences would be similar to those of a carbon tax. But a range of other approaches is possible, including approaches under which some permits, or the revenue therefrom, are allocated to groups which the Government considers especially deserving, for example energy intensive industry or the fuel poor. The traded price of permits in the market, and hence the incentive to reduce emissions, is unaffected by the initial allocation.

As noted in Paragraph 3.59, the impact of carbon taxes or permits could be enhanced by agreements which make their impact conditional on achieving specified savings.

Using taxes to value carbon would not mean that taxes in the energy field could not simultaneously be used for other purposes, including addressing other environmental externalities. In many cases, there may be synergies so that reductions in carbon might also lead to reductions in, for example, acid gases. What matters for carbon valuation purposes is that there is a "carbon element" in the tax which reflects differences between the carbon content of different fuels. It is not impossible that in overall tax levels, carbon differentials could be more than offset by differentials arising from other externalities or objectives. For example, taxes on motor fuel might be much higher than those on domestic coal use, even though coal was the more carbon-intensive fuel, on account of concerns about road congestion. In other cases, the uncertainties associated with combining a range of objectives in energy taxes might mean that taxes on energy use might be preferred to different tax rates on individual fuels.

carbon emission rights. This in turn implies that carbon will be valued in the market-place (see Box 3.1). It is possible that such trading will be limited to inter-governmental transfers, but it is rather more likely that carbon permits will increasingly be owned by individual firms who will trade between themselves.

3.68 Another implication of international climate change agreements is that the problems of higher energy prices for energy-intensive industry can be dealt with. Clearly, there is no merit in raising prices to meet a domestic emissions target if the result is to drive energy-intensive industry to move to another country with no carbon limit. Global emissions would not be reduced but local jobs would be lost. The more countries participate in an international agreement, the lower the risk of the problem. And the countries taking action could well agree among themselves measures to protect energy-intensive industry within their collective borders.

3.69 A "leading" approach to climate change implies three separate policy timelines:

- measures to comply with agreed targets;
- measures to prepare for future targets not yet agreed but probably involving not all countries and operating for limited time-periods; and
- measures to prepare for a world of long-term emission limits agreed between all countries, possibly based on the principles of contraction and convergence.[16]

3.70 There is no clear dividing line between these phases. Post-Kyoto targets affecting the UK could be finalised by 2005 but agreement might take longer, perhaps a lot longer, and the scale of the next targets is uncertain. Likewise, it is possible that we could be in a world of long-term universal targets by 2010. There is even a remote possibility of moving directly to the final phase from the current position.

3.71 In the same way, it is far from clear what the scale of future targets will be. The RCEP suggested that a 60% reduction for the UK by 2050 would be needed within a contraction and convergence agreement, but the exact figure is very uncertain. All that is certain, whether we move to a contraction and convergence world, as suggested by the RCEP, or follow the guidance produced by the IPCC about global levels of emission reductions that will be needed to avoid dangerous climate change, is that developed countries will need to make very substantial cuts from current emission levels over the century ahead.

3.72 There are risks that international agreements to abate carbon will not be reached and that in such cases, many countries would not move unilaterally. This should not detract from the argument that the scientific case for abatement is becoming increasingly strong and that there will therefore be increasing pressures on governments to reach agreements and a high probability of agreements being reached in due course.

Frameworks and trade-offs for policy timelines

Compliance with agreed carbon targets – to 2012

3.73 Measures to comply with the UK's Kyoto targets were set out in the UK Climate Change Programme. The measures are actually expected to deliver greater reductions than required, in order to give a high degree of confidence that the targets will be met and because the Government has also set a domestic goal to reduce carbon dioxide emissions by 20% below 1990 levels by 2010.

[16] "Contraction and convergence" is a possible basis for long-term international agreement on carbon abatement. It would entail developed countries reducing their *per capita* emissions (contraction) whilst developing countries' emissions expanded until all countries' *per capita* emissions converged at a level considered to be sustainable.

3.74 However, there is no automatic mechanism in place to ensure the UK meets its Kyoto target if events do not turn out as expected. For this reason it is crucial that energy sector developments continue to be monitored and that the assessment of new policies takes account of any contribution they might make to the target or the extent to which they might make it harder to meet. In the latter case, it is particularly important to factor in the cost of alternative measures to put the UK back on track to meet what are binding targets. This could be done using a shadow price for carbon.[17]

3.75 **Energy policy trade-offs affecting this period should generally give priority to carbon reduction if there is a material risk of failing to meet internationally-agreed emissions targets.** Failure to meet the target would be inconsistent with a "leading" role for the UK in response to climate change. This may require compensating policy measures in other areas to achieve other policy objectives.

3.76 Given the expected role of existing measures, the practical difficulties in moving to widespread carbon valuation (see Box 3.1) and the limited time that carbon valuation measures would have to affect the energy system before 2012, there might seem little reason to move towards carbon valuation in the short-term.

3.77 On the other hand, there are strong reasons for early progress towards carbon valuation:

- carbon valuation is likely to be the single most effective low carbon delivery measure in the longer-term, and to delay moving towards it would give a misleading signal;
- the Kyoto mechanisms (see Paragraph 3.26) allow for international carbon trading, which in turn implies valuation, in the period 2008 – 2012 and a draft EU Directive[18] proposes an EU wide trading scheme from 2005. It is important that the UK has the option of making full use of these mechanisms as a means of delivering its Kyoto commitments;
- there is a real possibility that by 2008, longer-term internationally-agreed emission targets will have been agreed which would enable greater reliance to be placed on carbon valuation; and
- carbon valuation is not an "all-or-nothing" issue. Although the long-term aim might be to use carbon valuation as the major low carbon policy measure affecting the whole of the energy market, in the shorter-term it could be limited to certain sectors and combined with other instruments if more widespread implementation would conflict with energy security or social objectives.

3.78 The UK has already made a start on carbon valuation through the Emissions Trading Scheme, a tradable permit scheme being taken forward by DEFRA for launch in 2002. The coverage of the Scheme is effectively confined to larger business energy users and participation is entirely voluntary.

3.79 **Consequently, it is recommended that HM Treasury/DEFRA give early consideration to expanding the use of carbon valuation through taxes or tradable permits to cover as much of the energy market as possible. This could involve expansion or modification of the current Emissions Trading Scheme and should ensure that UK companies could participate in international carbon trading schemes, including the draft EU scheme, as soon as these are introduced.**

3.80 It is also important to remove political barriers to carbon valuation. In this context, the main objectives are to press ahead with the fuel

[17] Recent work by DEFRA indicates that a point estimate of £70 per tonne carbon, together with a sensitivity range of £35–£140 per tonne carbon, could be appropriate illustrative values to use for a shadow carbon price. This work should be available shortly as a Government Economic Service Working Paper.

[18] Commission for the European Union (2001c).

poverty programme and to ensure that international agreements deal with the concerns of energy-intensive industry.

3.81 It is particularly important to address institutional or other barriers to the take-up of the technologies encouraged by the measures already in place. This should also lead to economic benefits and greater deployment of "no-regret options", such as many energy efficiency measures. On the other hand, there is little scope for innovation to play a significant role in meeting targets for this period.

Preparation for future carbon targets – post 2012 – keeping options open

3.82 The size, duration and starting points for future targets remains uncertain. The first consequence is that preparation to meet such targets should not involve commitment of large sums of money. The second consequence is that there is greater scope for trade-offs between environmental and other energy policy objectives since there are no binding carbon constraints at present.

3.83 With the scale and duration of future targets uncertain, it is not possible to put in place carbon valuation schemes that would fully reflect the longer-term cost of emissions. For example, if carbon taxes were to be used, it would be far from clear at what level they should be set. It is even possible that if post-Kyoto targets had not been agreed by around 2008, the UK might decide that implementation of any form of carbon valuation would not be worthwhile.

3.84 The most important preparation for this period is to establish[19] a greater range of low carbon options, ready for deployment as necessary. In some cases this will involve measures to keep existing options open. In view of the continuing uncertainties, we should not be seeking to establish every possible option, regardless of cost, but rather to take forward work on a sufficiently large range of options so that, allowing for the possibility that some might turn out poorly, the UK would even so still be able to make significant carbon reductions. Options that are robust to a range of future scenarios will be particularly attractive. Establishing these options will require a range of measures in addition to any possible role for carbon valuation. The difficulty of relying to a significant extent on carbon valuation, because of the uncertainty about the scale and duration of future targets, indicates that some Government judgements on which options to support will be needed.

3.85 Because policy relating to this timescale is inevitably more uncertain than when clear carbon emission targets are in place, greater use should be made of indicative policy statements, including targets not backed by instruments, in order to provide some indication to the market of expected future directions. Such an approach would include steps to discourage lock-in to technology likely to be inappropriate in most future scenarios.

3.86 In general terms, the options that might be deployed to meet the next generation of targets are likely to have been technically demonstrated to at least some degree. However, at least some will be at the stage where further process innovation will be important. Further public funding for innovation, perhaps in an international context for options capable of deployment across a wide range of countries, is likely to be a necessary condition for their establishment.

3.87 Although the creation of low carbon options and keeping existing options open is

[19] In this context, "establish" means that the technology should be technically proven; have been deployed at a commercial scale; be in at least its second phase of commercial-scale deployment, to allow for learning benefits from the first deployment and from pre-commercial deployment; and have been deployed to an extent which enables a significant part of any economies of scale to be exploited. With these criteria, the future costs of large-scale deployment should be reasonably predictable.

the main current activity relating to the post-2012 period, there is also a case for limited calling of options, even those which are not no-regret. This report recommends an expansion of the targets for renewables in the post-2010 period (see Chapter 7). This is partly to enable additional renewable technologies to become established as extra options and partly to deploy extra volumes of some technologies that would have become established anyway with current targets and measures. Aiming for this limited extra deployment at this stage will help to keep the UK on a long-term low carbon path and to ensure necessary infrastructure changes take place. However, it is not considered necessary that we plan at this stage for steadily decreasing carbon emissions towards a possible long-term goal. So long as a good range of low carbon options is established by 2020, the UK would be well placed to meet large long-term reductions.

Preparation for long-term universal emission limits

3.88 If long-term universal emission limits are agreed, carbon emissions will become a binding feature of UK energy policy. At this stage, the focus of policy choice will therefore have to focus on means of delivering other objectives at the same time as environmental ones, and on trade-offs between those other objectives.

3.89 The nature and scale of long-term targets is very uncertain and we do not know when this stage will be reached. The main preparatory measures are likely to fall into two parts:

- ensuring that the UK is able to participate fully in international carbon trading; and
- supporting research into the more speculative low carbon options and those whose deployment looks likely to be some decades away.

3.90 There is a strong role for innovation in preparing for these long-term limits. Innovation should be understood to encompass institutional as well as technical innovation. Institutional innovations required for a low-carbon energy system, such as changes to electricity distribution systems, are discussed in Chapter 7. Here the focus is on technological innovation, which is one of the primary means of creating the long-term options that are so necessary to an overall low carbon strategy.

3.91 Successful technological innovation is the product of a complex network of actors, stretching from basic university research to diffusion of commercial innovations in the market. Policy needs to encourage the supply side (the research and technology development system) and also encourage consumers and firms to seek and adopt new technologies (the demand side). The Renewable Obligation (see Chapters 6 and 7) is expected to encourage innovation in renewable electricity generation and is an example of a demand side measure.

3.92 Both the DTI and the Chief Scientific Adviser (CSA) have recently given attention to energy R&D.[20] The CSA's review of energy research stresses the importance of seeing innovation in system-wide terms and not just as a matter of individual, stand-alone technologies. It is important to tackle issues such as gas and electricity system operation. For future policy it will be important to frame innovation policy not just as part of industrial or competitiveness policy but also in relation to long-term low carbon objectives.[21]

3.93 Will UK promotion of innovation make much difference? Much technology development is now highly internationalised and some technologies can be "bought off the shelf". But not all technologies can be instantly and automatically adapted to UK conditions.

[20] The Energy Group of the DTI has looked at long-term R&D and the CSA established a working group specifically to inform the PIU Energy Review. A summary of its report is at Annex 8.

[21] PIU (2001b) develops these arguments further, especially in Chapters 2 and 4.

This is especially true of energy efficiency and many renewable technologies, where local conditions are critical to design. More generally, it is at least necessary to be an informed buyer of technology, and it is also important to be able to buy into wider technology development programmes by contributing to R&D directly. Nevertheless the domestic/overseas distinction is important in deciding priorities for UK R&D effort.

3.94 Should Government intervene and help finance innovation in energy? The classic case for government support is that the public good aspect of innovation – the results cannot be fully appropriated by individuals or firms – tends to discourage private sector investment. However, this does not make a special case for Government support for energy innovation in particular, or more support for energy innovation in the future. The distinctive characteristics of energy as a candidate for particular Government support are:

- until such time as carbon valuation is built into energy prices, the market does not provide incentives for commercial development of low carbon technologies;
- many low carbon options need to be developed for specific UK conditions; and
- the precautionary principle that is so important in preparing for the long-term low carbon future will not be fully reflected in private markets with their relatively short-term focus.

3.95 The CSA's review and the RCEP both make strong cases for expansion in publicly funded energy R&D for low carbon reasons. In the context of a ten-fold fall in UK public sector energy R&D in the last 15 years and a much lower spend on energy R&D than our main trading partners, the case for expanded energy R&D support is strong (see Chapter 7). The CSA's review also puts forward four criteria to inform policy for energy R&D. The need for a low carbon economy is at the top of the list and the other three are:

- achieving secure/sustainable energy supplies;
- dealing with long-term oil/gas depletion; and
- international competitiveness.

We endorse these principles. Further detail on the review's recommendations is in Chapter 7.

Conclusions: The principles of good energy policy

3.96 In looking at any proposed energy-related policy, whether it is consistent with the fundamental goal of moving towards a low carbon system is the most crucial question. It needs to be followed by asking which alternative policy instruments (or combination of instruments) are available to meet the relevant policy objective.

3.97 For each policy instrument or package, there is the need to assess:

- what are the impacts on energy security? What are the means and costs of mitigating any such adverse impacts? This is a key question in view of the importance of energy security in all future circumstances and is discussed in detail in the next Chapter;
- what are the impacts on economic, other environmental and social objectives? Again, what are possible adverse effects, how and at what cost can these impacts be mitigated?
- given that uncertainty means that many types of long-term future are possible, is the chosen policy robust to many different possible future states of the world – not just to those which seem currently most likely or which seem to be preferred? and
- does the proposed instrument or package help maintain existing options, or create new ones?

3.98 Some elements in the preferred set of objectives may take time to achieve and transitional periods may be needed in which pre-existing commitments must be met. Where this occurs the aim should be to separate out the desired long-term approach from transitional arrangements, and if long-term objectives sometimes need to be sacrificed to preserve existing commitments this needs to be clearly and explicitly recognised.

Summary of Recommendations

Main Recommendations

1. Where energy policy decisions involve trade-offs between environmental and other objectives, then environmental objectives will tend to take preference over economic and social objectives. The DTI should re-define its general energy policy objective. The new objective could be "the pursuit of secure and competitively-priced means of meeting our energy needs, subject to the achievement of an environmentally sustainable energy system". (3.35 and 3.37)

2. There is no simple way to resolve residual trade-offs. Each case will demand separate analysis. It is recommended that to assist this process HM Treasury should establish, and keep under regular review, shadow prices for key environmental externalities and other non-economic policy objectives. (3.44)

3. It is recommended that HM Treasury/DEFRA give early consideration to expanding the use of carbon valuation through taxes or tradable permits to cover as much of the energy market as possible. This could involve expansion or modification of the current Emissions Trading Scheme and should ensure that UK companies could participate in international carbon trading schemes, including the draft EU scheme, as soon as these are introduced. (3.79)

Other Recommendations

4. Where possible, Government should adopt long lasting energy policy signals in order to affect energy investments and ensure long-term changes. Where short-term policy adjustments are required, in response to particular events, these should be recognised as such and should not undermine long-term signals. (3.49)

5. Energy policy trade-offs affecting the period to 2012 should generally give priority to carbon reduction if there is a material risk of failing to meet internationally-agreed emissions targets. (3.75)

4. SECURITY IN THE ENERGY SYSTEM

Summary

Energy Security needs to be satisfied at all times – its importance derives from the critical role that energy plays in all aspects of everyday and business life. Without adequate energy security, the sustainable development objectives would be compromised.

There is a role for government in energy security given consumer expectations and market imperfections. But, where intervention occurs, governments need to ensure that their judgements about appropriate risk levels and methods of intervention are better founded than those expressed in the market.

No immediate decisions are needed about the rising share of gas in the UK energy system and the risks involved do not justify significant interference in energy markets at this time. However, there are a number of measures that would help to mitigate against risks of a higher gas share without major distortion of energy markets.

Imports can increase diversity in the energy system, however there are also a number of risks involved. Over the longer term measures to reduce the risks associated with oil will focus on development of alternative transport fuels and improvements in energy efficiency. There are also a number of measures to reduce the risks associated with gas imports, mainly in the international arena. Particularly important will be progress towards EU liberalisation.

The adequacy of the UK infrastructure is vital to energy security. Many of the energy markets in the UK have recently been liberalised, and the adequacy of incentives for investments in these new markets is currently unproven. However, the present situation is healthy and intervention would be premature.

Although some actions are needed in the short term, there is no crisis of energy security for the UK. However, a number of the risks described in this chapter should be closely monitored, particularly as they change over the next 20 years. Future security risks will be significantly less if the UK has in place a low-carbon strategy for the long term since this should reduce overall energy use and gas dependence beyond 2020.

Insecurity and risk

4.1 The sustainable development objectives – economic, environmental and social – are the main focus for UK policy towards the energy system. Cutting across these is the need for energy security. It can be seen as an underpinning objective that needs to be satisfied at all future points if other objectives, especially economic and social, are to be achieved. It is therefore, useful to discuss issues of security before moving on to look at carbon and the energy system.

4.2 The importance of energy security derives from the critical role that energy plays in all aspects of everyday and business life. The economic and social implications of breakdowns in the energy delivery system are very severe. There is a clear asymmetry between the value of a unit of energy delivered to a customer and the value of the same unit not delivered because of unwanted interruption.[1] Interruptions, or threats of interruption (including immediate network balancing issues) can quickly lead to widespread disruption given that it is difficult to store energy, especially electricity. The resilience of energy systems to extreme events is a major issue.

4.3 The importance of security in the energy system is highlighted by recent events:

- fluctuations in the price of oil;
- the Californian power crisis, which at its peak saw rolling brown-outs, blackouts and high wholesale prices;
- the UK fuel protests of October 2000, when fuel depots were blockaded;
- the expectation that the UK will become a net importer of gas within a few years and of oil a few years later;
- recent escalation of terrorism in the USA and its worldwide consequences; and
- the prospect of more distributed and intermittent generation on the distribution network.

4.4 By energy "insecurity" we mean a substantial *risk* of a physical supply interruption. This need not necessarily lead to *actual* interruptions in all cases. A market reaction to prospective interruptions will usually be sudden increases in price over the period of the expected shortfall. A prolonged period of high and unstable prices is, therefore, normally a symptom of high levels of insecurity.[2] Interruptions to supply can also derive from shocks to the energy system, which could in turn be the result of deliberate acts of disruption or unexpected generic faults in energy supply technology. We can think of

[1] Under the former trading arrangements for wholesale electricity in England and Wales (the Pool) the value of a unit of electricity supply not delivered due to interruption was administratively set at about 100 times the sale price of electricity to reflect this asymmetry.

[2] As opposed to more occasional and short-term "spikes" especially in wholesale energy prices, which are generally market responses to less serious risks.

supply interruption in terms of *quantity risk*, while the possibility of sustained high or spiky prices is *price risk*.

4.5 Different timescales are involved in energy security: ranging from the immediate – how to avoid a power station breakdown today from interrupting electricity supply – to the very long-term – what to do to avoid the risk in 30 years time that world oil may start to have become scarce and expensive. A low carbon economy, such as that considered in Chapter 5, would also have long term security benefits. It would have high energy efficiency, and so use less fuel and use a range of resources that are renewable (and so are often local) or are plentiful, as in the case of uranium. Such an energy economy offers some security benefits compared to the high-use, fossil fuel dependant system we now have.

4.6 But a long-term move towards lower carbon does not protect us against all risks. Energy efficiency, renewable energy and nuclear power are good *general* hedges against fossil fuel dependence, but in the short-term they offer no immediate response to a crisis, because their output will normally be at the maximum. Further, networks are still vulnerable in a variety of ways, and for as long as oil and gas remain important their supply could be disrupted. For these reasons, it is necessary to consider possible policy responses to a wide range of security risks, many of which are not connected to the low carbon economy.

4.7 This chapter discusses the role of Government in ensuring security in the energy system and suggests a number of general approaches which might lead to better security. It then considers the various perceived risks to energy security. The threat of disruption may come at any point in the supply chain, within this Chapter the risks are considered under two headings, strategic and domestic:

- **Strategic risks**: often involving the risk of interruption to the supply of fuel from overseas. The origin of the problem may be market power, political instability, or lack of investment in overseas infrastructure. These problems derive from outside the UK's borders.
- **Domestic system risks**: where the risk derives from low or inappropriate investment within the UK in energy equipment (production, transportation or storage); from technical failure; from terrorism; or, as in the case of oil supply in 2000, from fuel protests.

4.8 While these two kinds of risk usually have separate origins, policy to deal with the effects of one may also be effective at dealing with the effects of the other. For example, more gas storage would help to deal with the loss of gas supplies either from abroad or from indigenous sources.

Why government?

4.9 Because it is impossible to quantify the extent or cost of all of the risks to energy security judgements are needed, either by private markets or governments. Economic theory might suggest that the appropriate level of security is that which would be delivered by a competitive market system, so that decisions are based on a good knowledge of consumers' willingness to pay for different levels of security. Extra security would continue to be added until the cost of the last unit was just equal to the extra value consumers as a whole placed on it. In some cases, the value that companies in particular put on security can be discerned by offering different forms of contract. The conditions needed to be sure that markets will provide the "right" levels of security include:

- competitive domestic energy markets, without significant externalities;
- consumers being able to signal the value they place on interruption to their energy supply;

- consumers at all levels being able to insure against system failures;
- stable and predictable regulation;
- the general absence of any divergence between public preferences and the sum of private preferences; and
- the absence of cartels in world fossil fuel markets or of the possibilities of interference in markets for geopolitical reasons.

4.10 Where these conditions cannot be met, the full impact of price or quantity risks may not be borne by those who make decisions about security levels, and markets may under-provide security. Examples in the UK are:

- small consumers cannot signal their valuations of energy security;
- public and private risk aversion may differ because many security failures, such as those on electricity wires, will result in interruption of a whole area. However, individual valuations of security may assume continuing supply to neighbours in the event of interruption;
- the public valuations of gas and electricity networks will exceed the private valuation because these networks enable competition to take place between producers and suppliers and help to break down local monopolies; and
- the short time horizon and/or limited liability of private investors may cause them to discount excessively the possibility of low probability, high consequence events.[3]

4.11 Firms, consumers and politicians have also grown used to the expectation that Government will intervene when energy supplies are tight.[4] Because of this, consumers may fail to provide adequately for their own security, even to the extent that they can. Moreover, since Government will tend to be blamed for any failures, they will wish to avoid unwanted political consequences. The continued existence of "emergency arrangements" for most forms of energy, under which Government can suspend market operations, is evidence of this continuing political concern. DTI and Ofgem have also recently established a Working Group on Security of Supply in order to monitor a number of the risks to energy security.

4.12 The opinion of most of those consulted in our review as well as the evidence from past and present behaviour of most governments, is that despite the power of markets to deliver a considerable degree of security they will, to some extent, under-provide given consumer expectations and market imperfections. But, while there is a role for governments in delivering some aspects of security, government action can worsen as well as improve matters. Where intervention is suggested, governments need to be sure that their judgements about appropriate risk levels and methods of intervention are better founded than those of market participants, who have close knowledge of markets and who have commercial interests in security and stability. Sustained intervention (as opposed to monitoring) may only be needed in particular circumstances.

Achieving better security

4.13 A number of approaches, all of which might lead to better security, can be proposed:

- **Competitive markets.** As discussed above, in competitive conditions individual producers are encouraged to pay attention to consumers' needs. Consumers (especially large consumers) are also encouraged to think of how they might meet some of their own security needs.

[3] Federal Energy Regulatory Commission (2001).
[4] Because of the severe economic and social consequences of energy supply interruption it is generally believed that governments will "step in" if things go wrong. It is also very difficult in many cases for customers to easily or safely store their own energy.

- **Resilience.** A basic need is to ensure that energy systems are resilient to shocks. This serves to reduce both physical and economic vulnerability, where possible and subject to costs. Resilience is itself the product of **diversity** and **flexibility**. The basic principle of diversity is straightforward – not putting all one's eggs in one basket. Diversity may be seen as a general hedge against all kinds of risk and uncertainty. It is a property of a whole system rather than a particular option or technology, so that the same trend (for example more use of gas in the electricity system) may lead to greater diversity in one period, and less in another. It is less clear *what* exactly should be diversified and *how much* diversity is enough. The extent to which diversity is to be pursued depends on the balance between the extra costs and the degree of risk reduction achieved. **Flexibility**, the ability to adapt quickly at low cost, is also important; examples in the energy system could include the installation of dual-firing capacity in fossil fuel plants, the stockpiling of fuels to cope with supply interruptions, and the deliberate maintenance of excess capacity.
- **Self-sufficiency**. Many submissions to the review take it as self evident that domestic supply of energy is preferable, on security grounds, to imports. One possible reason for this preference is a conviction that the world will soon run short of fossil fuels. Chapter 2 explains why this view is exaggerated. A second reason is that imports are regarded as inherently more unreliable than domestic sources. However, as in other markets, energy imports allow us to access more diverse, and cheaper, resources, than if energy sources were produced solely at home. Experience with coal in the 1970s and 1980s, and the fuel protests of 2000 suggests that the equation of "domestic" and "secure" does not always apply. Imports of energy are not necessarily less secure than domestic sources. Where trade involves substantial market power on the part of producers, or there are good grounds for worrying about the political reliability of suppliers, then there maybe a case for government intervention.
- **International action**. This will be particularly important where risks are strategic. There are clear limits to what can be achieved by a relatively small player like the UK. Much of what is necessary to reduce strategic risks needs to be carried forward through the EU and the International Energy Agency. The EU has importance for two reasons. First, future gas security for the UK depends in part on the liberalisation of European gas network industries, and secondly, many of the wider issues of gas and oil security are handled through the EU.
- **Consistency with other objectives**. Wherever possible, security-enhancing policies should be consistent with, and promote, the policy objective of achieving a low carbon economy. This may not in all cases be possible and security considerations may need to over-ride environmental objectives, usually temporarily. But where there are policy choices in promoting security, those that promote the low carbon economy will generally be preferred over those that conflict with environmental objectives.

Resilience in the energy system

4.14 Both diversity and flexibility help to deliver resilience. Security is improved by having a diversity of different sorts of fuel in use within the energy system. Security will also be improved if there is a diversity of sources of the same fuel. Flexibility is important as it helps the energy system to react to unexpected events.

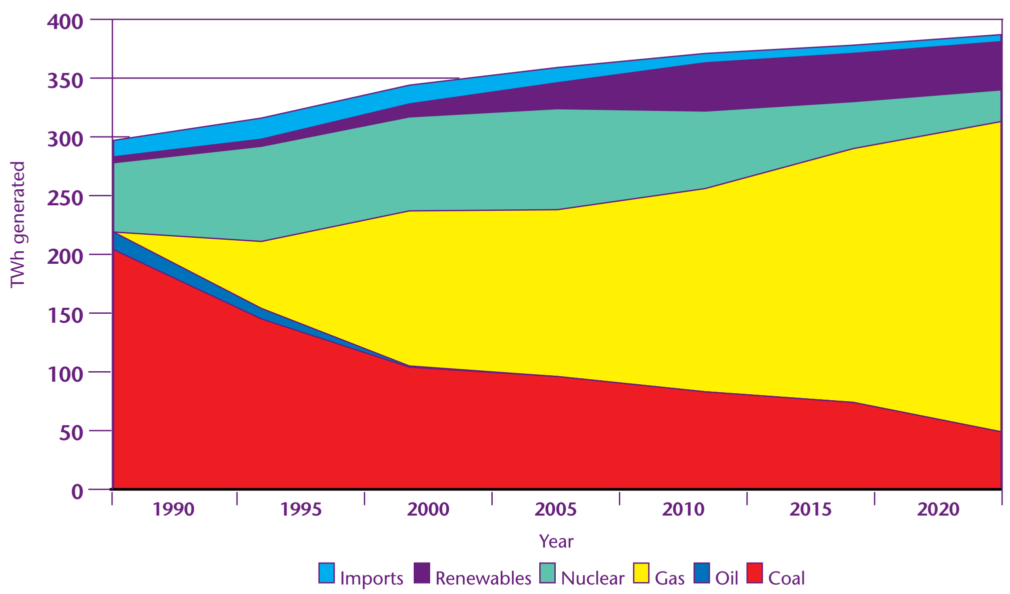
4.15 Concern about diversity has tended to be confined to the electricity system. The market for heating, especially in homes, is dominated by gas (and the share of gas in that market is growing). In transport, 98.5% of all energy used is oil-based.[5] In neither case is there a diversity of fuels, though in the case of oil, there is a diversity of sources. The prospects for diversifying away from oil and other hydrocarbon products in transport are limited in the period to 2020. In the longer-term, there are reasonable hopes that hydrogen may become an important transport fuel.

4.16 The immediate focus for diversity is in the power system (illustrated in Figure 4.1). When gas grew from a minuscule share of electricity generation in 1990 to some 40% today, it increased diversity. Further growth in the share of gas will represent a reduction in diversity. Forecasts based on "business as usual" suggest that gas may account for 60% to 70% of electricity production in 2020. In the meantime, the share from existing nuclear will fall, as probably will that of coal, while the share of renewables will rise. As gas is unlikely to be displaced in heating markets over the next 20 years, the overall reliance on gas in the UK energy system over that period is expected to rise. But beyond 2020, increased use of low carbon options, including zero carbon electricity and hydrogen, seems likely to depress the gas market share. In the long-term, a large share for gas in the energy sector may not be consistent with substantial cuts in carbon emissions unless carbon sequestration can be successfully developed.

4.17 This trend exposes risks relating to:

- import dependence;
- failure in the UK gas system;
- adverse interactions between the UK gas and electricity markets; and
- adverse interactions between the UK and continental European gas markets, making it difficult for the UK to access sufficient gas cheaply enough.

Figure 4.1: UK power sector fuel mix 1990-2020 (DTI projections)



Source: DTI (2000b) Central High Scenario

[5] DTI (2001a).

4.18 There is a wide range of possibilities open to Government to take counter measures in respect of these risks. They range from actions that relate to the gas market, to interventions in the electricity market, such as the imposition of restrictions on the approval of investment in new gas-fired generation, or the establishment of obligations on electricity suppliers for the purchase of coal-fired and nuclear electricity, analogous to the Renewables Obligation.

4.19 Restricting gas-fired generation and "carving out" market shares for other fuels would constitute a significant interference in the workings of the electricity market, and would impose new costs on consumers. It would not help to create a flexible energy system. The Renewables Obligation will already increase electricity bills. Other obligations might be cheaper, but any policy which stops companies from using the cheapest technologies has a cost which might be expected to grow as the market becomes more constrained. Despite the offsetting gains from enhanced security, the judgement taken here is that the imposition of further obligations would jeopardise the establishment of an effective electricity market. (The particular reasons for continuing to treat renewables differently are outlined in Chapter 7.) The risks of growing gas dependence are real, but – as perceived now – they can be dealt with by a number of measures that are likely to be relatively low cost and which will not cause significant distortion to energy markets.

4.20 Over the longer term the measures discussed in Chapter 7, in particular the increased use of renewable generation, will be valuable in contributing to diversity. They also provide a number of flexible generating options. Energy efficiency activities have a key role to play in reducing the overall level of energy required. Two other ways of increasing the diversity of electricity supply options are to make greater use of either coal-fired generation or nuclear power. Chapter 7 presents an approach to nuclear power which, although put in the context of a programme for a low carbon energy system, also takes account of the contribution of nuclear power to diversity. The next section considers the future role of coal.

Coal-fired generation

4.21 The use of coal in the generation mix adds to diversity and contributes to security. Coal-fired generation uses a primary fuel which is readily imported and freely available on world markets. Coal continues to have a firm, long-term future in the world energy industry. In the last year or so, coal has gained market share in the UK, partly in reaction to high gas prices. Coal seems, therefore, to have a continuing medium-term role in the UK energy mix.

4.22 Where the coal is mined in the UK there is the added benefit that it is an indigenous energy source. The UK coal industry has advantages in terms of its proximity to coal-fired generation sets, and the preference that many users have for UK supplies. The industry, particularly open-cast mining, currently suffers from problems relating to planning permission, and these are addressed in Chapter 8.

4.23 Coal suffers on account of its impacts on the environment, either from its emissions of the gases that give rise to acid rain or from its emissions of CO_2. The tightening of controls on SO_2 and NO_x has been accompanied by huge changes in the place of coal in the UK energy mix. Further anticipated tightening of EU regulations will mean that it will be essential to fit Flue-Gas Desulphurisation (FGD) equipment in order to run a coal-fired station, except on a peaking basis.

4.24 There are further possible obstacles in the way of future coal-burn arising from the prospect of controls on carbon emissions. Until now carbon constraints have not been imposed in the UK on coal-fired stations, yet the European Commission's draft trading directive would require mandatory carbon targets on all IPPC combustion plants from 2005.[6] The timing of a step of this kind should be considered with great care, in the light of the security benefits of coal.

4.25 In the meantime, it could be useful if at least some of the existing coal-fired generation stations can be retained, including some of those without FGD (it is generally agreed that life extensions can easily be engineered), to provide either peak capacity or back-up (the need for which will increase as the proportion of intermittent renewables grows). **The economics of operating coal-fired plant at low load factors would be improved if business rates were charged *pro rata* to energy delivered and not based on conventional assessment methods (i.e. value of buildings)**. There is no overwhelming justification for assessing business rates for generating stations on the basis of building value. Other measures of ability to pay may be more appropriate. Any revision could apply to all generation plant.

4.26 **It may be worth considering keeping some coal plant as a strategic reserve to be operated only if there was an imminent danger of widespread power cuts.** Such plant could be solely contracted to NGC and the costs covered through the NGC's regulated charges – this would be in addition to NGC's normal reserve arrangements.

Recommendations on diversity and flexibility

4.27 **There is no case for restricting the share of gas in the power sector at this time. However, the DTI/Ofgem Working Group on Security of Supply (WGSS) should monitor this situation, in particular to assess the market signals surrounding gas prices.** One reason for believing that no immediate decisions are needed to stop further increases in the use of gas in the electricity sector is that low carbon policies proposed elsewhere in this report should, to some extent, act as counter measures. Increased energy efficiency, and a growing share for low carbon options, provide no immediate contingency cover, but over time they could have a significant effect. Moreover, by around 2020 the early gas-fired stations will be nearing the end of their lifetimes. The need to replace them will ensure continuing opportunities to substitute away from gas if this is then thought desirable. It may also be the case that market participants will, to some extent, naturally hedge against exposure to the risks of over-dependence on a single fuel.

4.28 This does not mean that Government should do nothing in the shorter-term to guard against the risks. There are several other measures that would help mitigate against the risks associated with a higher level of dependence on gas. The Government should maintain an interest in all these developments since they would add back-up and diversity. **It is recommended that the DTI undertake an assessment of the cost-effectiveness of policy responses that could enhance security of the system and have in place contingency plans should the market level of diversity seem at divergence with the risks of future disruptions.** A number of additional measures which could assist diversity and flexibility of the energy system are listed below:

- energy storage is a key component in all energy systems: it is a means of balancing supply and demand and a buffer against shocks that would otherwise interrupt supplies to consumers. Fossil fuels currently act as a cheap and convenient store. **A major constraint on security is that it is, at the moment, costly to store energy for use in electricity systems.** At the grid scale only pumped storage has, to date, been cost competitive; off-grid, batteries can be used.

[6] Commission for the European Union (2001c).

Other options are becoming available, including a regenerable fuel cell based technology. In the longer-term a substantial hydrogen sector could very much reduce storage costs;

- should conventional pipeline sources of gas become tight or subject to disruption, **the availability of gas storage and Liquid Natural Gas (LNG) facilities** would significantly add to security. Departments should look at the barriers to private sector construction of either option, in particular at how these projects are represented in planning guidance. LNG trade, which opens up a global resource base, is rising rapidly under normal commercial incentives in several parts of the world. It would provide an important new source of diversity. If sufficient private sector investment is not forthcoming, then consideration may have to be given to the imposition of mandatory obligations on storage;
- **the development of electricity and gas interconnectors** are discussed later in this chapter. It is an obvious way of increasing the diversity of sources of supply and of providing greater resilience and security;
- possibilities for **improving the prospects of keeping existing coal-fired capacity open** have already been discussed;
- one way to provide greater security is to require the owners of some generation sets to have **dual-fired capacity** (most obviously, oil and gas). This must depend on the cost. A number of plant operators have already chosen to have this capacity; and
- the resilience of the electricity system will also be improved by **action on the demand side**. This can be addressed by load management – the development of metering, signalling and control technology will facilitate this – and through network loss reduction and end use efficiency.

4.29 DTI should monitor market developments in all these measures. **Dependant on the outputs of the monitoring recommended above and the DTI assessment of these measures, the WGSS should then review the need to develop policies to implement a number of low cost measures that will aid security without causing major distortions in energy markets**. It is also recommended that government should retain the lever of Section 36 consents under the Electricity Act 1989, as a means of allowing it to influence the fuel mix in electricity, but no action under these powers is recommended now (apart from that recommended specifically for CHP in Chapter 7).

Imports

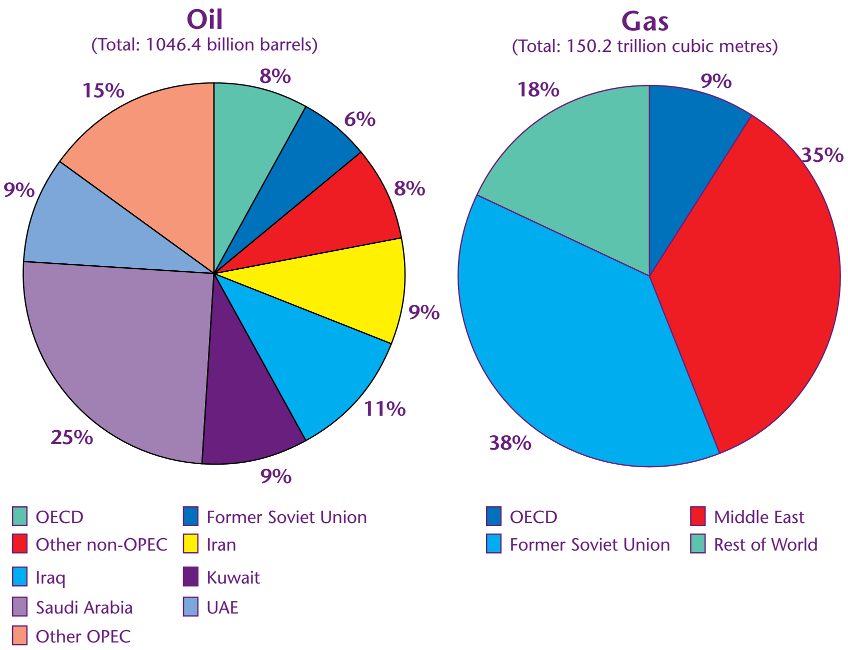
4.30 The UK currently engages in international trade in energy fuels and products. We are in the unusual position for a G7 country of being a net exporter of energy.[7] As discussed in Chapter 2 this situation will almost certainty change over the next 10–20 years, with the result that by 2020 we could be a significant energy importer.

4.31 The effects of higher levels of primary fuel imports have been seen by many of those who have submitted evidence to the review as a major potential source of future risk to the UK energy system. However, our dependence will be at least matched by the dependence of exporters of oil and gas on the revenues they receive from the UK. Concerns on imports are different from general concerns about diversity since imports can be a means to increase diversity.

4.32 Of the main fuels available to the UK – coal, oil, gas and uranium and renewable energy – only gas and oil raise major strategic risks. Uranium is plentiful, widely distributed throughout the world and currently cheap. Even more important, it is a very small proportion of the cost of nuclear power

[7] Illustrated by Figure 2.3 in Chapter 2.

Figure 4.2: Location of world reserves of oil and gas, 2000



Source: BP (2001)

generation, so the economic impact of price risk is small. Storing future uranium needs is straightforward in physical and economic terms. Proven world coal reserves are very large and well spread geographically: some estimates suggest that there are more than 200 years worth of world use at current production levels. Coal is currently available on world markets, and from domestic sources, either deep-mined or open cast. The world industry is generally competitive, though there have been some indications of market consolidation into a few large companies, in efforts to reduce over capacity, and possibly to increase prices. The UK has a large indigenous renewable energy resource.

4.33 The main strategic risks of imports have traditionally concerned oil and now, prospectively, gas. Location of known world reserves of oil and gas are illustrated in Figure 4.2. Concerns about imports focus on the exercise of market power, the political unreliability of possible suppliers or lack of investment overseas. The UK is currently more than self-sufficient in gas and oil, but over the next decade it will become a net importer of gas. Net oil imports are likely to follow in the 2010s. The precise dates by which the UK will become a net importer are a matter of some dispute: progress in energy efficiency, and market and technology conditions will have significant effects on timing, and projects such as PILOT are likely to yield extra exploitable UKCS resources.

Gas imports

4.34 The prospect of future gas import dependency and the likely sources of supply has been a major theme in submissions to the review. Currently, the UK has sufficient indigenous supplies of gas to meet demand. However, on many projections, the UK will become increasingly reliant on non-indigenous sources, notably from Norway (with 2–3% of proven world reserves), Russia (with 35–38% of proven world reserves), the Middle East (with 33–34% of proven world reserves) and Algeria (with 2–3% of proven world reserves).[8] The UK will become dependent at some point over the next decade on imports sourced from at least some of these countries, though it will still continue to produce gas from the UKCS. Even now the UK is importing gas at times of peak demand, though mainly from nearer neighbours like the Netherlands and Norway. However, the real issue is the growing dependence of the European gas system as a whole on imports from further afield.

4.35 This raises a number of questions for the review, namely:

- Are there enough global reserves to meet the UK's demand?
- What are the changing risks to the UK as it becomes increasingly trade dependent for gas? and
- What are the appropriate policy responses from the UK government?

Are there enough reserves globally to meet the UK's potential demand?

4.36 Some two thirds of the world's global gas reserves are already within economic distance of the European gas market. These reserves are equivalent to 100 years of current European consumption level.[9] With technology advances, the potential for both the level of discovered reserves and the area of economic capture improve. Hence the actual level of reserves available to Europe is likely to be higher still.

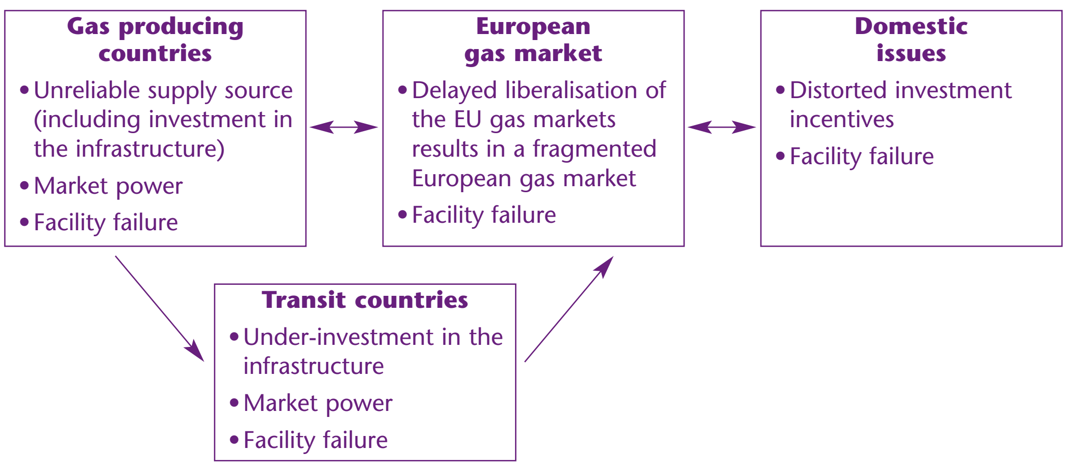
4.37 The question of whether there are enough reserves has therefore not been a major focal point of this review. The main emphasis of the work has been what risks are associated with the UK accessing this gas.

The risks associated with the UK becoming increasingly dependent on trade

4.38 As the UK becomes increasingly dependent on traded gas, the question is not a straight forward: Is self-sufficiency preferable to imports? It should be: What are the new areas of risks that the UK faces from accessing gas from outside of the UKCS? And what, if any, actions should the UK Government be taking to mitigate these risks?

4.39 Figure 4.3 highlights the four main areas of the supply chain to the UK accessing the gas and the key risks associated at each stage.

Figure 4.3: Key areas of risk for delivery of gas to the UK



[8] IEA (2001b).
[9] Shell (2001).

4.40 The risks in relation to the UK becoming increasingly trade dependent can therefore be summarised as:

- unreliable supply source;
- lack of investment in infrastructure;
- facility failure;
- market power; and
- delayed European liberalisation.

Unreliable supply source

4.41 The concern that the gas producing countries may prove unreliable trade partners focuses around the three main suppliers: Russia, North Africa and the Middle East. Would the gas producing countries cut supply to the European market – either deliberately or accidentally? This section looks at the potential for deliberate restrictions. Accidental restrictions are discussed below in the failure to invest and facility failure sections.

4.42 It is impossible to answer with any degree of certainty the question of whether the gas producing countries would deliberately restrict supply. An assessment of the risks suggests that Russia is unlikely to deliberately restrict supplies for two reasons. First, Russia has been a reliable trade partner for more than 20 years, through dramatic shifts in both its domestic politics and international relations. Further, there are clear mutual benefits from trade: 20% of European gas currently comes from Russia; and hydrocarbon exports, currently account for 50% of Russia's export revenue and 40% of its government revenue. Secondly, the disputes with neighbouring countries that have resulted in Russia restricting supply have typically focused around lack of payment for delivered gas. It is unlikely that similar problems would happen when trading with the EU.

4.43 The volatile nature of the economic and geopolitical situation in North Africa and Middle East has led some respondents to express concern that supplies may be deliberately restricted. While the difficulties facing these countries are real, they are heavily reliant on export revenues from fossil fuels for their economic stability, and they have a strong incentive to trade. Further, historical evidence - most notably the Gulf War - has shown that these countries have been reliable trade partners.

4.44 There would therefore appear to be no immediate threat of gas producing countries deliberately restricting supply to the European gas market. But, situations can change. Current and recent past experiences of trade are not an absolute guarantee of future supplies.

Lack of investment in infrastructure

4.45 Lack of investment in infrastructure can appear at any stage in the gas supply chain. The countries where this risk could be greatest are the gas producing countries, principally Russia, and the transit countries.

4.46 Some respondents to the review have wondered whether Russia's still-nascent commercial and legal structures will act as a barrier to Russia being able to generate the level of investment required to ensure it is able to meet future European supply requirements. A key question for the review is whether Russia's commercial and legal regimes will provide the stability which is necessary if frequent, involuntary, disruptions of supply to the European gas market are to be avoided. It is impossible to answer with certainty. Meetings with industry representatives have suggested an optimistic outlook for future Russian investment. A number of companies were considering future Russian opportunities. Past experience of British investment in Russia has not always been encouraging, and figures for foreign direct investment (FDI) are disappointing. FDI totals are a small proportion of what is likely to be required in the next 5-10 years in the energy industry. This indicates that the commercial regime, as well as political uncertainty, has to a certain extent acted as a barrier in the past and there is a still a challenge for the future.

4.47 Other responses to the review have focused not on the infrastructure within the gas-producing countries, but on the infrastructure which the gas-producing countries rely upon to deliver their gas to the European market. In particular, they have asked whether there will there be sufficient infrastructure to meet the demands of the European gas market?

4.48 The main area of concern focused on the gas infrastructure in Ukraine. Currently, some 90% of Russian gas flows through Ukraine. In theory investment in capacity has been more than sufficient to ensure supply. There is the potential for the Ukraine system to increase gas throughput by 50% with current capacity. In practice the actual capacity may well be much lower, and is likely to require substantial investment over the coming decade if it is to meet future demands. The Russian government has already taken steps to diversify its supply routes in order to reduce the risks associated with accidental disruption to supplies, and the review supports such actions. We should encourage Ukraine to implement reforms in its energy sector and gas-transit system so as to attract the investment required to increase the transit system's capacity.

Facility failure

4.49 Facility failure can occur at any point in the supply chain, and a major disruption of supply at any point has the potential to pose a significant risk to the UK. This review is not the place to carry out a major assessment of the risks and impact of failure for each facility on which the UK relies. One issue that arose frequently throughout the process of the review was the question of domestic facility failure. In particular, how vulnerable would the UK be if it suffered a significant facility failure?

4.50 The main concern in relation to domestic facilities focuses around the terminals where gas enters the UK. There are seven main beach terminals that are capable of receiving gas to the UK. Only two of these are capable of processing gas from outside of the UKCS - St Fergus and Bacton. As well as being connected to overseas gas supplies, St Fergus and Bacton are the two most important domestic facilities; they process 38% and 22% of all gas respectively.

4.51 There are plans for another interconnector to mainland Europe, and at present it would appear the most likely site for this is next to the existing Bacton-Zeebrugge pipe. The key facilities in terms of UK security are therefore St Fergus and Bacton, and the corresponding terminals in Norway and Belgium (given that any disruption at these would be just as serious as a disruption at the UK end).

4.52 This has led a number of respondents to express concern that if either of these facilities failed (either through natural or deliberate means) there would be a significant reduction in the volumes of gas available to the UK. Further, it could be many weeks before this source of supply was re-established. In an example of the effect of the disruption to a terminal, Easington was struck by lightning in December 1999: it took five days to return the terminal to full capacity and UK gas prices rose from around 15p/therm to a spike of 75p/therm in the interim period, despite the fact that Easington accounts for less than 15% of the gas in the system.

Market power

4.53 Market power can appear anywhere in the supply chain. Key areas of risk are the potential for a "Gas OPEC" and the market power in the transit pipelines.

4.54 By its very nature, it is almost impossible to be precise about whether a successful cartel will emerge. The differing nature and incentives of the gas-producing countries would suggest that the probability of a successful gas cartel operating over the timescale covered by this review is low. But such an event cannot be ruled out.

4.55 What would happen to supplies to the European gas market if a cartel does develop? The past trading performance of the gas-producing countries coupled with evidence from existing cartels, notably OPEC, would suggest that supplies to the European market are unlikely to be deliberately threatened since trade is mutually beneficial to both parties. However, the existence of a cartel might well result in higher prices to the European market.

4.56 The exercise of market power can occur at any point in the transit pipelines between the gas-producing countries and entrance into the UK. This review is not the place to carry out a major assessment of the potential for market power in the pipeline of every transit country to the UK. As a general principle, the less diversity in the routes that gas can take in order to reach the end market, the more potential there is for market power to emerge. Whether the market power is abused depends on how access to the pipelines is allocated, and on the degree of transparency that exists. In order to minimise the potential for the abuse of market power, there should be open and transparent access for third parties to each of the pipelines; and a regulatory structure that is capable of enforcing open access. Without these conditions, there is a possibility that the price of gas to the UK will be higher than if there were pipeline competition. In a liberalised market these possibilities would be much less serious since a broader range of supplies would be available.

Delays in the European liberalisation process

4.57 Liberalisation is a major issue in relation to the long-term security of the European gas market. Box 4.1 sets out why liberalisation is so important.

4.58 Neither a fully liberalised market, nor one dominated by local monopolies and long-term contracts will deliver cast-iron guarantees of physical deliverability in the face of exogenous shocks. The key difference is in the degree of flexibility that each offers. The existence of a large, liquid and deep market allows more flexibility. It does this by allowing the price mechanism to signal the effect of a shock – something that does not happen in a market characterised by a small number of players with

Box 4.1: Why liberalisation matters

Full liberalisation of the European gas market will create a large, liquid and connected market where gas can be freely traded, both within and between national borders, and where gas will be available at cost-reflective prices.

Liberalisation achieves this by:

- enabling existing infrastructures to be used more efficiently;
- allowing gas to be moved more easily between networks, encouraging the creation of trading hubs (such as Zeebrugge);
- separating network operators from network users, making transportation and storage capacity readily available on the basis of common carriage arrangements;
- providing clearer price signals that facilitate investment in new infrastructure; and
- allowing a range of companies to contribute to market-based security by providing signals for companies to sell gas back to the market when required.

high market shares; and who have used this market power to impose inflexible long-term contracts onto their customers. Responses to shocks are therefore likely to be more efficient in a fully liberalised market than in a market dominated by long-term contracts. It is for this reason that we encourage the UK government to continue its efforts in relation to full EU gas liberalisation.

Government response to risks

4.59 We do not at present see the risks associated with the gas-producing countries as a major threat to UK security and hence do not see an immediate need for significant government intervention. But situations change and an assessment of current risks is not a guarantee of future security. Hence, despite there being no immediate major threat to the UK, there may be potential future risks. The risks associated with gas imports should be kept under constant review.

4.60 Our analysis suggests that the best way to secure gas supplies is to encourage diversity both in the sources of supply, and in the facilities and infrastructure on which they rely. There are a number of steps that the government can take now to improve security and encourage diversity. These are measures that only Government can take, and by doing so, will assist private markets to achieve security of supply. Recommendations include:

- Working Group on Security of Supply should develop a series of indicators on the risks associated with gas imports;
- DTI should continuously monitor whether the measures taken by UK suppliers will ensure continued supply in the case of disruption. Further, it should carry out a full assessment of the options (including mandatory obligations on storage and dual-fired power stations) and have contingency measure in place if the market level of security seems at divergence with the risks of future disruptions;
- FCO should ensure that foreign policy is more fully integrated into the energy policy process as the international dimension to energy policy becomes more significant;
- DTI should continue to champion the liberalisation of European energy markets and support the European Commission in pressing forward with the relevant Directives;
- FCO/DTI, as part of the wider EU effort, should continue to develop close relations with the gas-producing and transit countries to ensure that the principles and benefits associated with trade are mutually agreed and shared;
- FCO/DTI, as part of the wider EU effort, should push for the liberalisation of pipelines in the non-EU transit countries, and for open and transparent tariffs for third-party access to these pipelines; and
- when the private sector submit proposals for locating future gas (including LNG terminals), DTI should consider, with the developers, the implications for future diversity.

Oil imports

Are there enough reserves globally to meet the UK's potential demand?

4.61 As argued in Chapter 2, future world resources of oil are unlikely to be a major concern in the period to 2020, and probably for some time beyond. Availability of cheap oil is less certain after 2020-2025, but there are already a number of technologies[10] being developed that are designed to extract unconventional sources of oil. It is likely that these will be much more viable by 2020, when the costs of these technologies are likely to have fallen. In the worst case, in the medium-term oil prices might rise over a number of years, reflecting increasing scarcity and the need to exploit low-grade reserves. For the medium- and long-term, therefore, oil will remain an important strategic security issue – but for the world as a whole rather than the UK in isolation.

4.62 There are interests in diversifying away from oil and other hydrocarbon products in transport. Prospects are limited in the period to 2020, during which time reliance will mostly be placed on improvements in transport fuel efficiency. After 2020 there are reasonable hopes that alternative fuels in transport, such as hydrogen, will become an important. For reasons of long-term security, as well as carbon benefits, early attention to energy efficiency and substitution for oil in the transport system is important. Much of this effort, both public and private, will necessarily take place in an international and EU context. Chapter 7 outlines some immediate actions.

The risks associated with the UK becoming increasingly dependent on trade

4.63 Even though the UK is a net exporter of crude oil, we cannot insulate ourselves from any upset in world oil markets. The fact of our becoming a net importer will not make much difference to this. While supplies of crude oil could be disrupted, for example, during periods of international conflict, the main impact of producer pressure has been on prices rather than quantities.

4.64 IEA figures suggest that the world as a whole will, in coming decades, become much more dependent on supplies of oil from the Middle East. Inevitably this carries risks. On past evidence, any physical disruption is likely to be temporary – perhaps a few months at most – since exporters depend on revenue from oil sales, just as we depend on their supplies. Additionally, exporters have little power to enforce a boycott of any destination for their product. The IEA and EU have put in place requirements for member countries to hold a certain level of oil stocks to guard against temporary shortages in supply.[11] The EU requirement is to hold 90 days' worth of oil products in stocks (this requirement has been reduced to 67.5 days for the UK, while we remain a net exporter). Recent experience suggests that when there is a major upheaval in world oil markets, oil remains available on international markets, although at a high price. This reflects a world where supplies come from a range of different suppliers. The potential for the oil market to disrupt the world economy remains. If supply becomes more concentrated in a few countries, these risks may grow.

[10] UNDP and WEC (2000).

[11] The IEA has put in place a number of co-ordinated emergency response measures, designed to help member states cope with short term supply disruption and price spikes. Cuts of supply to individual members or major disruptions are managed through the International Emergency Programme and the sharing of available supplies. Over the last decade the membership of the IEA has expanded to include most major oil consumers.

4.65 In order to minimise strategic risk of disruption of oil supplies we recommend that similar to gas:

- DTI/FCO should continue, together with the EU, its work on developing close relations with the oil producing countries to ensure the principles and benefits associated with trade are mutually agreed and shared.

The integration of foreign and energy policy recommended in 4.60 will also be important for minimising oil risks.

4.66 While there is no immediate strategic risk envisaged for oil supplies to the UK, the situation should be constantly monitored. If it became a more serious concern over the next 20 years, further ways of mitigating the risks could include: requirements for more oil storage, measures to extend the life of the UKCS as an oil province, and more focus on moves towards greater efficiency and alternative fuels (recommended in Chapter 7 as part of the move to a low carbon economy).

International action

4.67 Much of policy towards strategic security must take place in an international context. The EU will have an important role in taking some of these actions forward. The aim of the EC's recent Green Paper on energy security was to "sketch out the bare bones of a long-term energy strategy" – following this paper there should be a summary of responses in the first half of 2002, and then a White Paper.

Investment in UK infrastructure

4.68 The adequacy of the energy infrastructure in Great Britain is an important issue for security. The concern here is not with the availability of fossil fuels, but with the capital stock whereby those fuels and other energy sources[12] are converted into energy and transported around the country.

4.69 The key areas of energy infrastructure are:

- the natural gas transmission and distribution networks – the pipelines that carry gas from the terminals at which UKCS gas is landed or pipelines from Europe reach the UK, to consumers' premises;
- the electricity transmission and distribution systems – the wires that connect power stations with consumers' premises;
- power stations – that transform fossil fuel, or other forms of energy, into electricity;
- gas and electricity interconnectors – pipelines or wires that link the UK to other countries;

Box 4.2: Main proposals in the EU Green Paper on Security of Energy Supply

- The EU must rebalance its supply policy by clear action in favour of a demand-based policy.
- The EU must achieve a real change in consumer behaviour, highlighting the value of taxation measures.
- There must be an increased focus on climate change in the supply sector, through a doubling of the share of new and renewable energy sources (including biofuels) by 2010.
- The contribution of nuclear energy in the medium term must be analysed.
- For oil and gas, stronger mechanisms are required to build strategic stocks and to foresee new import routes.

[12] Other energy sources include nuclear power and the various forms of renewable energy.

- oil refineries – that transform crude oil into the oil products that consumers require; and
- oil networks – the network of pipelines and road and rail vehicles that carry oil products from refineries to consumers' premises or local distribution points.

4.70 Before the liberalisation of the gas and electricity industries, a process of public planning determined much energy investment. This tended to ensure that there was always sufficient capacity available to meet demand, but there were few incentives to ensure that capacity was provided efficiently. Indeed, public providers had a general incentive to play safe and to provide too much capacity, raising costs unnecessarily.

4.71 Now, while regulators are closely involved in investment by monopoly gas and electricity networks, investment elsewhere is determined by market forces. Even in the case of the monopolies there is scope to base investment on market signals. In the absence of clear evidence that markets cannot and do not deliver, only limited intervention in these processes should be countenanced. Governments have far from perfect information or foresight, and there is a significant danger that any intervention by public authorities – the government or regulators – to determine the level of investment, would lead us back to the old, less efficient, world. One danger is that government intervention would lead to wasteful over-investment. Government intervention could also undermine the security that the market would have provided: even the threat of intervention may upset the processes of private sector decision-making if investors start to doubt whether they will be allowed adequate returns on investment, or to assume that public sector decisions will be substituted for theirs.[13]

4.72 Nevertheless, given that experience with liberalised electricity and gas markets remains limited, it is prudent to review the situation in the light of the experience in California. There, for various reasons, an apparently liberalised electricity market does not seem to have brought forward the right level of investment, though, in fact, the main reasons for the supply failures in California seem to have been regulatory mistakes. Box 4.3 explains why the situation in the UK is very different to the conditions that led up to the problems in California.

4.73 The following section looks at two different investments – in power stations and in gas and electricity networks – and examines some reasons why some people suggest that public intervention may be needed to ensure security.

Investment in electricity generation

4.74 Since privatisation of the electricity market some 25GW of new generating capacity has been built.[14] Since the lifting of the stricter gas consents policy, in November 2000, consent has been given for a number of new power stations, but progress with their construction has generally been slow. Generation capacity currently exceeds peak demand by almost 30%.[15] It is this surplus of capacity that is contributing to low prices in the short-term wholesale electricity market, discouraging new build. There is no evidence that liberalisation is failing to bring forward sufficient new investment.

4.75 But circumstances could change. Failure to meet any of the conditions outlined at the outset of this Chapter (paragraph 4.9) could provide a case for government intervention. In the case of electricity markets some of these conditions may not be met. In particular, the

[13] For example, Ofgem argued that "Any Government attempt, however well intentioned, to dampen the price effects (associated with peak demands or supply shocks) runs the risk of undermining the incentives and signals that competition creates and which ensure security of supply." Ofgem (2001b).

[14] OFGEM (2001b)

[15] DTI (2001a)

Box 4.3 The Californian problem

California	UK
California still had regulatory controls on prices that electricity suppliers could charge consumers, and was unwilling to adjust those controls in the face of evidence of future shortfalls	Electricity supply price controls in Great Britain have been abolished for most consumers and Ofgem propose to lift all forms of direct price control in April 2002
Regulators prevented suppliers buying power on long-term contracts or otherwise hedging the volatile prices in the wholesale spot market	Under NETA, generators and suppliers are encouraged to use hedging arrangements and contracts and avoid exposure to the volatile prices in the Balancing Mechanism
Local opposition prevented construction of new generating plant	Generators have been able to manage local concerns and substantial amounts of new generating capacity have been built in recent years
Electricity demand was growing very fast in the late 1990s	Demand growth has been modest - around 1% per annum
Lack of transmission capacity in some areas meant that some plant was unusable	Transmission constraints are not a serious problem
Low rainfall reduced the potential of hydro plant in California and neighbouring states	This risk is hardly applicable in UK circumstances

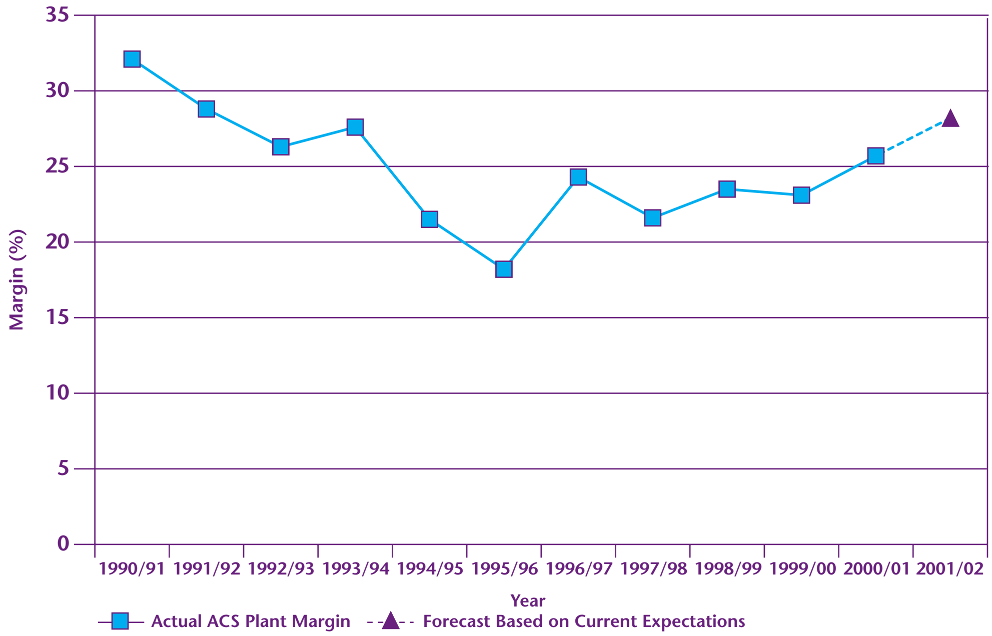
signals which suppliers receive concerning the valuation which domestic customers put on security are limited: large consumers may give signals by signing interruptible contracts, but this option is currently unavailable to small consumers. As a result there is already intervention to set service standards for domestic customers. This will continue to be necessary.

4.76 Whatever the theoretical arguments about the capacity of markets to provide adequate security, this must in the end be an empirical question. A significant plant margin is always needed to provide the means of meeting the extremes of demand and risks of plant failure. The capacity margin now in place seems healthy by historical standards (see Figure 4.4). The recommendations set out in Chapter 7 will reduce the rate of peak demand growth and stimulate renewable generation, further improving the situation. For this reason, there seems no reason to worry today about the fact that there is little current investment in capacity. Investments will need to be monitored (see below), but at the moment there is no cause for concern.

4.77 Investment incentives for generation plant will be affected by the new electricity trading arrangements (NETA). With well-designed market rules, when signals of scarcity start to appear new investment will be made.[16] Electricity forwards markets will be particularly important in providing the right basis for new investment. Some respondents have voiced concerns that, given the way in which NETA is working, the right signals will not appear.

[16] Including investment to defer retirement of existing plant.

Figure 4.4: Electricity generation plant margin (England and Wales)[17]



Source: Data provided by NGC

4.78 One worry is that recent wholesale electricity prices are currently well below the price that would be needed to justify new entry. As capacity margins tighten prices will rise - first by way of price spikes seen on particular days of shortage. But, given the times needed to make new investments in different sorts of capacity (see Annex 7), once price spikes start to appear, will it be too late to make the investment in time? Another point of dispute is the extent of present forward prices - with some people questioning the depth of the market.

4.79 Another concern is that current mechanisms will work only if there is an expectation that price spikes will be allowed to come through as necessary, so that a clear signal is given to the market at the appropriate time. Given Ofgem's recognition of the problem and the Government's desire to allow market mechanisms to work, the concern may be misplaced.

4.80 A final issue is that market participants will inevitably have limited experience of the workings of NETA over the long term, so the lack of an historical trend may make the first round of investment more risky than would otherwise be the case.

4.81 NETA is new, and given current spare capacity, it would be premature to think of any intervention on this account. The experience of other commodity markets is that extra flexibility will be added over time, on both the demand and the supply sides, as new possibilities for trading appear. The development of the capacity margin will be monitored both by Ofgem and NGC, and NGC will supplement the price signals in spot and forward markets with its own statements. Consideration could be given to possible means of intervention should investment not be forthcoming, but the main focus of attention should be on encouraging private investors to make the right choices.

[17] Figure 4.4 illustrates the electricity generation plant margin. This data has been normalised to an average cold spell (ACS) in order to allow comparison year on year.

Regulation will enhance energy security if it provides a stable background for investment in both the natural monopolies and the competitive parts of the market.

Investment in electricity and gas networks

4.82 There is a good record of recent investment in electricity and gas networks in the UK. Ofgem pointed to a generally healthy system, with lower levels of failure than in the past and continuing investment.[18]

4.83 Where there is competition, the need for government intervention can, in time, be reduced. Where there is a natural monopoly, as in the case of a significant proportion of the gas and electricity networks, there is a need for a continued regulatory role. While, some network investments are rightly seen as speculative commercial ventures so the limits of the natural monopolies are not always clear-cut, most of the networks of the main electricity and gas infrastructure providers are natural monopolies. They are essential facilities providing transport capacity and the arena for competition between competitive suppliers. But continued regulation of the monopoly networks will be needed – without regulation owners could either charge an artificially high price for security or under invest in security relative to customers' expectations.

4.84 The best way to regulate investment and service provision by natural monopolies is one of the most difficult questions of regulatory practice. It concerns regulators in many jurisdictions. Submissions to the review questioned the extent of the incentives to invest in the natural monopolies contained in current UK regulatory practice. This review has not been the place for a thorough review of the basis for regulating a natural monopoly, but some general propositions about the likely balance of incentives can be made:

- RPI-X regulation offers incentives to increase profits by cutting expenditure on investment below the levels assumed in the initial settlement;
- network companies always have an incentive to claim that they need to be allowed more investment than the regulator has allowed;
- a profit maximising unregulated monopoly would tend to under-invest to keep prices high and output, including the amount of security, low; and
- quality of service regulation constrains the ability of companies to cut costs at the expense of quality.

4.85 The conclusion is that:

- as is generally recognised, where RPI-X regulation is used, the scheme must aim to remove possible distortions, so that companies have broadly the same incentives to invest in quality-enhancing investments at different points in the regulatory cycle;
- Ofgem has started to refine and improve the RPI-X approach – although it still keeps a five-year review period; and
- it can be argued that a longer period of control is needed to provide the right incentives for long-term investment, though a longer-term settlement would tend to be accompanied by more intermediate monitoring of performance, and this would tend to accentuate the elements of "cost plus an allowable profit margin" regulation which are already present, even in current approaches.

[18] "Since vesting, the average performance of electricity distribution networks with respect to security of supply has improved modestly and has been largely limited to the period after 1996. The electricity transmission systems' annual unavailability has fallen from 9% in 1991/92 to around 4% for the years 1997/98 to 1999/00. Information on security of supply on Transco's network is more limited than that for the electricity transmission and distribution companies. However, as in electricity, there have been no widespread security of supply problems due to transportation failures since privatisation." Ofgem (2001b).

4.86 Regulators will, so far as possible, want to use market mechanisms to generate more information about the value that market participants place on different levels or types of service provision by the regulated monopoly. This is central to Ofgem's approach. Regulators and network providers increasingly use market-based mechanisms – like auctions, within which users bid for the right to use network capacity – to provide information about the need for new investment capacity. These mechanisms will only work well when there is a healthy level of competition in all areas of the network, and this may not always be the case. Energy markets are rarely completely competitive: there tend to be significant pockets of market power, and there are often relatively few competitors. In these circumstances, market signals may be incomplete and biased in favour of the interests of the incumbents. It is inevitable that final decisions about network investments by network operators will require some degree of ex-ante "approval" by the regulator and so some regulatory judgement is inevitable.

4.87 Recent experience with the use of auctions to allocate capacity in the gas network demonstrates some of the difficulties of using market mechanisms in complex energy markets. Inevitably it takes time to develop a mechanism that meets the particular circumstances. Where the mechanism creates a new source of funds, as with the short-term capacity auctions for gas, the merits of different ways of returning the money to users should be assessed against the full range of energy policy objectives – including the longer-run consumer interests in security and diversity of supplies. In the case of gas auctions, the industry has suggested that different mechanisms carry different implications for offshore developments. The DTI should maintain a continuing interest in the implications of onshore gas market developments for offshore activity.

Conclusion in relation to electricity and gas investment

4.88 The review has not come to a final judgement concerning the different claims about current levels of investment in networks and capacity. This would require a much more detailed process of investigation than has been possible. Two institutional conclusions are:

- the DTI, in collaboration with Ofgem, should continue to operate via the various emergency arrangements, the security standards on grid operators, and the regulations applicable to various licence holders;[19] and
- the DTI and Ofgem, through the recently established joint Working Group on Security of Supply, should maintain close contact with the main system operators, NGC, the Scottish electricity grid operators, the electricity distribution grid operators and Transco, to monitor network performance, availability of generating plant and sources of gas, including peak gas.

4.89 There are also a number of social concerns surrounding the regulation of UK networks, which must be balanced alongside security concerns. These are discussed in Box 4.4.

Gas and electricity interconnectors

4.90 As an island, Great Britain has relatively few interconnections, and those that exist are large and clearly identifiable pieces of equipment. This suggests that for many years to come these links can be treated separately from the natural monopoly networks that they link, and that different interconnectors could co-exist in competition with each other. For both gas and electricity, interconnections will provide an important source of diversity and of security.

[19] For example, the Gas Supply Regulations which require suppliers to have sufficient gas to meet a 1 in 20 winter.

Box 4.4: Social aspects of gas and electricity networks

Safety. An important social aspect of energy networks, and of gas in particular, is that they operate safely. Network safety is the responsibility of the Health and Safety Executive (HSE). There is a regular dialogue between HSE and Ofgem, regarding the levels of safety required and its implications for network operators' costs. There is no evidence that this approach is failing to provide appropriate levels of safety. The recommendation that economic regulators undertake analysis of significant proposals would help to point up any potential clashes between safety and cost reduction.

Extension of the gas network. The Government has set up a working group comprising DTI, DEFRA and Ofgem officials, energywatch, NEA, EST and representatives of the industry to consider the issues surrounding extension of the gas network.[20] The working group's initial report concluded that, whilst the extension of the gas network across the whole country could not be justified on cost-benefit grounds, the extension in some communities could be justified. The report recommends further work is needed to test the effectiveness of extending the gas network in addressing fuel poverty and further consideration should be given to assisting communities where gas and electricity are not the most appropriate fuels.

In addition to reducing fuel poverty, the replacement of oil or coal heating, or electric heating based on fossil fuelled electricity, with direct gas heating would reduce carbon emissions. This benefit should be included in the consideration of network extension. Also, where it is found to be worthwhile, Ofgem should allow some of the costs to be met by the generality of gas consumers, so that new consumers do not face materially higher bills than existing ones.

Cross subsidies between smaller network consumers. Existing "flat rate" distribution price controls may cause cross subsidy between different groups of consumers: rural consumers may be subsidised by urban ones or vice versa. In pursuance of the Embedded Generation Working Group proposals, it may be found that there is a case for regional access pricing within distribution networks. It would be sensible to give generators this price signal and further work is needed in order to assess whether there would be benefit in reflecting these charges in the tariffs applied to small consumers. Ofgem should investigate fully the possible distributional implications of any proposals, so that decisions can encompass Government and wider societal views on distributional issues.

4.91 A number of new interconnector projects are currently under discussion, including proposals for electricity interconnectors with Norway and the Netherlands, and the upgrading the gas interconnector with Belgium. These proposals are moving forward on a market-led basis with the presumption that regulation will be confined to ensuring that access is not restricted, and that it will not seek to determine prices or allowed returns.

4.92 European Commission funding is available for studies on new interconnector projects through the Trans-European Networks (TENS) fund. This helps to offset any inherent tendency of markets towards under-provision. There have also been proposals that the scope of TENS

[20] A material component of fuel poverty is associated with solid-walled homes in areas not connected to the gas network. Initial analysis suggests that, for England alone, if gas central heating and appropriate insulation measures could be provided, then 0.6 to 0.7 million out of the 0.9 million fuel poor households not currently using gas could be removed from fuel poverty. DTI, DEFRA (2001).

should be expanded to include support for interconnector construction. There may be a good reason for public subsidy in the case of investments in the peripheral member states, but there is less justification for subsidy elsewhere.

4.93 There appear to be no grounds at present to think that there is insufficient interconnector capability or that markets will not provide new capacity as needed. The DTI and Ofgem should adopt the following guidelines:

- the international regulation of large discrete infrastructure projects should be confined to requirements for open access; and
- there should be no major new initiatives for public funding for new projects, given that such proposals would be likely to undermine market-driven proposals and could be costly for consumers.

4.94 There should be maximum co-operation between governments to ensure that market-driven proposals do not founder on political or planning concerns.

Refinery and terminal capacity

4.95 There are currently nine major oil refineries in the UK with a capacity of producing 88 million tonnes per annum. Despite the recent shut down of two oil refineries in the UK, levels of throughput have not significantly decreased, since the remaining refineries have increased their production rates in response. Over the last 30 years, UK refinery production has fallen by around 14%, yet the UK remains a net exporter of petroleum products. As the UK becomes a net importer of crude oil over the next decade or so, some adjustment in the UK refinery sector may be needed: 90% of current inputs are North Sea crude (although some comes from Norway). At the same time, consumer demand in the UK may grow.

4.96 Would any reduction in UK refinery capacity, or increase in imports of refinery products, impose significant risks for UK customers? Europe as a whole is currently only a marginal importer of petroleum products, and there is a strong regional market.[21] Therefore, as long as Europe as a whole has a strong refinery sector, it is likely that the UK will continue to be able to access the full range of petroleum products.

4.97 A further issue is the balance of demand for different petroleum products. For example, in recent years the demand for diesel in Europe has risen unexpectedly. This has caused no serious problems. Over the longer term, the main issue may well be not so much overall volumes of demand for petroleum products, but the balance of demand between different products. Looking to the very long term, there will be a problem if, as in some PIU scenarios, the only fuel that was still required in the UK is kerosene for air transport.

4.98 DTI should monitor both what is happening to European refinery capacity, and the balance of UK product demand. Consideration might need to be given to ways of incentivising investment, if either looked like becoming a problem. But no immediate action is needed.

Availability of skilled labour

4.99 Although energy infrastructure is generally thought of as physical assets such as pipelines, wires and power stations, access to skilled labour to operate and maintain these assets is also essential. Skilled labour in the area of energy efficiency will also be important.

[21] Transport and Energy Statistics, Commission for the European Union website – http://www.europa.eu.int/comm/energy/index_en.html

4.100 The Government should encourage the energy industry to look at manpower and skills requirements of the energy sector in order to establish likely future shortages.

Exposure to terrorism, technology failure and domestic protests

4.101 The vulnerability of an energy system to terrorist attack is in part dependent on the importance to that system of a few very large items of plant, or a few sites. Both gas and electricity are inherently more vulnerable than fuel sources such as oil and coal, which do not rely on integrated networks. The gas network could be particularly vulnerable to the loss of one of two major terminals. This is not to suggest that there are substantial risks at present. The energy industries, in cooperation with Government and regulators, already make considerable efforts to ensure that their plant and systems are robust against risks of this sort.

4.102 In the case of gas, where the system relies on fewer input points than is the case with electricity, in order to guard against security threats, the government should consider whether existing terminals are the right location for future developments.

4.103 There are also risks to individual plants. The particular risks to nuclear power plants have recently been considered by the International Atomic Energy Agency.[22]

4.104 During the 1970s and 1980s coal was the main cause of energy insecurity, as strikes by coal miners created a temporary shortage in supply. Since then the UK coal industry has declined substantially, and this is no longer a present threat.

4.105 Following the fuel protests of September 2000, the Government has carried out a thorough examination of the arrangements for storing and transporting oil and oil products. There is no need for this report to review further these arrangements, and there are no recommendations for this sector.

The impact of liberalisation and company failure on security risks

4.106 Liberalised and competitive markets manage a wide range of risks. But there are some risks – especially those connected with extreme events – which competitive markets may not handle well. Hence the need for a continuing public intervention, for example in the form of emergency arrangements.

4.107 As in other markets, competitive provision exposes customers to the risk of company failure, but experience shows that these new risks can be handled, whether within the market itself, or by regulatory intervention. Given the central role of networks in gas and electricity markets, special arrangements are needed to ensure that network operations are not disturbed by any wider troubles of the operator's parent company. Ofgem have developed financial ring-fencing arrangements of this sort.

4.108 In the case of energy supply, where consumers would continue taking supplies from the system after their supplier had gone into liquidation, regulation is needed to devise rules for switching those customers to other companies. The rules developed by Ofgem have worked satisfactorily to date.

4.109 Recent failures, such as that of Enron, highlight the possibility that company failure might impact on the supply of electricity to the market. In practice, any problems relating to unfulfilled contracts within the balancing and settlement code were covered by NGC within the balancing mechanism procedures which

[22] International Atomic Energy Agency (2001).

were already in place. Other energy companies also needed to obtain new cover for risks that they had hedged with Enron's trading arm. There seem to have been no systemic problems.

Conclusions

4.110 Security has moved up the political agenda rapidly in recent years. Many of the energy markets in the UK have recently been liberalised, and the extent to which there are incentives for adequate investments in these new markets is currently unknown.

4.111 Although some actions are needed in the short term, there is no crisis of energy security for the UK. Future security risks will be significantly less if the UK has in place a low carbon strategy for the long term since this should reduce gas dependence beyond 2020. A number of the risks described in this chapter should be closely monitored, particularly as they change over the next 20 years.

4.112 **The recently established DTI/Ofgem Working Group on Security of Supply (WGSS) should expand its existing activities to take on responsibility for monitoring all of the risks to energy security discussed in this Chapter. In order to do this effectively it will need to:**

- **expand its membership to include representatives from the FCO, since many of the risks have an important international element;**
- **build on the Group's existing indicators to monitor all risks to security of supply discussed in this chapter; one completely new area for the group will be risks to oil supplies; and**
- **conduct ongoing monitoring of all of these indicators, in order to establish how the risks alter over time.**

4.113 Over the short term, the best responses to security risks are measures that deal directly with the risks in gas and (to a much lesser extent in the short-term) oil markets. The alternatives, including early action to discourage gas use and encourage readily available alternative fuels like coal and nuclear power, seem premature. They would conflict strongly with economic objectives, and some actions, such as encouraging coal on a large scale, would conflict with environmental objectives. If it is found through monitoring work that the risks to security rise over time, more wide-ranging and costly intervention in later years may be necessary. For the moment the primary responsibility for dealing with issues of security should rest with the private sector, backed up by judicious, but limited, intervention by the public sector.

Summary of recommendations

Main recommendations

6. The recently established DTI/Ofgem Working Group on Security of Supply (WGSS) should expand its existing activities to take on responsibility for monitoring all of the risks to security of energy supply discussed in this Chapter. In order to do this effectively it will need to:

- expand its membership to include representatives from the FCO, since many of the risks have an important international element;
- build on the Group's existing monitoring indicators to monitor all risks to security of supply discussed in this Chapter – one completely new area for the group will be risks to oil supplies; and
- conduct ongoing monitoring of all of these indicators, in order to establish how the risks alter over time (4.112).

7. FCO should ensure that foreign policy is more fully integrated into the energy policy process (4.60 and 4.65).

8. DTI should continue to champion the liberalisation of European energy markets and support the European Commission in pressing forward with the relevant Directives (4.60).

9. There is no case for restricting the share of gas in the power sector at this time. However, the WGSS should monitor this situation, in particular to assess the market signals surrounding gas prices (4.27).

10. DTI should carry out an assessment of the cost-effectiveness of policy responses that could enhance security of the system. These results should inform decisions on any contingency action taken in response to the monitoring (4.28 and 4.60). Key measures which should be considered include:

- increased availability of UK gas storage and Liquid Natural Gas (LNG):
  - Departments should examine barriers to private sector construction of either option, in particular at how these projects are represented in planning guidance;
  - if sufficient private sector investment is not forthcoming, then consideration may have to be given to the imposition of mandatory obligations on storage.
- the development of electricity and gas interconnectors (see recommendation 11 and 12).
- improving the prospects of keeping existing coal-fired capacity open, possibly by:
  - altering the basis on which business rates are charged; or
  - keeping some plant as a strategic reserve, to be operated only if there was an imminent danger of widespread power cuts (4.25 and 4.26).
- requiring the owners of some generation sets to have dual-fired capacity (most obviously, oil and gas).
- action on the demand side.

Other recommendations

11. DTI should retain the lever of Section 36 consents under the Electricity Act 1989, as a means of allowing it to influence the fuel mix in electricity, but no action under these powers is recommended now (apart from that recommended for CHP in Chapter 7) (4.29).

12. FCO/DTI, as part of the wider EU effort, should continue to develop close relations with the oil and gas-producing and transit countries to ensure that the principles and benefits associated with trade are mutually agreed and shared (4.60 and 4.65).

13. FCO/DTI, as part of the wider EU effort, should push for the liberalisation of pipelines in the non-EU transit countries, and for open and transparent tariffs for third-party access to these pipelines (4.60).

14. When the private sector submit proposals for locating future gas terminals (including LNG terminals), DTI should consider, with the developers, the implications for future diversity (4.60).

15. DTI and Ofgem, through the recently established WGSS, should maintain close contact with the main system operators, NGC, the Scottish electricity grid operators, the electricity distribution grid operators and Transco, to monitor network performance, availability of generating plant and sources of gas, including peak gas (4.88).

16. DTI and Ofgem should adopt the following guidelines with relation to new interconnector capacity (4.93):

- the international regulation of large discrete infrastructure projects should be confined to requirements for open access; and

- there should be no major new initiatives for public funding for new projects, given that such proposals would be likely to undermine market-driven proposals and could be costly for consumers.

17. There should be co-operation between governments to ensure that market-driven proposals for interconnectors do not founder on political or planning concerns (4.94).

18. DTI should monitor both what is happening to European refinery capacity, and the balance of UK product demand. Consideration might need to be given to ways of incentivising investment, if either looked like becoming a problem. But no immediate action is needed (4.98).

Social aspects of networks

19. Ofgem/DTI should look at the environmental as well as social benefits of installing direct gas heating when considering gas network extension (Box 4.4).

20. Where it is found to be worthwhile, Ofgem should allow some of the costs of extension work to the gas network to be met by the generality of gas consumers, so that new consumers do not face materially higher bills than existing ones (Box 4.4).

5. LESSONS FROM SCENARIOS

Summary

This Chapter summarises the results from detailed scenario-based projections of supply and demand in the long (2050) and medium (2020) term. The challenge for 2050 is to deliver significantly more energy services with substantially lower carbon emissions. In the medium term the challenge is to keep this option open.

The 2050 analysis shows that it is possible to deliver reductions in carbon emissions of 60% provided sufficient energy efficiency measures are adopted, the electricity system has very low carbon emissions and major progress is made towards a low carbon transport system, probably based on hydrogen. Such transitions are highly unlikely without strong policy attention to the development of low carbon options.

The 2020 analysis shows that significant carbon reductions are possible provided that energy efficiency is prioritised and the deployment of CHP and renewables is accelerated.

Other conclusions from the analyses are:

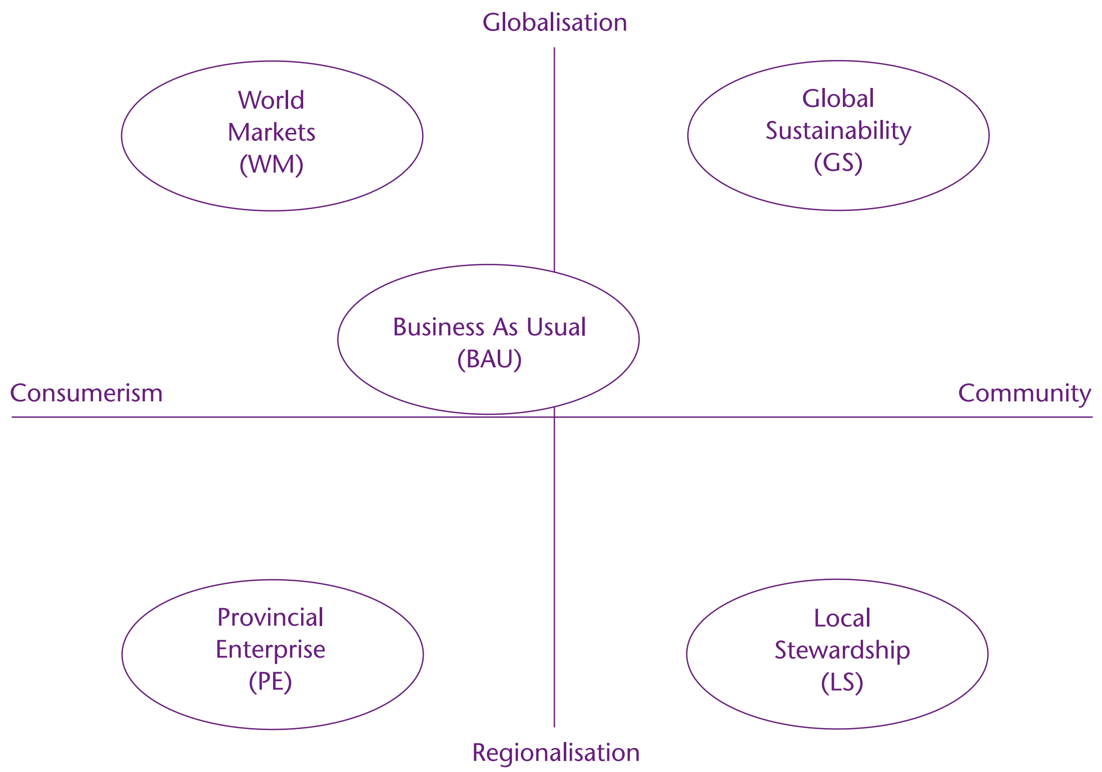
- significant carbon emission reductions are only achieved in scenarios where environmental objectives are prioritised;
- oil will remain the dominant road transport fuel to 2020 but by 2050 low carbon options are required and expected to be available;
- gas will be dominant in heating markets and in power generation to 2020;
- achieving a low carbon future requires a significant increase in the rate of adoption of energy efficiency measures in all sectors of the economy; and

- **in power generation, the lowest cost low carbon options for the future appear to be CHP and most renewable energy. This requires action very soon to accommodate changes to the nature of the energy system.**

5.1 No single part of the energy system can deliver all the Government's objectives. For this reason, our analyses focus on the whole system - the supply and conversion technologies, the demand technologies, and the infrastructure of networks and storage that links supply to demand. Equally important it includes the markets and the institutional structures that shape, and are shaped by, the technologies.

5.2 Some of the objectives of energy policy - notably a sustainable environment and energy security - require a long-term view. Yet the further into the future we look, the greater the uncertainty. Many decisions can be put off until there is a greater level of certainty, but not all. One way to explore these uncertainties is the use of scenario analysis - allowing consideration of a range of possible worlds, and the ways in which energy systems might evolve within them. The PIU approach has been to devise an internally consistent set of demand and supply assumptions based on the DTI Foresight scenarios, which include assumptions on behavioural change and an assumed consistent policy environment. Conclusions can then be drawn by comparing results across scenarios.

Figure 5.1 Locating the five scenarios on the grid of governance and social values



5.3 Figure 5.1 indicates the way in which the scenarios cover a spectrum of possibilities. Scenarios have been constructed for two horizons.

- **2050** – On this timescale major changes in energy markets and technology are possible. Attention is focused on the implications of the development of new energy sources and carriers, given the long lifetimes of some energy infrastructure.
- **2020** – Although the existing energy system has substantial momentum, limiting the extent of change by 2020, a large fraction of energy capital equipment will need to be replaced by then. The availability of indigenous fuel supplies will have changed significantly. For this time horizon a "business as usual" (BAU) scenario has also been examined. This is described more fully later in this chapter.

5.4 The longer-term possibilities are considered first and the conclusions used to judge whether developments to 2020 are on the trajectory required to achieve longer-term carbon reductions. The same broad approach has been used for both the 2050 and 2020 analyses. Demand for energy has been estimated by assuming the number of consuming units, the energy service level required and the efficiency with which that service is provided. Demand is aggregated into heating, power and transport. The supply options are then matched to these demands and the total primary fuel and carbon emissions derived.

5.5 Detailed descriptions of the scenarios and the different energy systems have been set out in PIU working papers.[1] This chapter identifies the implications for decisions in the near future.

The far future – 2050

5.6 The energy system in Great Britain could alter very dramatically over half a century. Almost all energy supply and energy use equipment will be replaced at least once. Institutions and market structures could undergo extensive change.

5.7 However, some similarities with the current system are likely to remain. About half of the stock of buildings for 2050 has probably already been built. Although the energy infrastructure of pipes and wires will be largely renewed and incremental change is therefore certain, the networks form a huge sunk cost so that complete transformation is unlikely.

Energy services: the driver of the energy system

5.8 Under all scenarios, the services for which energy is needed remain the same: heating buildings and industrial processes, powering machines and electrical appliances, and transporting people and goods. These service demands will grow, but in most cases more slowly than the economy. Once they are comfortable people will not want their homes to get any warmer, nor are they likely to want to spend more time commuting.

5.9 Demand for energy services is scenario dependent. In a low growth, conservationist world it might hardly change. At the other extreme, in a high growth, consumerist world the demand for energy services might double, with associated implications for levels of waste and traffic congestion. In intermediate scenarios energy services demand grows by about 50% in the period 2000-2050.

[1] PIU (2001e) and PIU (2001f).

5.10 This sets the resource productivity challenge for the energy system in 2050: to get 50% more output (energy services) with substantially lower carbon emissions.

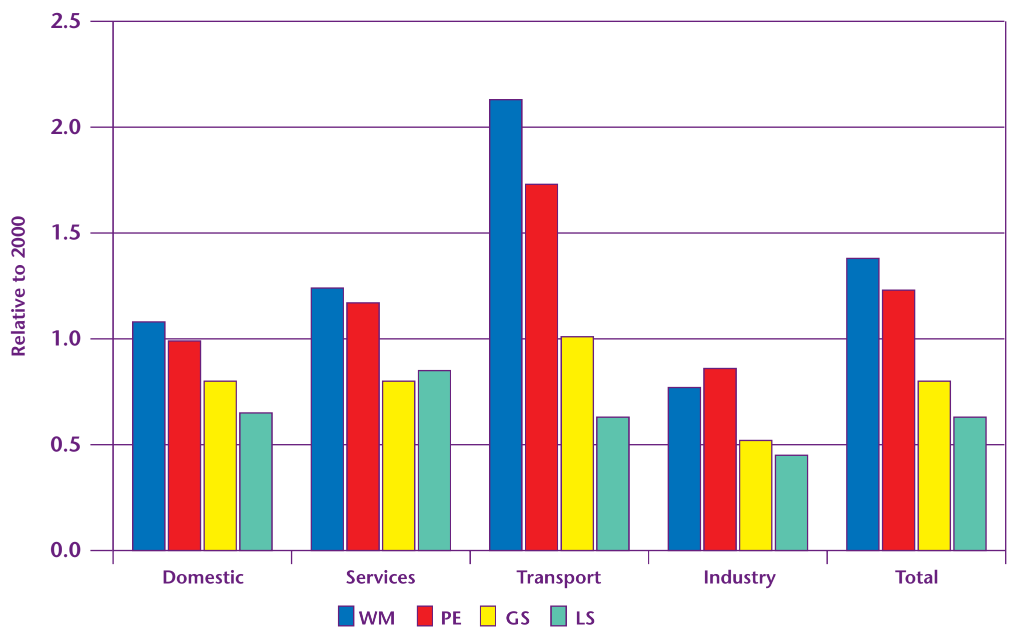
Getting more from less: improving energy efficiency

5.11 Levels of energy demand depend on the demand for energy services and on the efficiency with which energy is used. Energy efficiency will certainly continue to improve, as it has done historically. The rate of improvement will depend on innovation, reactions to energy prices and policy interventions to improve efficiency. The scenarios suggest that energy efficiency could improve by between 35% and 100% (i.e. doubled) by 2050. Assuming an aim towards the top of the range, this implies annual rates of improvement in excess of 1%. In the last two decades we achieved figures averaging about 1% improvement in housing[2], but less in industry and transport.[3]

5.12 Putting changes in the demand for energy services and in energy efficiency together, total energy use could either rise or fall, as shown in Figure 5.2. The sector with the strongest tendency for growth is transport, especially aviation. The use of electricity is also likely to grow. The demands for energy services that depend upon electricity – motors, electronics and lighting – are further from demand saturation than heat. Even with strong energy efficiency programmes the scenarios do not suggest that these demands for electricity will fall by more than 10-20%. Overall the level of energy use in 2050 might be within the range of 60% and 140% of current levels. It falls only in scenarios where policy and social changes give substantial weight to environmental goals.

5.13 Energy efficiency can make a big contribution towards delivering significantly lower carbon emissions, but this will need policy action. Even then energy efficiency alone will not deliver carbon emissions reductions on the scale expected to be necessary.

Figure 5.2: Energy demand by scenario in 2050



[2] DTI (1997),Table 7.4.
[3] DTI (2002).

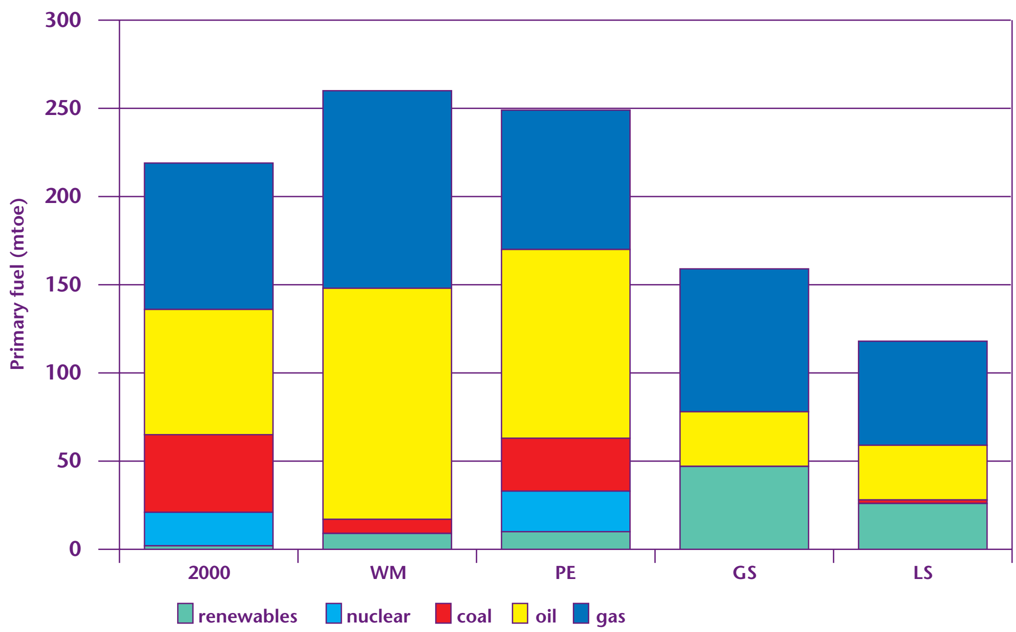
Energy supply: which fuels?

5.14 The change in the pattern of energy supply over 50 years is even more uncertain. Gas, coal, oil, nuclear and renewables sources could all make a major contribution. Their future will depend upon costs, on supply constraints, and on environmental considerations. Estimates of possible primary fuel supply mixes in 2050 by scenario are shown in Figure 5.3 and details are given in Box 5.1. The estimate shown for the GS scenario assumes that, as expected, renewables costs fall sharply such that renewables become the most cost-effective zero carbon form of electricity generation. If this were not to happen, or if the costs of nuclear or carbon capture and sequestration were to be lower than expected and other uncertainties with these sources resolved, then GS could show a significant nuclear or coal component.

5.15 Electricity is likely to remain a key form of energy in 2050. It has a rising share of energy demand under all scenarios and is clean and convenient at the point of use. The growth in use of renewable energy sources will have important implications for the electricity network. In all energy scenarios, the increased use of renewable energy and combined heat and power (CHP) implies major increases in the connection of embedded generators (power stations connected to the lower voltage regional distribution networks rather than the high voltage transmission grid). This has major implications for the construction, operation and regulation of the electricity distribution networks (see Chapter 7 and the Appendix to that Chapter). Infrastructure investment in the transmission system will also be required if significant use is made of off-shore power sources (wind, wave, tidal) or if a stronger connection with European systems is required (either for increased security or to add an element of diversity).

5.16 The scale of power generation technologies is likely to continue to fall. Some low carbon power options (nuclear and fossil fuels with sequestration) would necessarily be large scale. But both renewable energy technologies and (CHP) tend to be smaller scale

Figure 5.3: Primary fuel mix by scenario in 2050



than conventional power generation. CHP provides the most efficient way of using fossil fuels and biomass, so that by 2050 all low temperature heat could be provided from CHP units of an appropriate size. The development of fuel cells and low cost solar photovoltaics might allow micro-generation in buildings to deliver a substantial fraction of our power needs by 2050. Early action on grid investment, connection, regulation and pricing will be needed if this option is to be available.

Box 5.1: The use of different fuels in 2050

Natural gas: likely to continue to play a big role. Convenience in use makes it attractive as a heating fuel, probably also has a continued role in power generation. Most people expect gas to remain available in Europe in large amounts, and at low cost, unless geopolitical concerns restrict supplies. By 2050, the UK will, like most other countries, be predominantly dependent on imports. Strategic security is therefore a concern.

Oil: likely to retain a comparative cost advantage in road transport, and to remain essential in air transport. Demand critically dependent on transport use, vehicle efficiency and the development of alternatives. There are different assessments of world oil reserves, and some analysts are more optimistic than others. Even so, the ready availability in 2050 of low cost oil supplies cannot be assumed. Reduced reliance of road transport on oil could be achieved by using liquid biofuels, electricity or hydrogen.

Biofuels: might be available from indigenous sources, but only in significant amounts if the manufacture of ethanol from woody fuels is successfully developed. Even then domestic supply is likely to meet only a fraction of likely demand, and the development of a large biofuel import market would be required.

Hydrogen: the carrier most likely to displace fossil fuels for road transport. Whether it in fact will do so depends on the way fuel cell technology develops, and on the provision of an infrastructure for hydrogen production and storage.

Coal: unless gas is very seriously constrained, only likely to find a significant market in power generation. Even there, a substantial role is only possible, consistent with carbon emissions reduction, if engineered carbon capture and sequestration are successfully deployed.

Renewable electricity: wind, wave, tidal, biomass and solar may all play a major part in power generation supply by 2050. Despite the uncertainties, the PIU's assessment of long-term costs (see Annex 6) suggests that, with continued support and development, renewables could be among the most cost-effective options for reducing carbon emissions, particularly under the assumptions of the GS scenario. In this case, they could, by 2050, produce very large quantities of electricity.

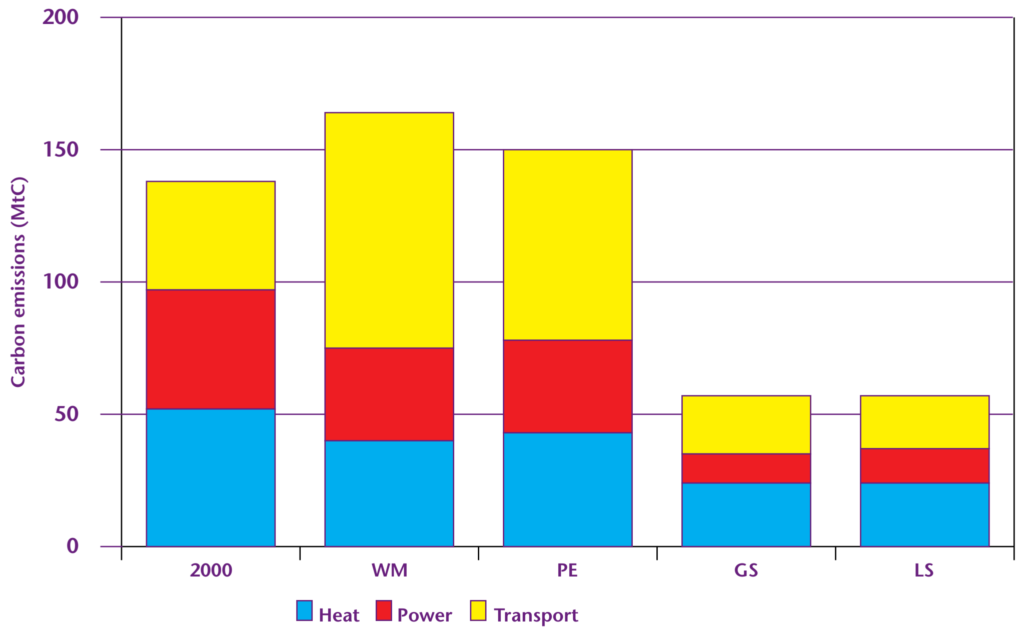
Nuclear power: a role that cannot yet be defined, since concerns about radioactive waste and low probability but high consequence hazards may limit or preclude its use. Costs of production could fall substantially if new modular designs are effective. Unlikely to compete with fossil fuels in power generation on cost alone, but might have significant role if low carbon emissions are required. If renewable costs do not fall as anticipated, and/or concerns surrounding waste and risks can be resolved, nuclear would be an obvious candidate for delivering low carbon electricity in scenarios such as GS.

Reducing carbon emissions: the key role of hydrogen

5.17 PIU estimates of carbon emissions in the different scenarios for 2050 are shown in Figure 5.4. Substantial reductions in carbon emissions are not achieved in the two scenarios which do not place high value on sustainability. The analysis also shows that if the demand for energy services grows broadly in line with current trends, then even the complete conversion of the electricity system to zero carbon fuels does not lead to carbon reductions of 60%. Major energy efficiency improvements will, of course, also help, but they are not enough. The RCEP's analysis shows that large cuts in carbon emissions might be achieved within an energy system which used fossil fuels for transport and biomass for heating. But an energy system of this kind would be costly, given likely limits on the availability of land for biomass and the cost of substituting biomass for gas for heating. The conclusion is that if major reductions in carbon emissions are to be achieved without large costs to the economy, new approaches will be needed in heat and/or transport fuel markets.

5.18 Research over the last 30 years into battery powered vehicles has not produced a viable system, and fuels derived from biomass are likely to be constrained by land use. The change which is most likely to reduce the role of oil in transport is the development of hydrogen fuelled vehicles.[4] The use of ethanol from biomass in advanced hybrid engines is one of the few configurations which could come close to the low carbon potential of hydrogen-powered fuel cells. However, although substantial technical challenges remain with hydrogen fuelled vehicles, there is growing confidence that they can be overcome. All the world's leading vehicle manufacturers now have major R&D programmes. The PIU scenarios which meet the RCEP target all include a shift to hydrogen in transport fuels. The transition to hydrogen fuel cell power itself will provide the opportunity for major improvements in fuel

Figure 5.4: Carbon emissions by scenario in 2050



[4] Prospects for transport technologies and new fuelling infrastructures are discussed in the PIU Working Paper, Fergusson, M (2001).

efficiency in road transport. Only in the longer-term would hydrogen then be used in heating fuel markets and this may not be appropriate given the ease with which electricity, which has much lower distribution costs, can be used directly.

5.19 The central question is how will the hydrogen be made? In the short-term, the cheapest source of hydrogen will be the reformation of fossil fuels – either "on board" from petroleum fuels, or from natural gas. These options still give rise to significant carbon emissions – though overall higher efficiencies can reduce emissions in some instances. Perhaps more important for the long-term, they may be essential to the development of a hydrogen fuel cell vehicle industry. The high efficiency of fuel cell vehicles and low levels of other pollutants are further prospective benefits from transition to hydrogen using fossil fuels.

Box 5.2: Towards a hydrogen economy?

Energy futurologists have long predicted the rise of the hydrogen economy.

Hydrogen does not exist in major quantities naturally and therefore cannot be mined. It has to be made, either chemically from fossil fuels or biomass, or by electrolysis of water. It is an alternative means of delivering energy.

Hydrogen (or other hydrogen containing fuel) is required for fuel cells. Fuel cells are essentially batteries that use a fuel input. Most of the world's major vehicle manufacturers are investing heavily in fuel cell vehicle R&D programmes.

The key advantages of hydrogen for use in fuel cells are that it:

- is clean at the point of use;
- is potentially cost effective;
- would be used in modular and small-scale devices;
- could be derived from many sources – central and decentralised;
- could be used introduced as a mixture with natural gas – "hythane";
- would have both transport and stationary use; and
- would provide zero carbon fuel storage.

However, there are some key problems to be resolved before the hydrogen economy can be introduced. These include:

- perceived safety problems;
- low cost fuel cells;
- low cost hydrogen storage;
- development of a delivery infrastructure; and
- low carbon hydrogen production.

Storage is a key issue to be addressed within hydrogen research.

If low production costs can be achieved, hydrogen fuel cells are likely to prove very attractive in transport and some stationary power markets because of pollution and efficiency benefits. However, they only allow transformation to a very low-carbon energy system in the context of zero carbon electricity supply. In this case, the storage potential of hydrogen may be a key factor in addressing renewables intermittency.

5.20 The long-term value of hydrogen is that it could be a genuinely carbon-free fuel.[5] There are two options for making hydrogen without carbon dioxide emissions:

- reforming fossil fuels with sequestration of the carbon dioxide produced; and
- electrolysis of water using zero carbon electricity.

Both imply major changes to energy infrastructure over a 50-year timescale.

5.21 Hydrogen production by reformation of fossil fuels with CO_2 sequestration is as yet unproven on a large scale. Substantial CO_2 disposal systems would be needed and the environmental risks and public acceptability of the technology are uncertain. In addition, engineered sequestration is likely to make most sense on a large scale, which means that a hydrogen distribution network would need to be constructed. This could prove costly, but it is possible that a hydrogen network could evolve gradually and at modest incremental costs – one model envisages gradual upgrading of the natural gas network to make it "hydrogen friendly", enabling an eventual switch to hydrogen. Reformation of natural gas without sequestration will be the lowest cost means to make hydrogen in the first instance, and could continue to be a low cost option even with the costs of sequestration and hydrogen transport included. The electrolytic route would also entail substantial investments, electrical output would need to double in order to provide sufficient energy for the road transport sector if most vehicles were run on hydrogen.

5.22 It is, therefore, not yet clear how the long run costs of reformation with sequestration will compare with the electrolytic route. It is perfectly possible to envisage a complementary role for both options, with the UK exploiting, perhaps, both CO_2 repositories under the North Sea and the large renewable resources available offshore. Moving toward a low carbon hydrogen based economy could therefore require the development of both a substantial low carbon electricity sector and C&S from fossil fuels. Given the uncertainties it is important that action is taken now to ensure options are opened up for both CO_2 capture and sequestration and for zero carbon electricity.

5.23 The task of constructing the energy infrastructure to supply hydrogen to the road transport sector will be large. Over this timescale other policies also play a role: land use planning and its implications for travel, public transport infrastructure and support for low power alternatives such as cycling and walking, can all make a substantial contribution in the long-term. These sorts of considerations are outside the scope of this report, though they may be critical to achieving long-term energy policy goals.

5.24 The displacement of oil fuel from road transport would leave oil playing a major role only in aviation fuels. As kerosene is the only acceptable petroleum fuel for aviation, this would have implications for oil refineries. It seems likely that carbon emissions from aviation will increase substantially as demand significantly outstrips prospects for energy efficiency, at worst (in scenarios where carbon emissions increase) increasing by over 500% to 2050.

Conclusions for 2050

5.25 On the evidence of the scenarios it seems possible to deliver reduction in carbon emissions of 60% by 2050. It requires continued and substantial progress in energy efficiency, the construction of a large, low

[5] Though hydrogen itself has no direct global warming effect, hydrogen leakage would have some indirect impact on climate through chemical interactions with other greenhouse gases in the atmosphere. But leakage rates would be low as any effect would be much less than the climate impact of the fossil fuel emissions displaced.

carbon electricity system, major progress towards a low carbon road transport sector and managed growth in air travel. All of this will require a policy environment that encourages the development and adoption of low carbon options.

5.26 A transition to hydrogen is, however, unlikely to be completed by 2050. Further work is needed on the implications of a transition to hydrogen for hydrogen manufacture and distribution, carbon dioxide sequestration, electricity network development and oil refining.

The foreseeable future: 2020

5.27 The view to 2050 indicates the long-term priorities required for substantial reductions in carbon emissions: energy efficiency, low carbon electricity and hydrogen for road transport. But it is less helpful in setting immediate policy goals. Many issues that affect developments to 2020 do not require a scenarios-based approach. A second set of scenarios looks at 2020, and provides the basis for recommendations for more immediate policy.

5.28 The work again uses the Foresight scenarios, but also considers a BAU scenario. BAU assumes the Government's existing policy measures, including those set out in the November 2001 Climate Change Programme, are implemented, but that there is otherwise minimum market intervention up to 2020. BAU should not be interpreted as a preferred or even more probable scenario. Indeed, as shown below, it is not consistent with current policy objectives.

5.29 Unsurprisingly, there is less divergence between results of the 2020 scenarios than there was in the 2050 scenarios. Even so, a large proportion of power generation capacity, and most demand side equipment (apart from buildings), will have been replaced by 2020. And some wholly new technologies, such as fuel cells, will probably enter the market. However, it is unlikely that any new technology will have major impacts by 2020 and much will depend upon the rate at which currently available technologies replace the existing stock.

Trends in demand

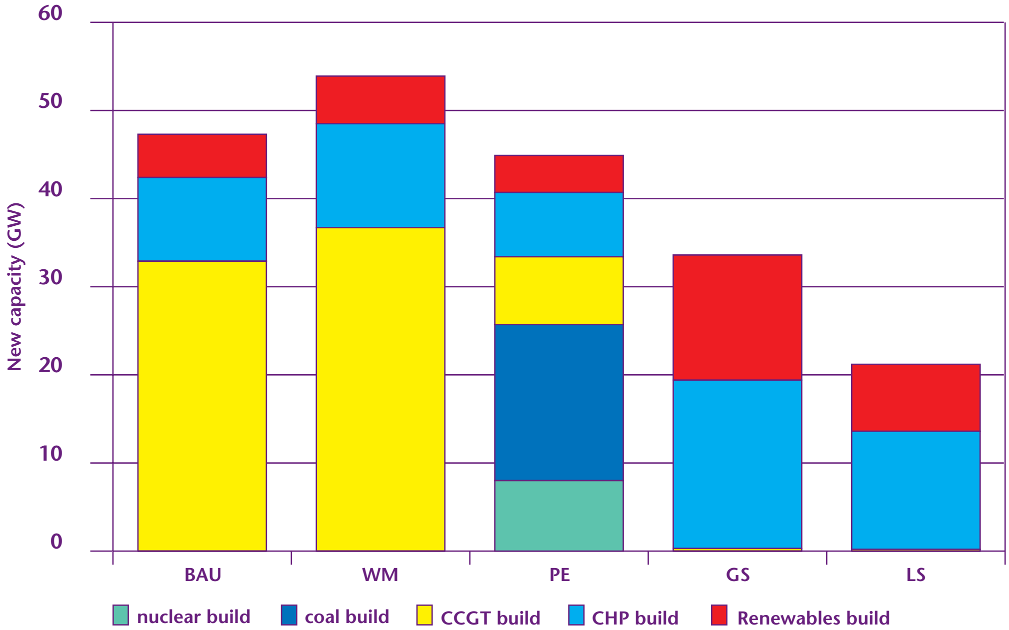
5.30 Declining trends in energy demand for heating in industry and buildings heating are likely to continue, and the growth in electricity demand might also be modest if energy efficiency policies are pursued with vigour. Demand for road transport fuels is, at worst, likely to be broadly stable. This reflects improved fuel efficiency, and the assumption of lower rates of travel growth than in the past. More optimistically, a combination of efficiency improvements and sustainable transport policies could reduce demand by 20%. Aviation demand still seems likely to grow strongly, and there is less scope for efficiency improvement. Aviation fuel demand is almost certain to grow, and, at worst, it might double.

Trends in supply

5.31 In the 2020 scenarios, oil remains the dominant transport fuel, though there could be niche markets for biofuels, gases and hydrogen. By 2020 it is possible that the UK will be importing 80% of its oil needs (see Annex 7). Gas remains the dominant fuel for heating, and further growth in the gas market share is to be expected. Indeed, the overall demand for gas is up by 30% if the BAU path is followed, and gas takes a major share of the electricity market. The UK could be importing 80% of its gas in 2020 (see Annex 7).

5.32 Major fuel switching is only likely in the power generation sector. About half the current generating power capacity (36GW) is expected to be closed by 2020. Changes in demand mean that up to 50GW of new capacity could be needed. But with strong energy efficiency programmes this could be reduced to below

Figure 5.5: New electricity generation by scenario



25GW. The maximum required build rate of 2.0-2.5 GW annually is not in itself a problem. This level has been achieved in the past. The major issues are around the type and fuel of new capacity. Figure 5.5 shows the way that new capacity might be constructed (or avoided) in different scenarios.

5.33 Without Government intervention in the market, new capacity will be met primarily by gas, largely in Combined Cycle Gas Turbine (CCGT) stations. The share of gas in power generation might then rise as high as 75%. However, this is not inevitable. An emphasis on diversity might lead to a role for nuclear power and/or coal. Such an approach would require significant intervention. Alternatively, an emphasis on environmental sustainability would lead to expansion of (gas-fired) CHP and renewables.

Carbon emissions

5.34 Figure 5.6 shows the emissions by scenario in 2020 compared to current levels. All the scenarios indicate a continuing dependence on oil for transport and gas for heating, both of which will be largely imported by 2020. For heating, gas dependency and carbon emissions can be reduced by increased energy efficiency and wider adoption of CHP. There is wide scope for changing the fuel mix in the electricity system where total carbon emissions could be reduced, however this will not occur without support for one or more of the low carbon options. Figure 5.7 shows how long-term carbon emissions move in the different scenarios.

5.35 Radical change in the energy system is unlikely by 2020. But if the system is to meet long-term environmental goals, trends over the next 20 years will be important. The UK will need to increase the rate of energy efficiency improvement and to reduce the carbon intensity of energy. In energy supply, there is most scope for change in electricity, in particular through the expansion of renewable energy and CHP. This will require action to accommodate increased small generation in electricity markets and networks.

Figure 5.6: Carbon emissions by scenario by end use in 2020

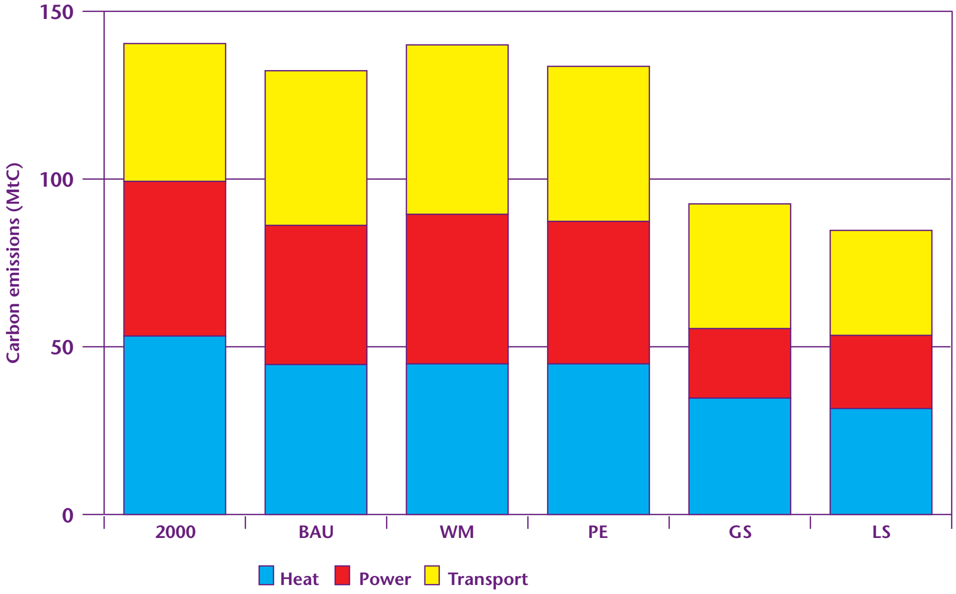
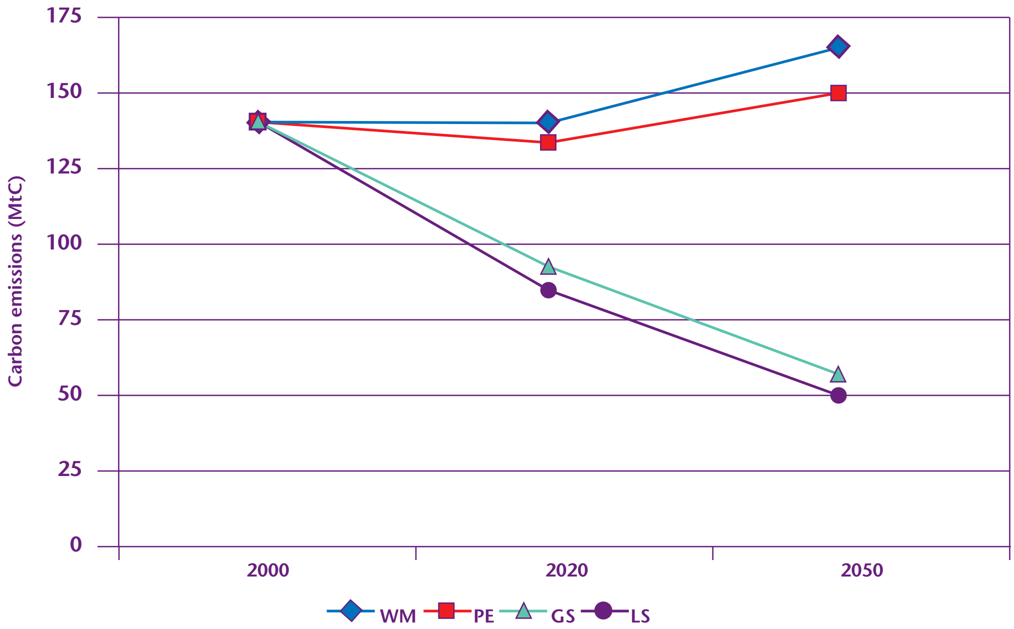


Figure 5.7: Trends in carbon emissions by scenario



6. OPTIONS FOR A LOW CARBON ENERGY SYSTEM

Summary

The PIU's scenarios indicate that deep cuts in greenhouse gas emissions by 2050 are possible. This would require the development of a wide range of low carbon options.

As well as broad market-based instruments, more targeted policies would be needed, given market failures and other barriers to the development of low carbon technologies.

Criteria for assessing the low carbon options should be: scale of potential contribution; cost per tonne of carbon saved; potential for innovation, learning and cost reduction; extent of synergies and conflicts with other policy objectives; flexibility; and applicability to UK circumstances.

Energy efficiency can make a very large contribution, has very low (or negative) net costs, has no conflicts with other policy objectives, and is flexible. In the area of transport, there are substantial potentials but limited knowledge about costs.

New renewables represent a huge potential UK resource, offer large synergies (and very limited conflicts) with other policy objectives, and are flexible. Costs are generally high now, but innovation prospects are good: costs should fall significantly via learning effects.

Nuclear power represents an established very low carbon technology with substantial potential contribution. It offers scope for cost reduction, and has important synergies with other policy objectives, though the nuclear waste issue is unresolved.

Capture and sequestration of carbon may have a large potential contribution, but is presently subject to a wide range of uncertainties. It needs further study.

Transport fuel switching is very important for the medium to long term, and there are good prospects for hybrid and fuel cell vehicles, though costs are currently high.

Increased support for technology development, including R&D and demonstration, will be crucial to realising these options.

The analysis in this chapter provides the basis for the programme set out in Chapter 7.

6.1 Facilitating the delivery of a low carbon energy system should now be at the heart of energy policy. The UK needs to position itself so that it can move towards the levels of greenhouse gas emissions that are likely to be needed as part of the global response to climate change. Chapter 5 indicates that this is possible, but policy action will be essential, both to ensure delivery of low carbon energy and to minimise the risks and burdens of doing so. While the UK will not want to commit itself unilaterally – both because greenhouse gases are a global problem, and because to do so would damage competitiveness – it needs to act now to establish a range of low carbon options.

6.2 It should start with those options that involve "no (or low) regrets" because they have associated economic and environmental benefits. Some developments are necessarily international or even worldwide, but the UK is an important participant in the process and some options, especially renewables and some kinds of energy efficiency, need to be developed to meet particular UK circumstances. The energy system should be moving in the right direction so that emissions continue to decline and cost-effective options, which will allow for deep long term cuts, are brought forward in a timely fashion.

6.3 There are three ways in which the energy system can be moved in the right direction:

- reducing the overall demand for energy services: transport, heat and power;
- reducing the amount of energy used to deliver a given amount of transport, heat and power; and
- reducing the amount of carbon emitted for each unit of energy consumed, requiring a change in the energy supply mix.

6.4 Long term changes in lifestyle – rural/urban settlement and work/leisure patterns – could have profound effects on demand for energy services, especially transport. Reduction of transport demand could be critical to achieving long term energy policy goals, and Government should continue to work for this objective. Changes in the way customers relate to energy may also influence the types of technology that develop. Though policy can influence overall levels of demand for energy services, the focus of this chapter is on the other ways of influencing the energy system.

6.5 This Chapter sets out the criteria by which low carbon options should be judged, explains the potential of different options, and draws conclusions about synergies and conflicts with other objectives.

The options and their potential

6.6 There is a range of options for moving the energy system onto a low carbon path. This Chapter considers the major options and Annex 6 gives more details. The list is not exhaustive. Some potential technologies – for example, large tidal barriers, geothermal power, solar hot water and micro-hydro – are not discussed. The focus is on those options which at the moment seem to have the greatest potential.

6.7 So far as is possible, the options are assessed against the following criteria:

- the **scale of the potential** contribution to carbon emission reduction, both in 2020 and more speculatively in 2050. This requires an assessment of the physical potential and the likely build rates;
- **costs per tonne of carbon saved.** Estimates are made of the carbon content of the energy saved or displaced. Resource costs are negative (there are net economic benefits) when the investment saves energy more cheaply than it can be supplied, and positive when fuel switching requires energy to be produced by means which are more expensive than the cheapest commercial option, which is assumed to be CCGT. The main estimates are for 2020, but some current figures are also presented;
- long-term potential for cost reduction through **innovation, learning or market growth**. The various technologies and options are at varying stages of maturity. Where intervention favours a nascent technology, there are often significant prospects for future reductions in unit costs by way of learning by doing and economies of scale;
- the extent of **synergies or conflicts** with other policy goals. The main object of this Chapter is to assess the merits of different ways of saving carbon, but where an option also helps to meet other objectives this is a bonus, just as it is a cost where other objectives are threatened;
- **flexibility** of response. Options which allow a flexible response in the face of changing circumstance and information are to be preferred; and
- applicability to **UK circumstances.** Options which are particularly well adapted to UK geographical, commercial and political circumstances are generally to be preferred, especially since technologies which suit other countries better than the UK may be best developed elsewhere. If use is made of each nation's comparative advantage, then the world as a whole is likely to develop the widest range of new options.

6.8 Table 6.1 at the end of the chapter summarises the potential contribution of each option in 2020 and 2050; the cost per tonne of carbon saved in 2020; and the potential for development specific to the UK.

Energy efficiency

Scale of potential contribution

6.9 Energy efficiency can significantly reduce the demand for energy, and so reduce the production of carbon. In just about every part of the economy there is a vast range of technical possibilities. The technical potential – the improvement to be had from using the most technically efficient technology currently commercially available – is very large. What matters most for short-term policy is the economic potential – that part of the technical potential which yields energy savings which more than pay for any extra investment cost under standard investment criteria. These investments could reduce energy demand by 30% in the economy as a whole, equivalent to a potential annual saving worth £12 billion (see Annex 6).

6.10 There would be some offsetting second-round effects as people adjust to the improvement (the "rebound effect"). In the business sector, an increase in energy efficiency delivers an increase in productivity. This is translated into higher incomes and will, to some extent, produce an associated increase in energy demand. Equally, for some individuals, notably the fuel poor, the extra efficiency allows them to achieve greater comfort from the same expenditure, so that a large part of the extra efficiency does not produce a fall in the consumption of energy. The rebound effect is expected to reduce the energy savings from improving energy efficiency by only about 10%.[1]

Cost

6.11 Costs per tonne of carbon are either negative (since there are net resource savings) or low.[2]

- The existence of a large, but untapped, economic potential implies either that there are significant market failures; or that the analysis ignores hidden costs, such as unrecognised risks, or management and consumer time. Even if allowance is made for some hidden costs, most energy efficiency measures provide a very low cost approach to reducing carbon emissions.
- For the vast majority of energy users, energy is a small fraction of total costs. In a complex world, both households and most businesses have higher priorities. They do not seek to maximise the economic efficiency with which they use energy. Whether there are market failures or hidden costs, policies that transfer responsibility for energy efficiency investment onto a smaller number of well-informed players are likely to be the lowest cost approach to delivering energy efficiency improvement.

Innovation

6.12 The scope for cost-effective energy efficiency improvement has remained broadly constant over the last 25 years. This is because, over time, innovation has created new economic potential from the technical and theoretical potential, while barriers to implementation have remained. While policies proposed here should remove some of these barriers, a continued process of innovation in energy efficiency can be expected, so that energy efficiency should remain a low cost source of carbon saving throughout the period. The Chief Scientific Adviser's (CSA's) review of energy research identified energy efficiency as one of six key areas in which increased funding for R&D and development could have a significant impact on progress towards a low-carbon economy. In particular, it recommended increased support for cross-cutting technologies, such as innovative software and hardware, and demonstration projects to explore further the combined impact of different technologies.

Synergies and conflicts

6.13 Energy efficiency can contribute positively to all the key objectives for energy policy.

- **Economic:** to the extent that energy efficiency is cost effective, the cost savings contribute to improved economic efficiency, reduce household energy bills, and improve business competitiveness.
- **Environmental:** reducing energy demand cuts all the emissions associated with energy.
- **Social:** reducing the energy bills of low income households plays a central role in the Government's strategy for reducing fuel poverty.[3]

1 PIU (2001d).
2 DTI (2002).
3 DTI, DEFRA (2001).

- **Security:** at any given level of economic output, energy efficiency reduces pressures on supply, including imports; it may also reduce the risk of energy systems having insufficient peak capacity.

6.14 Nevertheless, while the resource costs of many energy efficiency measures are negative (and the economic benefits positive), there may be other economic and social costs associated with the chosen policy measures. For example:

- higher energy prices, reflecting the environmental externalities associated with energy consumption, would be an important means of improving the incentives to become more energy efficient, encouraging innovation and drawing consumer and management attention to the possibilities. Higher prices would, however, impact adversely on those consumers who do not increase the efficiency with which they use energy, and, if policies are not consistent with other countries, would worsen the competitiveness of internationally traded energy-intensive sectors; and
- where subsidies are used to unlock the potential, then the income transfers involved will need to be assessed.

Flexibility

6.15 Energy efficiency measures are by their nature small scale and precisely targeted within the UK. They constitute a flexible response to the need for carbon reductions. However in many cases they can only be effectively implemented at the point of capital replacement, so that (especially for buildings) the timescale for delivering the full potential can be lengthy.

Energy efficiency in transport

Scale of potential contribution[4]

6.16 Significant improvements in energy efficiency are possible in the transport sector. The next round of EU agreements needs to reflect and help bring about these advances. Through the current EU voluntary agreement, car manufacturers have already pledged to reduce the CO_2 emissions of new cars by 25% on 1995 levels by 2008. The early indications are that the agreement is proving an effective means of securing better fuel efficiency and lower emissions. Hybrid engines, using both battery electricity and internal combustion engine technology, combined with advanced body features could provide efficiency gains of 50%. Fuel cell electric vehicles could deliver further efficiency gains.

Costs

6.17 There is currently very little data available on the costs per tonne of carbon saved from innovation in the transport sector. The costs and benefits of individual energy efficiency measures in transport do not seem to have been studied in as much depth as in some other sectors.[5] The EU voluntary agreement indicates that significant improvements can be made without serious detriment to the cost of cars, or to the cost base of car manufacturers, so that the cost per tonne of carbon saved through efficiency measures to date is probably negative. But the cost-benefit parameters should be investigated further, in the context of both future EU voluntary agreements and further domestic action to improve vehicle efficiency.

Innovation

6.18 Hybrid electric petrol vehicles are currently commercially available at a price

[4] Prospects for transport energy efficiency are explored in Ferguson (2001).
[5] The last comprehensive analysis was Department of Energy (1989). It is now outdated.

premium of about 20%, partly offset by the fact that they have 15-25% better fuel efficiency. The cost premium is expected to fall rapidly and hybrids are likely to be fully cost competitive before the end of the decade.

6.19 In the aviation sector, IPCC predicts a 40-50% improvement in fuel economy might be achieved by 2050.[6] However, this is less than the historical rate of improvement and is likely to be significantly outstripped by projected growth in air travel. There are options to improve fuel efficiency more rapidly than BAU, but these are not cost-effective at the current (tax-free) price of kerosene. Efforts to improve aviation fuel efficiency will inevitably be mainly at international or European level.

Synergies or conflicts

6.20 The transport sector is currently heavily dependent on a single energy source, oil and is likely to remain primarily oil-based for the next two decades. On BAU projections, energy efficiency will offset road transport growth over this period. This provides a synergy with **security** objectives (no increased dependence on oil) and **environmental** objectives (no increase in greenhouse gas emissions; reduced vehicle noise).

6.21 Access to mobility is an important issue for social inclusion, for both poor and rural communities.[7] Energy efficiency measures in road vehicles could increase the price of new vehicles. This could have a knock on effect on demand, and so on the prices of older vehicles used by poorer people.

Flexibility

6.22 As for wider energy efficiency, most such measures in the transport sector are, by their nature, small and precisely targeted, thus they present an extremely flexible response to the need for carbon reductions.

Efficiency in supply

6.23 The most obvious way to reduce the carbon emissions associated with energy production is to make that production more efficient. In the electricity sector it takes on average 100 units of primary energy to make 39 units of final energy. Energy is lost at each stage of the process, including transportation to final customers. The effects of liberalisation have been beneficial in reducing these losses, because there are extra profits to be had from increased efficiency, and this has stimulated investment in higher efficiency gas-fired power stations and improvements in the use of transmission and distribution networks. Innovation is likely to continue to be important, including technologies which further improve efficiency, such as fuel cells for distributed CHP.

Combined heat and power (CHP)

Scale of potential contribution

6.24 The major source of inefficiency in most power generation is heat loss in exhaust gases. CHP plant uses this productively: the exhaust heat is collected and used, instead of being wasted. The process can be very efficient, especially if the plant is operated to match the demand for heat, with electricity used on site or exported. The effective efficiency of power generation can be 80% or higher. CHP use has traditionally focused on large industrial sites. However, smaller devices, including micro-CHP suitable for individual homes, will soon be on the market. Large-scale CHP investments have the potential to save perhaps 3 MtC in 2020,[8] a sum equivalent to the savings available from a number of generation options. However, the scope for longer-term growth is probably more limited.

[6] IPCC (1999).
[7] Social Exclusion Unit (2001).
[8] Based on ETSU (1998).

Cost

6.25 For the foreseeable future, so long as fossil fuels are used in power generation, CHP will in the right circumstances provide a cost-effective carbon reduction option. As Table 6.1 shows, estimates suggest that many schemes can yield negative costs per tonne of carbon saved (net resource gains), though the viability of particular projects depends on local conditions. CHP investment was stalled in 2001, partly as a result of the treatment of CHP-produced electricity in the early months of NETA, but also because gas prices have been rising in real terms while electricity prices have been falling. This makes the economics of CHP much more difficult than previously. It is not commercially viable to use expensive gas to make cheap electricity, even though the process is technically energy efficient. Small generators may also face difficulties and high costs connecting to local networks. However, even under these conditions, CHP may be a low cost means of carbon abatement relative to other options being considered.

6.26 The economics of micro-CHP appear to be very favourable at the costs and efficiencies assumed by the manufacturers, but this has yet to be tested in the market.

Innovation

6.27 Industrial CHP is a mature technology. Micro-CHP has yet to be developed commercially: it presents substantial future prospects. The CSA's review of energy research identified micro-CHP as an area which merited further research. For example, the development of micro-CHP (eventually using fuel cells) could have widespread application in small-scale household generation.

Synergies and conflicts

6.28 CHP, like demand-side energy efficiency, can contribute positively to all the key objectives for energy policy.

Supply options

6.29 Major changes in carbon production need fuel switching – so that the carbon content of primary energy is reduced – as well as energy efficiency. Fuel switching accounts for much of the downward trend in the carbon ratio identified in Figure 2.8: the switch to gas and nuclear in electricity generation accounted for much of the UK's CO_2 emission reductions in the 1990s. The scope for further switching from coal to gas is now limited. As the Magnox nuclear power stations close, the movement could even be away from low carbon sources of power. Given the aim of switching to sources of energy which have zero, or near zero, carbon emissions, the main options are: the various new renewable technologies, new investment in nuclear power, carbon capture and sequestration, and new transport technologies. Each is considered in turn, as are new transport technologies relying on one or more of the zero carbon sources.

New renewable technologies

Scale of contribution

6.30 The UK is very well endowed with renewable energy resources. It has the best wind and marine resources in Europe. While renewables are sometimes seen as a homogenous group, they are in fact a wide range of quite different technologies, which can in principle contribute to the low carbon economy in a variety of ways.

6.31 Taken together the leading options – onshore wind, offshore wind, marine (wave and tidal stream), solar photovoltaic (PV), energy crops – have the potential to meet a substantial proportion of the UK's energy needs. Offshore wind has potential for more than 100 TWh/year, PV over 200 TWh/year, and wave and tidal power have potential up to 700 TWh/year[9] (compared to current UK electricity use of 360 TWh/year). Energy crops can be used for electricity, heat or liquid fuel. The other technologies generate electricity.

6.32 There are other renewable technologies – hydropower, geothermal, biomass wastes, or solar hot water – that are either technologically mature or have more limited potential for use in the UK.

6.33 Since most generating units are small, they would need to be installed in large numbers in order to secure a substantial amount of energy.[10]

Costs

6.34 All renewable technologies offer very low carbon energy supply, with zero CO_2 in use. While some renewable technologies are already cost effective, most are currently more expensive than fossil fuel alternatives. There is a considerable variation, depending on the stage of development.

6.35 In general, renewable energy sources are expected to be subject to substantial reductions in cost as volumes of plant rise. This is because learning effects and economies arising from large-scale manufacture of small devices should lead to large reductions in unit costs. The feedback loop from experience in deployment to improvements in design and cost reduction is rapid for most renewables. Given the potential for substantial reductions in costs as volumes increase, current costs per tonne of carbon saved are therefore an incomplete measure, since today's investment buys a wider range of options for the future. By 2020 some technologies could show negative costs per tonne of carbon.

6.36 **System costs.** In addition to the direct costs of the generating technologies, renewables have the potential to impose additional costs on the system. In particular, unlike all other generating options, wind, solar and wave energy produce variable and unpredictable output. The system costs of unpredictable intermittency are disputed, but many studies suggest they are low in comparison to generating costs.[11] Analysis for the PIU[12] assessed the costs of intermittency on the assumption that system services required to deal with increasing levels of intermittency would be provided using electrolytic storage plants. In practice, lower cost options may be available, such as holding older plant available on stand-by. The analysis suggests that:

- costs are negligible at low levels, indeed small amounts of intermittent generation cannot be detected by the system operator;
- costs are less than 0.1p/kWh for 10% of electricity from intermittents;
- costs are less than 0.2 p/kWh for 20% of electricity from intermittents.

The analysis also suggests that at large penetrations (45% or more of peak demand) costs could rise to 0.3p/kWh or more. However, as such high penetrations are unlikely to be reached for many years, such costs are very uncertain.

9 Technical potentials quoted based upon DTI figures; see PIU (2001h).
10 However there are exceptions, such as the possibility of large tidal barrages (e.g. the Severn Barrage). Such a project would be large-scale even in relation to a technology like nuclear power. The feasibility and costs of such a scheme have not been studied in this review and would deserve a large separate study.
11 A review of studies is provided in Milborrow (2001).
12 See Appendix to Chapter 7 for more details, and Milborrow (2001).

6.37 Locational factors specific to renewables may also impact upon system costs. Connection charges to the grid are reflected in the costs quoted above, but charges that reflect any need to upgrade the local network are not. These are generally small in comparison to generation costs, though there are exceptions. The fact that some marine resources are remote and therefore of lower value to the system is reflected in the PIU's assessment of carbon saving costs (see notes to Table 6.1 below and Annex 6). However, substantial upgrading of the national grid transmission network will not be needed in the short-to-medium term.[13] In the longer term, such changes might be needed if a large contribution from renewables is to be realised. The DTI's proposed study of an offshore cable from the West of Scotland illustrates the range of possibilities. The long-term costs are uncertain but could be significant.

Innovation

6.38 The results of a detailed analysis of the cost reduction potential of the leading options over the next 20 years are summarised in Box 6.1 (and see Annex 6). The work suggests that the leading options – onshore and offshore wind – have the potential to become among the cheapest low carbon options, although sustained support will be needed for some of the other technologies, such as solar PV and wave power, which offer significant potential for the long term.

Synergies and conflicts

6.39 **Security of supply.** These sources of energy are indigenous and generating units are largely small scale. They also tend to be decentralised and dispersed, making them less vulnerable than larger units. The main security issue concerns intermittence. Individual renewable power plants pose no threat to security. The design and operation of the electricity network can be modified to accommodate increasing levels of intermittent power, overcoming security problems. And as indicated above, the costs are small.

Box 6.1: The costs of renewable technologies world-wide in 2020

On-shore wind – likely to fall to 1.5–2.5 p/kWh.

Photovoltaics – likely to see sustained and substantial cost reductions over the next 20 years, but PV will inevitably do best in countries with the most sun: the cost in the UK could still be as high as 10-16 p/kWh.

Offshore wind – likely to fall to 2-3 p/kWh.

Energy crops – the cost of combustion will probably fall substantially, but reductions in the costs of crop production and processing will also be needed; the best estimates for the average costs lie in the range 2.5–4 p/kWh.

Wave and tidal – cost reductions are uncertain, the issue is how rapidly large-scale devices will come onstream; early devices may come through at 4-8 p/kWh.

Note: remote sources need to compete against wholesale electricity prices (currently around 2 p/kWh) and need to be transported at a cost to consumers, while deeply embedded sources, like building integrated PV, have the less stringent target of retail prices in commercial and domestic sector (around 5-7 p/kWh). The effect on generating costs of the intermittent nature of some renewables is included in these cost estimates.

[13] Upgrading some existing "pinch-points", such as the England-Scotland interconnector, would benefit renewables, but the benefits are not unique to renewables and do not represent a "cost" for renewables.

6.40 **Other environmental impacts.** Most renewables produce negligible life-cycle emissions of local air pollutants or solid wastes and produce no other harmful by-products. The partial exceptions are energy crops, which produce manageable outputs of NO_x and ash, and PV which uses some potentially harmful heavy metals. The main impacts are local: visual intrusion, noise and wildlife impacts. While the noise impacts of new wind turbines are small, visual intrusion is a significant factor, most notably for onshore wind.

6.41 **Economic and social.** The support needed to get technologies to the point where unit costs fall substantially comes at a cost. The existing Renewables Obligation will cause a price increase to domestic consumers which could be as large as 4.5% in 2010.[14] The proportionate increase on industrial bills will be larger: it could be double the size of the domestic effect. Both increases will be phased in gradually over the period as the obligation takes effect. Looking to the very long term, profound changes to the way energy is transmitted and utilised may be required. As already discussed, if renewable energy power plants are large and remote, significant upgrading of transmission capacity will be needed, especially from Scotland. If plants are small and distributed throughout the distribution networks, the design and operation of the network will have to change. This may have significant implications for expenditure. However, since the entire energy system will, in any case, need to be replaced over this time horizon, there may be little or no net impact on bills.

Flexibility

6.42 Renewable technologies offer a flexible response to the need for low carbon options because they come in small units, and are quick to construct. While they may have high construction costs per unit output, total capital outlays can be small. The potential for cost reductions is large, though inevitably uncertain. If costs do not respond to learning as envisaged, then different options can be developed.

Energy from waste

Scale of contribution

6.43 Waste management strategy needs to focus on waste minimisation, reuse, recycling and composting,[15] however, to the extent that incineration or other potentially energy yielding options are required, maximising energy from waste can displace other sources of energy, in the form of electricity or heat. To the extent that fossil fuels are displaced, energy from waste can contribute to carbon emission reduction.

6.44 The Waste Strategy 2000[16] outlines several ways in which energy can be recovered from waste. The most common method of energy recovery is by waste incineration, but other options include materials recovery with energy released as a by-product (for example, anaerobic digestion), and waste disposal, with fuel recovered as a by-product (for example, landfill gas).

Synergies and conflicts

6.45 Generating more energy from waste can cut down on landfill and also help to preserve finite primary materials, but is not as environmentally desirable as options higher up the waste hierarchy.[17] There is some public anxiety concerning the health risks of incineration plants, although this also extends to other options, such as landfill sites. There is

[14] OXERA (2001).
[15] A discussion of the various policy instruments for tackling waste operating at EU, national and local level, are included in PIU (2001b).
[16] DEFRA (2000).
[17] The waste hierarchy is set out in DEFRA (2000)

also a body of opinion that argues that policies that promote energy from waste could inhibit waste reduction and other options higher up the waste hierarchy. In addition, the flexibility of future waste policy responses could be compromised if large-scale capital investment was dominated by waste incineration. However the Government believes that the recovery of energy from waste has an important role to play in sustainable waste management, alongside recycling and composting. To this end the Government is also keen to promote the development of more efficient and environmentally benign technologies such as gasification and pyrolysis. An assessment of waste management issues and options is being taken forward in a separate PIU project.

Nuclear power[18]

Scale of contribution

6.46 Nuclear power could supply a substantial proportion of UK electricity and so could play a major role in a low carbon economy. Nuclear power currently produces around a quarter of UK electricity. Over the coming 20 years all but one of the UK's nuclear stations will have reached, or be very close to, the end of their currently expected lives.

6.47 Nuclear power stations are large: recent designs, all of which use thermonuclear fission, are typically 1-2 GW. There may be limitations on the availability of suitable sites for nuclear power stations. The most likely outcome is that new stations would be built on existing nuclear sites.

Costs

6.48 Nuclear power stations emit zero CO_2 in use. Some CO_2 is emitted during construction, but overall carbon emissions per unit of energy delivered are very low compared to fossil fuels. The costs of producing electricity from a new nuclear station are uncertain, probably in the range of 2.5-4.0 p/kWh in 2020, using a mix of PIU and industry analysis. Industry estimates lie at the bottom of this range, and are predicated on assumptions of series build, rapid construction and very good operating performance and relatively low discount rates. On the industry's estimates, nuclear power would be very competitive with other sources of zero carbon power. At the higher unit costs, it is less competitive. In either case nuclear power seems likely to remain more expensive than fossil-fuelled generation, especially in a liberalised market.

Innovation

6.49 Nuclear power is a mature technology and existing designs have relatively limited technological "stretch". Current development work and radical new technologies could produce a new generation of smaller, modular and inherently safer reactors which might be significantly more competitive than those available today. This development work is the subject of international collaboration[19] and will take at least 15-20 years to reach commercial fruition. Fusion reactors are unlikely to reach commercial maturity within a 50-year timeframe. The CSA's review of energy research recommended that priority be given to work on materials capable of withstanding heat and plasma fluxes in an operating reactor over a sufficient length of time.[20]

Synergies and conflicts

6.50 **Security.** Nuclear power is effectively an indigenous source of energy. Uranium can be stockpiled and reserves are large (potentially over 250 years' worth of current world use).[21]

[18] This section draws on Annex 6 and PIU (2001i).
[19] A leading example is the USDOE-sponsored programme for 'Generation IV' reactors.
[20] Annex 8.
[21] OECD NEA/IAEA (2000) p.29.

Nuclear stations are large "point sources" of energy, and there must be sufficient available capacity to cope in the event of planned or unplanned outages.

6.51 The extent to which nuclear stations are vulnerable to deliberate attempts either to disrupt power supplies or to precipitate an accident is not clear. Nuclear stations are designed to be highly robust physically. This vitally important issue requires the attention that it is already getting from specialists in military/strategic security.

6.52 **Environmental risks.** At the moment there is no agreed solution to the very long term management of radioactive waste. DEFRA has recently initiated a review of nuclear waste management[22] with the aim of reaching a public consensus on acceptable ways to deal with existing and unavoidable waste. It is envisaged that this process will take five years. The CSA's review of energy research identified waste-handling as the key priority for publicly-funded R&D in relation to nuclear fission technology.

6.53 The other main environmental issue associated with nuclear relates to the risk of accidental radioactive releases, rather than routine emissions. Although stringent UK and international regulations mean this risk is very low, the potential consequences of such accidents are very large. Innovations in nuclear design may be able to offer inherently safer designs, which will also produce much less waste. These new designs are not likely to become available for 15 to 20 years.

6.54 **Social and economic.** As with the other technologies considered, any programme of public assistance for new nuclear investment would carry costs for domestic and industrial consumers or taxpayers. Nuclear power, like other technologies, also needs to be acceptable to the general public and to those who live near nuclear facilities. The acceptability of new build may or may not constitute a serious problem, and may improve if there is a more obvious need for the technology, but cannot be taken for granted.

Flexibility

6.55 Nuclear investments are large-scale. Moreover, costs are best reduced if a series of stations can be built to the same design. Nuclear power tends, therefore, to be a relatively inflexible source of carbon savings as a programme of series build would entail considerable investment in large-scale and long-lived plant. A sustained programme of investment in currently proposed nuclear power plants could adversely affect the development of smaller-scale technologies, including possible new generations of nuclear plant.

Carbon capture and sequestration

Scale of contribution

6.56 There is growing industrial interest in removing CO_2 from fossil fuels before it is released into the atmosphere, sequestering the carbon in deep repositories so that it is "locked up" and does not enter the atmosphere. CO_2 capture and sequestration (C&S) can be, in principle, applied to any fossil fuel power station. It is also feasible to produce hydrogen from fossil fuels for use in transport, and to sequester the waste CO_2. There are two discrete steps: first, the CO_2 must be captured; and secondly, the CO_2 must be transported to a geologically appropriate repository. The technique of carbon capture is well known, and likewise there is already some experience of sequestering CO_2, although the CSA's review of energy research identified this as an area in which fundamental research may be needed.

[22] DEFRA (2001c)

CO_2 is already injected into some oil fields for enhanced oil recovery. But the two halves of the process have yet to be brought together and demonstrated on a large scale.

6.57 The size of the potential CO_2 reservoirs available is uncertain. Estimates of the global potential of deep saline aquifers range from 10 years global emissions at current rates to twice the carbon content of estimated recoverable fossil fuel reserves.[23] Estimates of the potential of depleted oil and gas reservoirs also vary. However, suitable sites are not evenly distributed around the world, and the UK has access to potentially large CO_2 repositories under the bed of the North Sea.

Cost and innovation

6.58 CO_2 C&S can reduce emissions by 80-90%. Early indications are that CO_2 C&S would be able to provide power at 3-4.5 p/kWh,[24] without allowing for any associated benefit for enhanced oil recovery. The technology has been demonstrated on a small scale, but substantial uncertainties surround both costs and feasibility. If the CO_2 could be used for enhanced oil recovery, there would be added costs – for example at the wellhead – and benefits, from oil sales.

Synergies and conflicts

6.59 The main question about the **environmental impact** of C&S is whether the CO_2 would stay in the ground.[25] As efficiencies are decreased by CO_2 C&S, NO_x emissions would rise compared to plants without carbon capture. There is a related question of whether sequestration will be publicly acceptable.

6.60 C&S could, if successful, offer substantial carbon emission reductions from a range of fossil fuels. If the CO_2 from gas was sequestered, then there would be no obvious gains in **security**. If the process was applied to a coal-fired power station, then the continued use of coal for power generation would bring associated benefits to security. If CO_2 C&S provided the basis for hydrogen production then this would allow the transport sector to reduce its dependence on oil.

Fuel switching in heating

Scale of contribution

6.61 The potential for switching to low carbon fuels for heating is probably limited. Heat markets which use oil or coal are now very limited, and while gas will replace some of them, the contribution to lower carbon emissions will be small. The larger long-term issue is the prospect of using zero carbon fuels for heating. Apart from CHP, already discussed above, the main possibilities seem to be some limited use of biomass, and in the much longer term, the possible use of hydrogen. However both biomass and hydrogen may have more cost-effective initial uses (CHP and transport respectively). It could also be that if low carbon electricity were cheap enough, it could be attractive to switch to electricity from direct sources of heat, but this is at present a distant and uncertain prospect.

Coal mine methane

Scale of contribution

6.62 A small new industry is being established to tap the methane in abandoned coal mines. The methane can then be used to generate electricity, displacing other sources of fuel. The

[23] UNDP/WEC (2000). The main source of this wide variation is uncertainty about the integrity of geological formations – if only “capped” aquifers are suitable then the resource is much more limited.
[24] PIU (2001f & h).
[25] The legal status of disposing of CO_2 in the sub-sea strata needs to be clarified in the light of the OSPAR and London Conventions on marine pollution.

economics depend on the size of the mine, and hence the volume of gas available. The largest mines provide enough gas for the process to be economic in its own right. But studies suggest that, without some kind of support, it would not be economic to exploit smaller mines. A related process – coal *bed* methane – taps the methane in virgin seams of coal, and it may have potential to provide a significant new (but not carbon free) source of primary energy supply, though not to divert gases which would otherwise have leaked into the atmosphere. The particular merit of coal mine methane activity is that it may use gases which would otherwise not remain underground, but would leak to the atmosphere, forming part of the UK inventory of greenhouse gas emissions. In such cases, the environmental gains are, therefore, significant.

Transport fuel switching

Scale of contribution

6.63 Transport is likely to remain heavily dependent upon oil for the next two decades. However in the longer-term a switch to low carbon energy vectors for road transport appears feasible. The reduction in CO_2 emissions will depend on the technological route. The most promising option currently appears to be hydrogen produced from low or zero carbon electricity or from fossil fuels with CO_2 C&S. Biomass has low life cycle CO_2 emissions. Given the high proportion of CO_2 emissions from the transport sector, these reductions could make a significant contribution to climate change goals.

6.64 In the aviation sector, there do not appear to be any alternative fuelling options to kerosene, even in the medium-term. Hydrogen may offer possibilities in the very long term, but there are significant technical barriers – such as on-board storage of hydrogen in aircraft – to be overcome.

Costs

6.65 As highlighted previously, the cost per tonne of carbon saved from efficiency improvements to date is probably negative, but there is currently little detailed data available, and this issue should be explored further. Hybrid vehicle technology also looks likely to be cheaper when it moves into mass production. The large technical and commercial uncertainties surrounding new fuelling options makes it more difficult to forecast the costs of the longer-term technical possibilities. But fuel cell vehicles offer good prospects as a long-term CO_2 reduction measure, though the timescale for their becoming cost effective depends on progress with the significant remaining technical hurdles.

Innovation

6.66 There is broad consensus amongst motor manufacturers and commentators that hydrogen fuel cell vehicles will replace the combustion engine by 2050. The use of hydrogen would require the development of a new infrastructure to make, transport and store hydrogen. However it is possible to envisage an evolutionary path towards a hydrogen network – for example gradual upgrading of the natural gas network to make it hydrogen friendly, whilst continuing to produce hydrogen locally for (initially small) early markets. This may avoid the need to develop an entirely new parallel infrastructure from scratch. Any major changes to fuelling technologies or infrastructure would need to mesh with international developments.

6.67 The use of ethanol from biomass in advanced hybrid engines is one of the few configurations which could come close to the low carbon potential of fuel cells. In the short term, the use of biofuels in transport is constrained by the availability of suitable agricultural land, crop yield and the demand for biomass for other uses. From UK production, biofuels could provide niche markets and contribute to wider markets, but are unlikely to supply most UK road transport fuel. In the longer-term, new technologies that widen the range of crops suitable for liquid fuels production could change this.[26] Wider adoption would depend on the development of these options and/or expansion of the international market.

Synergies or conflicts

6.68 **Security of supply.** Diversity in energy is currently focussed on the electricity generating sector, with the transport sector largely dependent on oil. Fuel switching in road transport would significantly reduce our dependence on oil. However, a wide variety of new transport fuels need not be sought, since additional distribution infrastructure could have additional resource costs and diversity can be sought in the origins of fuels rather than the type of fuels.

6.69 **Environmental.** The move to low carbon fuels would significantly reduce local air pollutants. Hybrid and fuel cell technologies would reduce vehicle noise. While hydrogen could potentially provide an alternative to kerosene in aviation, the impact of additional water vapour emissions at high altitude may also have significant global warming potential.

6.70 As Table 6.1 shows there is in all cases considerable uncertainty about the cost of the various options. Technologies which may be very cost effective in some circumstances may be less advantageous in others, and in all cases the precise path of future cost reductions is in doubt. All the technologies and options which show negative carbon abatement costs in 2020 – most obviously energy efficiency, CHP and wind – are obvious candidates for a "no (or low) regrets" approach. However, some technologies which have the potential to reach this point by 2020 are not there yet, and even where resource costs are negative, some support may be needed to get things moving. Options which show a positive carbon abatement cost may also be worth pursuing, whether because of the longer-term potential, or simply because they may be needed in order to meet low carbon commitments.

[26] Specifically to enable bioethanol production from woody crops and vegetable wastes.

Table 6.1 Carbon abatement costs and potential contribution to carbon emission reductions for the leading low-carbon options

	Carbon abatement cost £/tC (2020)*		Potential contribution to carbon emission reduction		UK specificity
	Minimum	Maximum	2020 (MtC) **	2050 (MtC)	
Domestic energy efficiency	–300	50	15	30	Strong
Service sector Energy efficiency	–260	50	4	10	Strong
Industrial energy efficiency	–80	30	9	25	Varied
Transport energy efficiency	Probably negative	Needs to be assessed in detail	14	30	International industry
Large CHP	–190	110	3	5	Strong
Micro CHP	–630	–110	1	5	Significant, given UK gas dependence
Onshore wind	–80	50	1	5	International industry
Offshore wind	–30	150	8	>20 ***	Good prospects for UK specific developments
Marine (wave and tidal)	70	450	small	>20 ***	Good prospects for UK specific developments
Energy crops	70	200	3	10	International industry
Solar photovoltaics	520	1250	<1	>20 ***	International industry
Nuclear	70	200	7	>20 ***	International industry
Carbon sequestration	80	280	small	>20 ***	Good prospects for UK specific developments

* Based upon estimated cost ranges for 2020 (see Annex 6).

** Approximate and taking into account practical constraints on build rates by 2020 for nuclear and offshore wind; that land use constraints limit the contribution from onshore wind; and assuming that the practicable potential for PV is constrained by the likelihood of continuing high cost in a 20-year timeframe.

*** A large proportion of electricity could be generated in this way by 2050, reducing emissions by at least 20 MtC compared to using gas. The potential increases substantially if electricity (or hydrogen made from it) is used to meet demands currently met from other sources, such as for transport.

General notes to Table 6.1:

Costs per tonne of carbon saved for all large-scale supply technologies assume that CCGT generation is displaced. Cost range for CCGT in 2020 is 2.0–2.3 p/kWh. This assumes that capital costs for CCGT decrease slightly and efficiency improves slightly, as widely predicted (see Annex 6), and gas price increases to a range of 0.85–1.0 p/kWh.

Emissions saved by displacing CCGT are assumed to be approximately 0.1 kgC per kWh.

Emissions savings per kWh are assumed to be 1 for renewables, nuclear and energy efficiency, 0.9 for C&S and 0.4 for CHP.

Cost ranges for all power generation technologies include grid connection charges. The value of energy displaced by offshore wind and wave energy is reduced by up to 0.5 p/kWh to make allowance for the remote nature of these sources. Renewables costs allow for the inherent generation costs of intermittency – reflected in the relatively low load factors for these technologies. Additional system costs due to intermittency are not explicitly included because compared to generation costs these are very small, and make an insignificant difference to the inherent uncertainty surrounding estimates of generating costs.

"Deeply embedded" generation – PV and micro CHP – is assumed to displace end use rather than central station electricity. The costs of energy displaced therefore include an element of transmission and distribution costs, assumed to add 1.5–2.5 p/kWh to generating costs. The cost range of energy displaced for these options is therefore 3–4.8 p/kWh.

The energy efficiency costs are based on the work of the Government's Inter-Departmental Advisory Group on Low Carbon Options. A very wide range of measures is incorporated (see PIU 2001b). The cost range reflects the uncertainty about the extent to which cost effective measures are not adopted because of either market failure or hidden implementation costs (see Annex 6).

7. A PROGRAMME FOR A LOW CARBON FUTURE

Summary

This Chapter draws on the analysis of Chapter 6 to develop a programme of action leading towards a low carbon future. A package of policies is required to:

- internalise externalities and create a level playing field for low carbon options;
- maximise synergies with other policy goals, such as energy security;
- support R&D, drive innovation and create new low carbon options; and
- remove or ameliorate specific barriers and market failures.

Energy efficiency should be at the centre of low carbon strategies – much can be achieved at very low cost. A step change in energy efficiency is needed, with a new target of 20% improvement in household energy efficiency by 2010, and a further 20% improvement by 2020.

The wide range of renewable energy technologies represents the most important priority among zero carbon supply options. Institutional barriers need to be overcome if the UK is to meet its current target of 10% of electricity met by renewables by 2010. A new target of 20% should be set for 2020.

Nuclear power could be an important, zero carbon option for the future. The need now is to take a range of actions which keep the nuclear option open.

Combined heat and power (CHP) is an important low (but not zero) carbon option and needs further assistance to overcome institutional barriers.

Carbon capture and sequestration (C&S) could be important in allowing greater use of fossil fuels in a low carbon world. UK efforts to reduce uncertainties surrounding C&S are urgently needed.

Transport energy use is a major issue in the long term. Policy should support improved energy efficiency in vehicles, development of long-term low and zero carbon options and reduction in aviation demand.

Government needs to keep asking what alternative strategies should be put in place to promote low carbon futures if energy efficiency, renewables and CHP deliver less, or are much higher cost, than currently expected.

7.1 This Chapter draws on the analysis of Chapter 6 to develop a programme of action leading towards a low carbon future. A package of policies is required to:

- internalise externalities and create a level playing field for low carbon options;
- maximise synergies with other policy goals, such as energy security;
- support R&D, drive innovation and create new low carbon options; and
- remove or ameliorate specific barriers and market failures.

7.2 The next section reviews each option in the light of the analysis in Chapter 6 of potential, costs and benefits, and makes recommendations concerning the policies that would best develop each option for the future. Chapter 3 explains the general context of policy-making for low carbon futures – in particular the need for a blend of market-based and regulatory instruments. While many of the policies outlined below are concerned with targeting low carbon options directly, in the longer-term carbon valuation should become more important.

7.3 The overall approach to innovation is an important part of this programme. The Chief Scientific Adviser's Energy Research Review Group[1] has considered energy technology development needs, and has placed climate change objectives at the top of its list of drivers for technology change. It has also suggested that there is a strong case for raising the level of publicly funded low carbon energy research, together with the possible establishment of a new Energy Research Centre (considered in Chapter 8). It recommended that a range of basic and applied research, development and demonstration activities is important to the majority of technologies, but emphasised that there should be sufficient focus on the basic research from which step change breakthroughs are more likely to come. The CSA's review has proposed six key areas in which increased levels of funding could have a particularly significant impact for new R&D. They are energy efficiency; carbon sequestration; wave and tidal power; solar PV; hydrogen production and storage; and nuclear waste. These priority areas fit well into the programme recommendations made in this review. **DTI and OST should take steps to increase the level of**

[1] Chief Scientific Adviser (2001).

funding for low carbon energy R&D. The priority areas of the Chief Scientific Adviser's Research Review Group represent a good starting point.

Energy efficiency

7.4 Energy efficiency has the closest match with all the major sustainable development objectives. It can assist the economy as well as help to achieve social and environmental goals.[2] Our examination of the potential has shown that the long-term scope for improved energy efficiency is large (see Chapter 6); and our assessment of potential futures (Chapter 5) is that increasing the rate of energy efficiency improvement is very likely to be needed to deliver a low carbon economy. It can be supported on the basis of least cost and "minimum regrets" and can become the centre of a new energy policy.

7.5 As in other areas of low carbon policy, energy efficiency policy should seek to improve economic viability further, encourage innovation, and address market failures. Pricing carbon will assist the first of these goals (see Chapter 3). But much can be done even with prices at current levels. Market failures and other barriers that constrain the adoption of energy efficiency are set out in Annex 5.

7.6 Energy taxes as well as carbon taxes can encourage energy efficiency. The rates and bases of energy taxation vary markedly between different types of uses, transport, heat and power, domestic and industrial. Different treatments are to be expected since taxes fulfil a variety of purposes, including revenue raising. In the long-term, if policy goals are to be achieved, energy prices should be increased to reflect the environmental costs of energy use. Existing taxes should, over time, be looked at with this end in view.

7.7 Multiple policy interventions are likely to be required to achieve energy efficiency objectives, with a mix of regulations, negotiated agreements and incentives. The strategy for Government should be to identify the agents best placed to deliver energy efficiency in each sector and then:

- agree a long term framework for targets and policy;
- use regulation and targeted financial mechanisms to give strong incentives; and
- support technical and market innovation from research through to implementation.

7.8 Many energy efficiency policy instruments have been introduced in recent years. In many cases the priority is now to evaluate their progress and to enhance them with new resources, rather than seek new and different approaches.

7.9 Government should affirm the importance of faster improvement in energy efficiency. The review has considered the case for setting an aspirational target for energy efficiency improvement across the economy. While this would send a strong message, there are difficulties in defining and measuring energy efficiency at this aggregate level. On balance, setting targets for each sector will prove a better approach. **DEFRA should develop energy efficiency indicators, targets and monitoring mechanisms for each sector of the economy.**

7.10 Energy efficiency programmes have concentrated largely on deploying cost-effective technology. The role of innovation in long-term energy policy requires a shift of emphasis. It is a common misconception that energy efficiency is always "low tech". This has not been true in the past, and certainly will not be in future. For example, developments of advanced control systems, micro-turbines, fuel cells and smart metering will be very important. Public funding

[2] PIU (2001b).

for R&D expenditure on energy efficiency in the UK is very low, although evidence from overseas, indicates it can be more cost-effective than R&D into energy supply.[3]

Household energy efficiency

7.11 The household sector has the most consumers and the biggest market failures. It therefore needs particular attention. **DEFRA should develop a Strategy for Home Energy Efficiency to set out a clear, long-term framework. This should include an aspirational target for home energy efficiency of 20% improvement by 2010 followed by a further 20% improvement by 2020.**

7.12 The analysis of possible futures indicates that targets for a 20% improvement by 2010 and a further 20% in the following decade seem suitably challenging, but deliverable. At expected rates of growth in energy services, this might reduce household energy demand by 10% in each decade. This is broadly consistent with the goals of the UK Climate Change Programme. Demand reduction targets would be simpler to monitor. But targets for genuine efficiency improvements are preferable, and there is data that can be used to monitor these.[4] The strategy will need to set out in detail how the target will be defined, delivered and monitored. It is clear that new policy instruments, or amplification of existing instruments, will be needed.

7.13 If domestic energy efficiency can be increased in line with the targets of successive 20% improvements in energy efficiency, then energy savings averaging £5 billion annually can be released.[5] The net gain to the economy is less than this since investments are needed to make the savings. In very broad terms the net gain in a year would reach about 0.25% of GDP by 2020.

7.14 Different policy instruments will be needed, building on existing approaches. These should include:

- Government and energy supplier programmes;
- capacity building in local authorities, voluntary organisations and energy efficiency installers;
- Building Regulations and product standards;
- incentives to action from "home movers"; and
- incentives to encourage energy services markets.

Government and energy supplier programmes

7.15 The Government's aim is self-sustaining energy efficiency markets, including energy services, where the energy supplier delivers both energy units and energy efficiency. This will require major changes in the culture of both suppliers and customers, so may not be achieved rapidly. Medium-term policy will need to follow a twin track approach:

- an incentive framework for viable energy services; and
- programmes to deliver activity in the current market structure.

7.16 The Climate Change Programme target for emissions reduction of approximately 5 MtC/year by 2010 is not matched by long-term fully funded policy measures to deliver the level of investment needed. A long-term strategy and target will go some way to addressing this problem, but enhanced programmes will be needed too.

7.17 Energy efficiency work in vulnerable households ("Warm Front" in England and the equivalents in the devolved administrations) has

[3] US National Academy of Sciences (2001).
[4] For example BRE (2001) sets out an approach for assessing the contributions that improved insulation and heating system efficiency make to household energy demand changes, and the Market Transformation programme has relevant data for appliances.
[5] PIU (2001c).

a strong social focus, and therefore should continue to be supported by public expenditure.[6] There are particular problems addressing the fuel poverty of the lowest income households in "hard to heat" homes with solid walls and no access to gas. It is right to give greater attention to these homes, including through innovative measures such as micro-CHP.[7]

7.18 Obligations on energy suppliers, such as the Energy Efficiency Commitment (EEC), operate over a wider range of social groups. They are expected to deliver the largest carbon savings in the domestic sector and have been shown to be cost effective.[8] These programmes will operate in a revised and expanded form from 2002 to 2005. In order to reduce uncertainty in the industry, DEFRA and DTI should make an early commitment to extending the EEC from 2005 to 2010, on the basis that it would, at a minimum, be kept at existing levels. Subsequently, and by the end of 2003, the Departments should review the scale of the commitment for this additional period in the light of the initial experience.

7.19 Decisions on the future level of EEC will need to consider the financial costs and benefits. The costs of delivering the programme will fall on household gas and electricity consumers. It is estimated that the level of EEC proposed for 2002-2005 will raise prices by 1.2% over that period. The estimated benefits in reduced energy costs will rise to about 1.6% of bills by 2005 and last for the lifetime of the relevant measures (8-40 years).[9] However, the benefits will not be uniformly spread and households that are not included in any schemes will be losers. The net effect will be a gain in economic efficiency and welfare, but also a cross-subsidy. Both effects will tend to grow if the programme is expanded.

7.20 Energy supplier programmes could risk reducing incentives for investment by householders themselves as householders might choose to delay their own investment decisions. Programmes need to be designed to encourage innovation and greater householder involvement. The framework of the EEC allows energy suppliers to improve their profitability by delivering their obligations more efficiently than their competitors. This is a driver for commercial innovation. Incentives for delivery through energy services will be increased. In the medium-term, further innovation might be achieved by including the domestic sector in emissions trading through a modification of EEC.[10]

Capacity building and co-ordination

7.21 Expanded energy efficiency programmes increase the challenge to overcoming the barriers to public information, understanding and trust. Exhortation alone has not historically been very effective; more targeted approaches are needed. Government and supplier schemes will need to be supported by other activities – co-ordination, raising consumer awareness, and individual advice. These need to be managed locally. In particular, there needs to be active involvement from the key agencies – including health, social services and social housing providers – working with vulnerable households.

7.22 Local Government is well-placed to act as a facilitator of local action, working with other agencies. Energy efficiency needs to be brought into the mainstream of local authority work. Local authorities will need the powers, duties and funding necessary to play a bigger role, including in energy service companies. DEFRA's review of Local Authority energy efficiency activity will be important in this respect. Local

6 DTI, DEFRA (2001).
7 DTI, DEFRA (2001).
8 National Audit Office (1998).
9 DEFRA (2001a).
10 PIU (2001c).

activity could draw on the network of Energy Efficiency Advice Centres. These already provide personal advice, but could play a wider role in local schemes. Other voluntary sector organisations could also play an enhanced role in innovative approaches, but they are generally under-funded.

Building and product standards and policies

7.23 Policy instruments should seek to limit the extent to which consumers make decisions about unfamiliar technical choices. Consumers do not want to buy homes or appliances that have high running costs and are environmentally damaging. They expect Government to set minimum standards and generally seem willing to accept any small additional purchase costs that result.[11]

7.24 A large proportion of energy is used to light and heat buildings, and therefore a low carbon economy will require low carbon buildings to become the norm. Plans for further improvements will require changes in construction, initially to bring our standards up to those of other northern European countries. While regulatory changes which are well signalled can give greater certainty to business, regulation should allow designers and builders freedom in how to deliver a given performance. The performance levels specified will depend on Regulatory Impact Assessments. These should include an allowance for carbon value and cost reduction through market transformation (see Chapter 3). Within this framework, standards are likely to move progressively to require new homes to meet very low energy requirements for space heating.

7.25 If major changes were to be brought in too quickly, there would be very real concerns about the construction sector. Detailed consultation with the industry and other stakeholders will be needed. A balance needs to be found that promotes innovation, but at an acceptable rate. DTLR should review the costs and benefits of moving to "near-zero space heating" buildings well in advance of the next review of the energy efficiency component of Building Regulations.

7.26 A long-term framework also needs to consider the role of renewable energy, including solar water heating, especially in electrically heated buildings. But building integrated photovoltaics (BIPV) have the most potential. These are currently expensive, although they are already economic as an alternative to expensive cladding.[12] Analysis indicates that BIPV will approach cost-effectiveness sometime after 2020 (see Annex 6). With an allowance for the benefits of carbon reduction and innovation, inclusion in all new buildings might be justified somewhat earlier.

7.27 Building Regulations also play a role in the improvement of the existing building stock. They already contain provisions relating to new boilers and glazing.

7.28 For appliances, energy efficiency should be part of integrated product policy. The EU is the appropriate level to set standards on traded goods. Energy efficiency labels are currently required on all the major appliances, and standards are in place for boilers and refrigerators. The Framework Directive promised in the EC Energy Efficiency Action Plan[13] provides the appropriate context for future action. DEFRA should take the lead in Europe in pressing for a more comprehensive programme of cost-effective EU energy efficiency standards and negotiated agreements. This will require collaboration with European partners. The programme should pay particular attention to new products in which market growth is expected, like digital TV equipment and air-conditioning.

[11] PIU (2001d).
[12] ETSU (1998).
[13] Commission for the European Union (2001b).

Home movers

7.29 Moving house provides an opportunity for improving energy efficiency, as renovation work and new financing are more likely at this time. Home movers may undertake energy efficiency work which is otherwise considered too disruptive. Financial incentives of various kinds are potentially most effective at this point. The private sector should be encouraged to support "home mover" energy efficiency. EEC programmes may be a useful source of finance. The rules and administration of EEC should allow energy suppliers to deliver their targets in this way. One further option for financing is banks and building societies. DEFRA's Strategy for Home Energy Efficiency should consider the option of a negotiated agreement with the finance sector to reduce the cost of financing energy efficiency measures by funding them as part of mortgage offers.

7.30 Market based measures of this type should form the basis of Government's approach to home movers. A more controversial option would be to regulate performance levels for existing homes, for example a requirement that all homes should be brought up to a level achievable with cost-effective measures, but only at the point of sale or re-renting. This approach would have major implications for the housing market and enforcement agencies. It should not be adopted at this stage. However, it might be reconsidered in future if more market-oriented policies do not prove successful.

Energy services

7.31 Many of the barriers to energy efficiency might fall if suppliers marketed energy services. At the same time the level of Government intervention needed to promote energy efficiency might be reduced. But establishing energy services businesses is risky. There can be no guarantee that household energy services will ever be commercially viable. But supply market liberalisation provides new opportunities. In the early years, the emphasis has been on cost reduction and customer acquisition and retention, but as costs converge, suppliers are beginning to offer more added value services. And new products, such as micro-CHP systems, may provide opportunities for establishing energy service offers.

7.32 Government should not try to design commercial packaging for energy services. Instead the policy framework should set the right incentives for commercial energy services. The new arrangements for the EEC from April 2005 provide increased incentives. However, there are structural issues that could also be addressed. It is not helpful to energy services for long-term customer/supplier relationships to be treated as inherently anti-competitive. In particular, potential energy services suppliers find the "28-day rule" – which allows customers to change supplier at 28 days notice – a regulatory barrier. For contracts that include longer-term energy efficiency financing (but only for those contracts) Ofgem should modify the 28-day rule, with other approaches used to protect customers against excessive charging.

Non-domestic energy efficiency

7.33 Businesses have a key role to play in delivering climate change goals. To do this they need clear signals that Government will encourage energy efficiency innovation and implementation. Energy efficiency in larger and energy intensive companies is being addressed. The recent formation of the Carbon Trust, enhanced capital allowances, the Negotiated Agreements linked to Climate Change Levy reductions and the Emissions Trading Scheme (ETS) are important new initiatives. The Negotiated Agreements and Emissions Trading give strong incentives to many of the most energy intensive industrial sectors.

7.34 The success of the ETS could be important in ensuring that UK business plays an early role in international carbon trading, linking UK emissions reduction to a liquid market and a global price. Companies should continue to be encouraged to join the ETS in return for commitments to additional carbon reduction measures.

7.35 Given the barriers to energy efficiency investment, the Negotiated Agreements form a key part of the package. They are expected to deliver a large fraction of the total carbon savings in the industrial sector.[14] Ideally, in the longer-term, the agreements should be structured to deliver emissions reductions up to the level which is cost-effective at the appropriate shadow price for carbon (see Chapter 3).

7.36 Greenhouse gas emissions and energy use are important issues for environmental reporting. Ofgem, DEFRA, the Environment Agency and the Electricity Association are developing "key performance indicators" for the energy sector. DEFRA has already produced greenhouse gas reporting guidelines for business. An earlier PIU report[15] recommended that Government should consider the extent to which voluntary measures and the proposals from the Company Law Review will lead to a level of reporting which meets its objectives.

Commercial buildings

7.37 In the commercial sector energy costs are generally a lower part of total costs than in industry, so energy price signals are weaker and other instruments are needed. There are some similarities with the household sector. DTLR should develop Building Regulations to deliver a phased transition to low energy commercial buildings, including consideration of the use of renewable energy such as photovoltaics. Major appliances and common equipment types should be addressed with the approach to labelling, standards and Negotiated Agreements set out above.

7.38 Tenanted buildings are a particular issue in the commercial offices sector. A bigger role is required from large commercial landlords and property managers. This could include energy audits at each new letting or rent review with a requirement for action if a good practice threshold is not achieved. The Government already supports a proposed EU Directive on the energy performance of buildings, which will provide the basis for the necessary audit and certification.[16]

7.39 Energy services offer a way forward in the commercial sector, possibly more quickly than in households. But the drivers are weak. The legislative framework allows for EEC outside the domestic sector and extension to the commercial sector should be considered.

7.40 Further policy measures are needed to induce cost-effective energy efficiency measures in commerce. The Government should give early attention to this area and consider a range of options.

Small and Medium-sized Enterprises (SMEs)

7.41 The scope for energy efficiency savings in SMEs is large. The problems of smaller SMEs are very similar to those of the domestic sector. They face more barriers in implementing energy efficiency than other businesses, in particular in skills, access to capital and control of the buildings they occupy.

7.42 Energy efficiency messages might be communicated effectively as part of broader SME advice and support activities. The PIU report on resource productivity[17] sets out proposals to develop a resource productivity strategy for small businesses, including energy

14 DETR (2000).
15 PIU (2001b).
16 Commission for the European Union (2001e).
17 PIU (2001b).

efficiency, in conjunction with the small business community. This will address:

- advice services, provided wherever possible through a "one-stop-shop" approach;
- linking advice to installation; and
- an enhanced role for regional and local bodies.

Public sector

7.43 Government needs to lead by example. Public sector buildings are major energy users. Targets for emissions reduction are set out in the Climate Change Programme. These are important goals. The use of Government procurement to improve environmental performance more generally is considered in the PIU report on resource productivity.[18]

7.44 Government could play an important role in establishing energy services markets by purchasing its own energy in this way. Procurement procedures could also support high standards of energy efficiency for office equipment. Life cycle costs, rather than minimum capital costs, are already the basis of public procurement guidance.[19] However, these do not reflect the environmental costs of energy use or the potential for the public sector to contribute to market transformation.

7.45 As part of Government's leadership role in energy efficiency, HM Treasury should include departmental energy efficiency targets in future Public Service Agreements, and the Office of Government Commerce should develop model energy services contracts for use in tendering throughout the public sector.

Renewables

7.46 Analysis in Chapter 6 suggests that renewables present the most flexible supply option in terms of carbon reduction potential and compatibility with other goals. Renewables are, therefore, likely to make a substantial contribution to the low carbon programme in the UK. They represent the most important new options that need to be made more commercial in order to ensure that the UK can put itself on a path to the low carbon future at an acceptable cost.

The current renewable energy strategy

7.47 The current renewable energy strategy is made up of the Renewables Obligation (RO), capital grants, and wider support expenditure. The Obligation[20] requires licensed electricity suppliers to buy an increasing percentage (measured in TWh) of their supply from eligible renewable resources until the share reaches 10% in 2010, subject to the extra cost being not more than 3p/kWh. They do this by buying Renewables Obligation Certificates (ROCs) and presenting them to Ofgem as proof that they have met their obligation.[21]

7.48 Capital grants are designed to meet part of the cost of the more expensive technologies, offshore wind and energy crops, so that they can compete in the RO. There is a total of £230m of capital grants available until 2005.[22] It is expected that, as a result of the RO and the capital grants, the costs of offshore wind and energy crops will fall considerably over the next few years, thereby reducing the need for future capital grants. Other technologies, such as offshore wave, tidal stream and photovoltaics, will then probably become the next generation

18 PIU (2001b).
19 HM Treasury, DETR (2000).
20 DTI (2001g).
21 ROCs are issued to renewable generators by Ofgem.
22 PIU (2001a).

of technologies which would benefit from access to grants. There will therefore be a continuing need for capital grants after 2005. DTI should review the extent of the need for capital grants for renewable energy after 2005. This need should be assessed in time for the 2004 Spending Review.

7.49 Finally, a total of £55.5m is available for research and related activities into renewable energy over the next 3 years.[23] The Chief Scientific Adviser's review of energy research recommends that, in this and other areas, spending over the longer-term should be brought in line with the UK's nearest EU competitors.

7.50 The current mechanisms are primarily, although not exclusively, focussed on renewable electricity technologies. While a reasonable proportion of the available capital grants are eligible to household or community schemes, such schemes cannot access the extra value of ROCs unless the electricity is sold to a licensed supplier. DTI should undertake further analysis of the possibilities and benefits of mechanisms or schemes to promote renewable energy producing heat, plus household and/or community projects, especially those which in practice fall outside the Renewables Obligation.

How much investment is feasible?

7.51 Chapter 6 established that the resource base for renewable energy is very large. The main technical consideration is the feasible rate of deployment. In order to get more than 20% of electricity from renewables by 2020, build rates for the leading options would need to be at levels never before seen in the UK. Onshore and offshore wind would need to be installed at a rate of between 1-2 GW per year in the period 2010-2020.[24] This would be a challenge, but 1.5 GW and 1.6 GW of onshore wind was built in Germany in 1999 and 2000 respectively, and a further 1.2 GW was installed in the first eight months of this year. Build rates of 1 GW per year were also seen Spain in 2000, and 600MW in Denmark in the same year.[25] There is also a potential need for upgrading of electricity transmission from Scotland if marine and wind resources from the far North and West are to be exploited. The DTI's recent proposal to examine the feasibility of an offshore cable along the West Coast is an important first step (see also paragraphs 7.139-7.143).

The cost of the investment

7.52 Cost can be assessed in two ways: the implied cost per tonne of carbon over the lifetime of a programme of investment; and the burden on the current generation of consumers if they are required to support the investment.

7.53 While renewables do not generally do well on the criterion of the current cost per tonne of carbon, the potential for future cost reduction is large.[26] This suggests that the objective should be to create markets that enable "learning by doing"[27] in order to secure economies of scale and reduce costs. At the same time, R&D should be stimulated so as to encourage step changes in renewables technologies which could significantly reduce their costs. In this case, investment today buys a set of options for the future. Uncertainties make it difficult to calculate rates of return to this kind of option investment. Preliminary work of this kind suggests that renewables costs need to fall quite rapidly (as Chapter 6 suggests is possible) if such investment is to be competitive with other low carbon options.

23 PIU (2001a).
24 This takes account of low load factors.
25 www.windpower-monthly.com
26 Analysis of long-term renewables costs is briefly described in Annex 6. See also PIU (2001a).
27 IEA (2000).

7.54 The RO now aims to ensure that by 2010, 10% of electricity is sourced from renewable energy, providing the costs are acceptable. This implies a maximum increase of up to 4.5% on the average domestic customer's prices by 2010, using the buy-out price as the indication of maximum cost.[28] The cost will be lower than this if supply develops to meet demand and the buy-out price is not used. The impact on industrial consumers will be greater than this, perhaps double the domestic burden in percentage terms.

7.55 If there were a target of more than 10%, then this would increase costs to consumers, though it would reduce the costs of meeting the 10% target.[29] The exact cost will depend on the prospects for reducing the costs of supplying renewable energy and the size of the overall demand for electricity. Detailed analysis of the costs of meeting targets in the 20%-30% range has been carried out. This suggests that the total cost of meeting a 20% target in 2020 would be around a 5%-6% addition to household electricity prices.[30]

The balance between technologies

7.56 There is more than one approach to renewables development. Two extreme cases would be:

- a very cautious approach would aim to open up a few renewable options at minimum cost, but avoid significant deployment if costs were higher than the cheapest alternative energy sources; and
- an ambitious approach would aim to open a wider range of renewable options and seek to maximise deployment of the lowest cost renewables, even if their costs were for the time being higher than alternatives.

7.57 In practice, the cautious option is difficult to sustain. If costs are to be brought down by the learning process, the full establishment of renewable options requires a significant level of deployment. This is a system issue, not just a question of stand-alone investment. For example, if offshore wind is to be developed, investment is needed in associated infrastructure (like specialist barges). This requires much more than the demonstration of a few separate offshore plants.

7.58 If renewable options are to be genuinely available for the future, it will be necessary to show that renewables can be deployed on some scale – exactly how far and how fast this deployment should be pushed depends on the evolution of the costs of each technology. This requires not only the development of infrastructure – i.e. the skills and equipment necessary to deploy technologies – but also an altered electricity network culture whereby "new" technologies, renewables or otherwise, become accepted as "normal".

7.59 Maximising deployment of cheaper technologies would contribute more to short-term carbon emission reductions, but at the expense of having fewer options for the longer term. Opening up a wider range of options, including some deployment for each of them, suggests higher costs for the present generation. It also means – given limits to acceptable total programme costs – less short-term contribution to carbon emission reductions. In practice, neither extreme (cautious or highly ambitious) seems desirable; by 2020 policy needs to aim both for significant deployment of the cheaper renewables, but should not neglect the development of a wider range of future alternatives.

A new renewables target

7.60 Continuing financial and political support, coupled with institutional change, will be needed until such time as the costs of different

[28] OXERA (2001).
[29] OXERA (2001).
[30] Derived from OXERA (2001).

forms of renewable energy are competitive with the cheapest alternatives. There is an established programme of financial support in place to 2010 for renewable energy through the RO,[31] and a series of capital grant programmes to 2005. The RO has not yet been launched, and it is too early to judge its success or otherwise. It will be reviewed in 2006/7. Around that time other developments, such as European Directives and international climate negotiations should also be reviewed.

7.61 Should the targets be expanded beyond 2010? The arguments against a larger target are:

- the RO is only just coming into effect so it is too early to say what the costs of a new target would be;
- the UK would be unwise to make a firm commitment to a larger target for 2020 until it knows the extent of its international obligations;
- most renewables are currently an expensive low carbon option, so it would be better to meet any commitments we have by adopting lower cost options first; and
- existing approaches might conceivably establish options capable of meeting at least 20% of all the UK's electricity needs.

7.62 The arguments for a larger target are:

- a target is the obvious and clear means of announcing a long-term commitment;
- the industry needs greater assurance that demand for renewables will continue to grow after 2010 than is currently on offer: if this is not forthcoming the impetus of shorter term development to 2010 may falter;
- the UK Government needs to continue to support options which have a particular applicability in the UK environment, since nobody else will;
- it would allow deployment at a rate which enables learning to occur in order to reduce costs significantly and thereby fully establish a wider range of renewables options;
- it would act as a stimulus to R&D;
- it would reduce the cost of meeting the 2010 target;[32] and
- the need to develop the infrastructure required to deploy these investments.

7.63 The balance of the argument favours making a firm commitment to a larger target for 2020 in the near future.

Recommendation:

- Any process of target-setting for almost 20 years ahead is inevitably ambitious, given the uncertainties about costs and other market and political developments. **In order to encourage a range of renewable options, and maximise the chances of rapid and long-term learning and cost reductions, DTI should immediately set a firm target of 20% of electricity to be supplied from renewables for 2020.** While this target is best presented in percentage terms, uncertainty about the level of electricity demand means that in practice the target should be set in physical terms. A further 39TWh is a reasonable target (equivalent, over the further ten years to 2020, to the RO up to 2010). This will turn out to be 20% of electricity supply if energy efficiency policies work to the extent that electricity demand in 2020 is mid-way between a business as usual future and the most environmentally sustainable of our scenarios. If energy efficiency programmes are as effective as hoped, this target might turn out to be more than 20% of electricity supply.

[31] The RO actually lasts for 25 years, up to 2027, but the percentage target does not rise after 2010.
[32] OXERA (2001).

What mechanisms should be used?

7.64 It would be imprudent for the Government to commit itself to the policy instruments that could deliver larger post-2010 targets until it is clear how well the main current instrument – the RO – is operating. New mechanisms and approaches may or may not be needed. The RO combines an obligation with competition, and a limit on costs to consumers. Existing mechanisms might therefore be built upon to deliver more substantial long-term targets. However, there are several uncertainties about the future development of renewables which could affect the type of mechanism required – for example, the rate of deployment of renewables, the rate of fall of costs of renewables, and the extent to which institutional barriers are overcome. It is too early to specify a particular mechanism. The RO is due to be reviewed in 2006/7. By 2008, **DTI should establish the renewable energy support mechanisms to ensure that the 2020 target of 20% is met.**

7.65 If the UK was to introduce a wider scheme for carbon valuation, the need for a special scheme directed at renewables only would decline, though some continuing support for renewables would probably still be needed, perhaps on grounds of the associated learning effects.

Table 7.1: Questions which are frequently asked about renewable energy

Question	Answers
Doesn't intermittent power need costly back-up elsewhere in the system?	• While intermittents supply below 5% of electricity, the costs would be insignificant.[33] • Between 5-10% of supply from intermittents, the cost would be about 0.1p/kWh rising to 0.2p/kWh for 20%.[34]
Are systems with a high proportion of renewable energy secure?[35]	• Renewable energy poses no problem for system security. Indeed, such sources probably improve local security. • Distributed generation tends to improve strategic security.
Don't planning problems stop renewable energy projects getting off the ground?	• Because of their size, most renewable energy planning applications are considered by local authorities – unlike larger energy projects that are decided by the Secretary of State. • Average planning application success rate are the same as for most planning sectors, but this rate varies with technology and wind and biomass projects in particular have had problems in obtaining permission.
Aren't the costs of renewables high?	• Costs range from 2.5-3.0p/kWh – i.e. levels which are close to competitive – for electricity from landfill gas and onshore wind, through to 4-5p/kWh for offshore wind, 6-8p/kWh from energy crops and higher for tidal stream, wave and photovoltaics.

[33] Milborrow (2001).
[34] Milborrow (2001).
[35] Strbac and Jenkins (2001).

Table 7.1: Questions which are frequently asked about renewable energy – continued

Question	Answers
Aren't the costs of renewables high? (continued)	• But long-term projections show reduced costs so that some renewables are likely to be the cheapest low carbon energy source by 2020.
Isn't the scale of the contribution which can be by made renewables too small to make a real difference?	• Renewables are typically smaller than conventional technologies and individual generating units may range from a few KW to tens of MW. • But installation can be in large numbers. Offshore wind farms are typically in the 50-500MW range, with many such schemes planned in Europe. • 20 GW of onshore wind is already built world-wide, and the capacity is rising by 4.5GW/year.
Is there sufficient resource to meet demand?	• The UK resource is in principle more than sufficient to meet the UK's energy needs. • UK's wind and marine resources are the best in Europe.
Aren't the other environmental impacts of renewables harmful?	• Modern wind turbines are very quiet in operation. • Wildlife impacts are generally very small. • Visual intrusion is an issue for onshore wind.
Will technological progress be as rapid as has been assumed?	• Wind energy and biomass use is already widespread and these are low risk technologies. • Photovoltaics are a well-known technology, but require more R&D to capture cost-reductions. • Other technologies e.g. wave and tidal stream are still at the demonstration level, and are therefore more risky.

Institutional and market barriers to the greater use of renewable generation

7.66 The progress of new renewable generation is by no means straightforward; a number of barriers stand in the way of the deployment of these technologies – notably the prices received by intermittent generators in the electricity markets; the costs of connecting embedded generation to the network; and the working of the planning process. All need to be addressed urgently. If they are not it will not be possible to make enough progress towards even the existing renewables target.

7.67 The Appendix to this Chapter deals with these issues, and with investment in Scottish networks, in detail. It also contains detailed recommendations. In essence these are:

- Measures are underway which may help small generators with respect to NETA. **Ofgem should develop transitional arrangements to be ready to be implemented by January 2003 in case current measures are unsuccessful in**

helping small generators. Consideration should be given to potential legislation to move the agenda forward.

- For network investment for embedded generation, **Ofgem should ensure that that the recommendations of the EGWG are implemented by 2005. DTI should consider legislation to move this forward in the event of obstacles to progress.**
- **Ofgem should ensure that future changes to electricity trading and grid access arrangements do not discriminate unfairly against renewable and CHP generation.**
- For planning: detailed recommendations are presented in Chapter 8.

Energy from Waste

7.68 Energy from waste incineration is exempt from the Climate Change Levy, and it is currently proposed to include new, cleaner, energy from waste technologies, such as pyrolysis or gasification, as well as landfill gas, in the RO. Energy from waste incineration projects will count towards the 2010 target for renewable sources if this waste is derived from non-fossil sources, but will not be eligible for ROCs.

7.69 Although the potential for energy from waste is modest, energy from waste needs to be extracted as cleanly as possible. There are, however, thought to be a number of disincentives to the development of energy from waste. These centre on problems with the planning process (which are dealt with in Chapter 8). Other issues that need to be addressed include:

- stricter environmental standards, monitoring, reporting and sanctions – examples might be: more incentives to pre-treat waste prior to incineration; tighter limits on the proportion of the waste stream that goes to incineration; restricting new incinerators to an appropriate fixed proportion of the waste stream;
- strengthened commitment to creating transparency in local authority plans (waste contracts etc), while at the same time trying to ensure that local decision making is based on a clear understanding of risk and national need, and that facilities are appropriately sited to be able to exploit local industrial, commercial or domestic sector demand for CHP; and
- more support for R&D into new technologies; for example pilot schemes for gasification, pyrolysis and anaerobic digestion, enabling the environmental effects of new techniques and treatments to be fully understood.

Nuclear power

7.70 As with renewable technologies, this section considers: the role which nuclear power might play in a low carbon economy; the balance of interest in the different sorts of technologies; the case for government intervention; the mechanisms which might be used; and the barriers which currently stand in the way of new investment.

7.71 Nuclear power offers a zero carbon source of electricity on a scale which, for each plant, is larger than that of any other option. If other low carbon options were to prove difficult to develop, then the case for using nuclear power would be strengthened.

7.72 A decision whether to bring forward proposals for new nuclear build will lie with the commercial sector, and so would need to meet private investors' criteria. As outlined in Chapter 6, nuclear power will probably remain more expensive than fossil fuelled generation, though current development work could produce a new generation of reactors in 15-20 years that are more competitive than those available today. Nowhere in the world have new nuclear stations yet been financed within a liberalised electricity market. But, given that the Government sets the framework within which commercial choices are made, it could, as with renewables, make it more likely that a private sector scheme would succeed. Fully liberalised energy markets are still relatively new, and so it is too early to say whether or not new build might be financed in such a market.

7.73 Nuclear power based on fission is a mature technology, and there is a well-established global industry, with nuclear stations currently being built in some countries. In this it differs from renewables where support is justified on the grounds that they are nascent industries, needing support if they are to fulfil their potential to help with the long-term carbon problem.

7.74 The general approach taken in this review is that, if there is to be public support, the aim should be to try to create options which are both flexible in their deployment, and which offer new prospects. The desire for flexibility points to a preference for supporting a range of possibilities, each of which could be abandoned, should it fail to meet its promise. The desire for new options points to the need to develop new, low waste, modular designs of nuclear reactor, and new types of renewable and decentralised energy, rather than to public support for a large and inflexible programme. There is no current case for public support for the existing generation of nuclear technology.

7.75 There are, however, good grounds for taking a positive stance to keeping the nuclear option open. The reasons relate to possible future needs if existing approaches both to low carbon electricity generation and energy security (see Chapter 4) prove difficult to pursue cheaply enough. At present, the lead time from announcement of a proposal to build a new nuclear station and its commissioning would be long: the aim should be to ensure that if nuclear were to be supported some time in the future, the lead time would have been reduced substantially. DTI and DEFRA might consider what realistic lead times currently are for new nuclear build, and the scale of reduction that might prove possible should the recommendations in this section be followed. Keeping the nuclear option open also means maintaining an adequate skills base both for R&D and to ensure sufficient personnel to staff new nuclear stations.

7.76 The main reason why the option will still be open, at least for some years, is that the nuclear industry is an international one, using designs which have been developed to meet circumstances in many countries. Nuclear power stations are still being built, notably in East Asia. More than most technologies, nuclear power station designs are developed to be suitable for a wide range of countries, even though substantial technological knowledge (including regulatory knowledge) is needed to transplant them to individual countries. The availability of nuclear design of international origin is not going to change for some years to come. But two actions are needed now to maintain the necessary UK presence:

- the DTI should contribute to the international process of developing radically improved reactor designs, engaging with others in the development of new low cost, low waste designs (we note that the Government's objectives already include the important aims of promoting the adoption of safe and secure new reactor designs in all countries which choose in the future to build new nuclear plant); and
- DTI is currently sponsoring a Nuclear Skills Group to assess needs in the nuclear industry, including the need to maintain intelligent customer capability if we are to keep the nuclear option open. The DTI should ensure that UK regulators are adequately staffed to assess any new investment proposals, and are also pursuing opportunities for common international safety standards.

7.77 The DTLR's proposals for the treatment of major infrastructure projects within the planning system[36] (referred to in more detail in Chapter 8) address the current concerns which investors have concerning the planning processes applicable to large projects, including nuclear power plants. These processes have become long and cumbersome.

7.78 As the Government establishes a new framework for encouraging a low carbon economy, it should also aim to ensure that the nuclear industry is treated fairly in relation to the other alternatives. There are two recommendations:

- DTI and HM Treasury should ensure that any new nuclear build should benefit from any methods that will be used to value carbon and internalise the externalities of fossil fuel use. In addition, any new investment in existing stations that substantially raised nuclear capacity (and which would reduce carbon emissions) should be considered for similar treatment, subject to independent evaluation of any case made; and
- DTI should ensure, using independent evaluation, that the nuclear industry fully internalises its external costs, including risks such as waste cost escalation.

Both should be signalled early in order to provide incentives for the industry. The DTI should also take the necessary actions to keep the nuclear option open, as specified above.

7.79 The focus of public concerns about nuclear power are on the unsolved problem of long-term nuclear waste disposal, and perceptions about the vulnerability of nuclear power plants to accidents and attack. The problem of nuclear waste is mainly an historic one, since new nuclear stations would make only a small addition to the total (there would be a roughly 10% increase in the total stock of waste if all current reactors were replaced by new nuclear capacity). Nevertheless, these concerns overlay all the choices. Any move by Government to advance the use of nuclear power as a means of providing a low carbon and indigenous source of electricity would need to carry widespread public acceptance, which would be more likely if progress could be made in dealing with the problem of waste. It is important that Government should act to resolve the waste issue as soon as possible, learning as necessary from international best practice. Public acceptance, in waste and other areas, would need to be built on an open and transparent public debate.

- DTI and DEFRA should stimulate a public debate about nuclear power, and in particular on the trade-offs between nuclear-specific risks and carbon abatement potential. This needs to be part of the wider public debate on energy recommended in Chapter 10.

7.80 **Does this approach do enough to address current needs?** About 9 GW of existing nuclear capacity is expected to have been removed from the system by 2020. Continued pressure to improve energy efficiency will reduce the needs for supply. But some replacement capacity will be needed. The electricity industry has, in the past, had to cope with this scale of replacement and can do so again. A wide range of technologies is available – gas-fired stations; renewable power; CHP; coal-fired stations; energy from waste resources; coal-mine methane; and on-site generation – though gas-fired stations are generally the most competitive.

7.81 The private sector will continue to be free to put forward an application for new nuclear construction. Indeed, it has been suggested that nuclear capacity should be replaced with nuclear capacity. The industry's present proposals are for a large programme of new

[36] DTLR (2001b).

build, amounting to some 10 GW. This would be beneficial in terms of the carbon savings, and, the industry argue, in terms of the cost reductions that could be achieved. Certainly learning effects apply to nuclear technology as well as to renewables, though historically they have been often overlain by the cost consequences of more stringent regulation. However, the desire for flexibility points to a preference for supporting a range of possibilities, rather than a large and relatively inflexible programme of investment such as is being proposed by the nuclear industry.

7.82 There is no requirement, in system terms, to replace any particular generation technology with the same type of generation. It is not clear how quickly decisions need to be taken by investors on new build, partly because the lead time to completion is unclear. While construction times could be shortened, current licensing and planning procedures could add much to cost and be lengthy. Regulatory risk needs to be minimised wherever possible to ensure private finance, but the public needs to be assured that the highest standards of safety and environmental protection will continue to apply.

CHP

7.83 CHP is a low cost option for carbon abatement. DEFRA should publish, as soon as possible, its strategy to deliver its 2010 target of achieving 10 GW of "good quality" CHP. In the long-term CHP will benefit from policies that put an appropriate value on carbon. However, industrial CHP is a mature technology and not zero carbon. It does not merit or need support through a premium price to encourage "learning by doing" cost reduction in the same way as new renewable technologies. However, CHP should be given sufficient support to overcome current market and institutional barriers.

7.84 CHP generators face potentially non-cost-reflective elements in wholesale power markets. And there are barriers to the connection of generation in distribution systems. These issues are considered and recommendations brought forward in the section on renewables. In industrial markets, CHP faces many of the same barriers as other energy efficiency investments, in particular because environmental benefits are not fully internalised, especially for exported power.

7.85 The Government announced in the Pre-Budget Report that, subject to legal and other constraints, it would consider the environmental case for providing more favourable treatment for CHP within the CCL, taking account of the role which CHP might play in meeting the UK's Climate Change targets. In addition, the following recommendation would assist CHP:

- DTI should ensure that policy towards Section 36 consents requires proposers to show they have considered alternative sites with heat loads, if Government is asked to approve a proposal not linked to CHP. But this should not, as far as possible, impose a new planning burden on stations.

7.86 Although there is likely to be further development of industrial heat networks in conjunction with major CHP projects on industrial sites, it is not likely that such networks will be either large enough, or complex enough, to require regulation as natural monopolies. It is also unlikely that new heat networks for domestic or small business heating will become a cost effective option outside individual buildings or small groups of buildings, even in the context of measures for carbon abatement and increases in small scale local generation. This is because:

- heat transport is some 20 times more expensive than gas transport;
- heat networks lose significant energy in transport, while gas networks lose very little;

- local gas-fired boilers are generally a fuel efficient alternative; and
- local systems offer greater control to the customer.

7.87 The conclusion is that there is no case for specific government support for such networks in addition to whatever wider support is available for CHP. Nor are new heat networks likely to develop in such a way as to require detailed regulation.

7.88 Micro-CHP is a new technology and faces some different obstacles. Its deployment will require changes to electricity distribution network and market operation to enable very small-scale generation. Ofgem should ensure for micro-CHP that:

- there are simple and standardised connection terms;
- settlement profiles allow the technology to be used without the costs of installing two-way meters, where the scale of power exports does not justify these costs; and
- in the medium-term, advanced metering technology should be introduced.

CO_2 C&S

7.89 The potential benefits of CO_2 C&S are that it could be:

- a means to preserve diversity of fossil fuel sources for power generation, including high carbon fuels such as coal, while at the same time meeting the need for deep cuts in CO_2 emissions; and
- a potential source of low carbon hydrogen for transport and other applications

It also has the merit of being well suited to UK circumstances, especially if linked to enhanced oil recovery in the UKCS.

7.90 At the moment uncertainties surrounding costs, safety, environmental impacts and public and investor acceptability are large. Steps should be taken to reduce these uncertainties. It appears impossible to do this unless the technology is demonstrated on a large scale in the UK context. At present it is not clear how best to do this, and the crucial next step is to undertake much more detailed analysis of the appropriate role for government, coupled with possibilities for international collaboration. Estimates of the cost-effectiveness of this option as a means of saving carbon are contained in Table 6.1: for 2020 the estimates range from £80/tC to £280/tC. The costs will differ depending on the fossil fuel used. Many estimates show gas-fired generation as providing the cheapest base, but since the costs of gas and coal-fired plant depend on assumptions about gas prices, the relative position may change over time, with coal-fired generation becoming more competitive. The technology holds fewer prospects for substantial reductions in unit costs than renewable technologies, but efficiency improvements can be expected (possibilities for cost reductions in coal gasification technologies are discussed in Annex 6).

7.91 The DTI Review of the case for Government support for cleaner coal demonstration plant,[37] which ran in parallel with the PIU review, endorsed the case for support for the development of carbon capture and storage mechanisms, while recognising that there was the need for more work on the environmental, technical, legal, economic, infrastructure and social issues involved. The DTI Review also suggested that further attention should be paid to ensuing that, if carbon capture develops satisfactorily, it should be able to benefit from generalised regimes which reward low or zero carbon options. We support

[37] DTI (2001h).

the recommendations of this DTI Review. **DTI should decide whether to support a programme for carbon capture and sequestration, and if so by what means.**

Coal Mine Methane

7.92 The potential for tapping coal mine methane is discussed in Chapter 6. Methane is an important greenhouse gas and there is a clear environmental gain in using it, for example to generate electricity, provided it would otherwise have escaped. Special treatment to incentivise use of this source would need to be linked to evidence of actual leakage.

Transport

7.93 The scenario analysis shows that achievement of CO_2 emissions reductions in line with the RCEP recommendations would require development of a low carbon transport system. The Government recently published a consultation draft of its *Powering Future Vehicles* strategy.[38] This aims to promote the development, introduction and take-up of low carbon vehicles and fuels, and to ensure the full involvement of the UK automotive industry in the new technologies. The recommendations below consider the role of transport in the energy balance.[39]

7.94 The transport sector is likely to remain primarily oil-based until at least 2020. While oil security is not a major current concern, our economic dependence on transport, increasing dependence on fuel imports, constraints on fuel diversity in the transport sector in the medium-term and potential resource depletion in the long term, all reinforce the need to monitor the oil supply situation, and to achieve the potential for energy efficiency in conventional road vehicle engines. Issues relating to the security of oil supplies are addressed in Chapter 4.

[38] DTLR, DTI, DEFRA, HMT (2001).
[39] Much of the analysis in this section draws on Ferguson (2001).

7.95 There is currently little data available on the costs per tonne of carbon saved, either from energy efficiency or fuel switching in the transport sector. DTLR and the Inter-Departmental Analysts' Group on Low Carbon Options should consider how best to address this lack, in particular in relation to new technologies.

7.96 The transition to a low carbon transport system would need to engage a wide range of industry and other players. Government must articulate clear objectives. Targets can help promote progress to shared goals, but they must fit within a strategic framework aligned with international developments. Targets should be outcome-based and not, wherever possible, be technology prescriptive. The longer-term possible shift to zero carbon hydrogen powered vehicles needs to be considered as part of the development of the energy system as a whole, so that it goes hand-in-hand with the development of low carbon electricity. Intermediate steps may be needed, so that, for example, the next round of EU voluntary agreements need to reflect and bring about the technological potential in hybrids. **DTLR should work with EU partners and motor manufacturers to secure further improvements in the energy efficiency of road vehicles and to open options for low carbon fuelling in the longer term.**

7.97 There are major challenges in the introduction of radically new approaches:

- there are significant technical challenges yet to be overcome in commercialising the fuel cell hydrogen car, and these concern both the fuel cell technology itself and means of on-board production or storage of hydrogen;
- new and unfamiliar technologies need to be supported by standards, guidelines and design norms. There is a natural reluctance to undertake such efforts until it is clear that a new technology will be forthcoming;

- there are barriers to public acceptance of radically new technologies. People need to be reassured that new systems are both safe and reliable;
- with all alternative fuels, there is a "chicken and egg" problem whereby vehicle manufacturers will not deploy new technologies if there is no refuelling infrastructure, whereas energy supply companies are reluctant to invest while there is no significant demand; and
- with a range of vested interests competing for future markets and the constraint on public policy not to "pick winners", there is a danger that the "pathway dilemma" will persist making actors hesitate to back any one technology decisively.

7.98 If the hydrogen route is taken, the development of a UK infrastructure to deliver hydrogen would be a major endeavour. Investment in most new infrastructures has depended on Government intervention, mainly in nationalised industries. At this stage, when the future course of development is uncertain, it would be wrong to commit to one infrastructure so that we were potentially "locked-into" an inappropriate technology. This suggests an incremental approach: whereby small-scale projects are financed as demonstrations. Depot-refuelling vehicles are an ideal for such demonstrations.[40]

7.99 The UK is already well placed in some aspects of fuel cell R&D but should consider doing more to support demonstration projects. UK funding for energy R&D including transport is lower than that in many other countries,[41] and consideration should be given to increased funding, given the strategic priority and technical challenges faced by the transport sector. The Chief Scientific Adviser's review of energy research identified hydrogen production and storage as one of six key areas in which increased support for R&D and development would be particularly beneficial. It advised that there be a dedicated hydrogen research programme separate from, but complementary to, that for fuel cells.[42]

7.100 Public policy, conducted internationally through negotiations between vehicle manufacturers and a range of governments, needs to keep these problems in mind. The danger is that the technological developments currently envisaged fail to become viable. Transport demand management policies, such as congestion charging and land use planning, are already being used in pursuit of objectives such as congestion reduction as well as environmental objectives. If technological solutions do not realise their potential, it may prove necessary to address the transport energy balance through greater dependence on such measures.

7.101 Aviation is a major problem with demand outstripping energy efficiency and no alternative to kerosene on the horizon. Handling the projected growth in aviation energy use and CO_2 emissions must become a priority for the transport community. Air transport issues need to be considered in wider transport planning. **DTLR should prioritise discussion of taxation and other measures to manage aviation demand in EU and international forums.**

7.102 Even if major reductions of CO_2 emissions and energy consumption are achieved in the transport sector, this will not address wider concerns such as congestion, social exclusion, air quality, noise and road casualties. In addition, different fuels (though not inherently more hazardous than present fuels) will call for new health and safety standards, to protect both workers and consumers.

[40] Transport for London are to take delivery of three fuel cell buses in 2003 which will be refuelled at depots.
[41] Chief Scientific Adviser (2001).
[42] Chief Scientific Adviser (2001).

Seeing the programme as a whole

7.103 The aim of the above programme is to enable the UK to develop the basis for a low carbon energy system, by maximising support for the options that offer the largest benefits, and securing options for the future. Policy should:

- place much greater emphasis on end-use energy efficiency and CHP – these offer low cost CO_2 savings and synergies with other policy goals;
- expand support for renewables beyond 2010 – these have the potential to secure substantial cost reductions;
- keep the nuclear option open, while ensuring that the energy system can respond flexibly to new information;
- consider how to open up the option of capture and sequestration of CO_2 as part of the clean-coal programme; and
- support both energy efficiency in vehicles and the development of zero carbon fuelling options for the long term.

7.104 Policies to encourage innovation and new technologies have here been assessed in terms of the contribution they can make to opening up a wider range of low carbon options. A different case can also be made in terms of the possibilities for generating new UK industries, poised to obtain significant exports, if and when the world as a whole starts down a low carbon route. In practice, the range of energy technologies which the UK could sell to the rest of the world in these circumstances will never be limited just to renewables. Elsewhere in the world substantial environmental gains can often be made by investment in cleaner and more efficient conventional plant. These possibilities should not be forgotten. Nevertheless, the potential to export new technologies is a consideration to be weighed with the other benefits.

Who pays?

7.105 Looking out over the period to 2020, it appears likely that many renewables, and nuclear and CO_2 C&S will all continue to cost more than fossil fuel alternatives. We expect that unit costs of all will fall over this time, most dramatically for some renewables. This means that larger contributions need not imply ever rising net costs. It is, however, clear that the policies advocated for developing these options will place some burden on consumers or taxpayers. Finance will also be needed for energy efficiency investments. In the very long term, it appears likely that further costs will be entailed in developing new infrastructures. These costs are uncertain. If new infrastructures can be developed as existing investments are replaced, incremental costs may turn out to be modest.

7.106 Households in general will already bear higher prices than otherwise as a result of the existing EEC and the RO. Whether household fuel bills will actually rise or fall will, of course, depend on the course of primary energy prices and the scope for continuing gains in efficiency in the energy industries. And most households should be able to contain their bills by increased attention to energy efficiency and many will receive help under the EEC.

7.107 The existing RO could increase average electricity bills by about £12 a year.[43] If the proposals contained in this review were to succeed in giving additional confidence to the renewables industry, then this might reduce this cost. However, the establishment of a new target for 2020 would have the effect of increasing electricity bills by perhaps £15 a year, though this would occur after 2010, and by

[43] Based on an average domestic electricity bill of £260/p.a.

then many other factors will have worked both to raise and to lower bills. This could be more than offset by the effect of the EECs which would, if continued to 2010, as proposed in Paragraph 7.18, reduce average bills for gas and electricity by approximately £20 by 2010.

7.108 The burden of the RO, but not the EEC, also falls on industrial and commercial users. Given the lower unit prices charged to industrial consumers, a given cost of renewables support has a greater proportionate impact on bills. Again, the proposals contained here would not impact until after 2010. At that point, attention would need to be given to the effect of this increase in costs on the competitiveness of those industries that are the heaviest users of electricity, in the context of their total energy costs relative to their overseas competitors.

7.109 Serious problems of this kind are focused on a limited number of industrial firms in the international trading sector. In the non-traded sector the problems are much less significant. Nevertheless, the impacts of higher prices could be serious for energy intensive companies, especially since most firms of this kind are already energy efficient. It may be possible to find means of compensating these industries. The potential competitiveness problem reinforces arguments against the UK getting much ahead of its competitors in carbon pricing terms. The problem is one that the Government should keep under review.

Fuel poverty

7.110 The overall balance of net costs on different consumer groups is not yet clear. Much will depend on success in delivering cost reductions and on how effectively the uptake of cost effective energy efficiency and CHP can be facilitated. Continued targeting of energy efficiency to the fuel poor is particularly important. Fuel poverty is primarily a social challenge. But it is difficult to address it through conventional social policy alone. Incomes, house size, energy efficiency levels and prices all contribute. The reason most of our northern European neighbours do not face similar concerns is not that their energy is cheaper, but that their housing stock is of better quality.

7.111 While incomes may be expected to rise, future price levels are uncertain. Figures presented in the Government's Fuel Poverty Strategy indicate that a reasonable rate of price movements to 2010 are between increases of 15% for gas and 5% for electricity and falls of 10% for gas and 2% for electricity.[44] The proposals in this review are estimated not to raise this by more than about 1%.[45] In the least energy efficient homes, on which key programmes are targeted, we expect any increases to be more than offset by improvements in energy efficiency over the same period. Predictions beyond this period are very difficult to make.

7.112 Targeting income subsidies to address the problem is likely to prove difficult until the numbers involved are substantially reduced. Fuel poverty therefore constrains the use of pricing instruments in the domestic sector. Given the importance we attach to such instruments, this is an important constraint and emphasises why fuel poverty should be tackled as quickly as possible. This is already the intention of the Government and devolved administrations.[46]

7.113 Currently cost-effective measures of the type being implemented through Warm Front and the EEC can achieve a lot. At current energy prices, they can reduce the costs of affordable warmth, in even a "hard to heat home"[47], to about £400 per year, provided gas-

[44] DTI, DEFRA (2001), para. 3.30.
[45] Calculations set out in Annex 4.
[46] DTI, DEFRA (2001).
[47] Approximately 6 million homes, mainly built before 1920, have solid walls. They are significantly more difficult to insulate and therefore to keep warm than other homes.

fired central heating is available. This sum is only 8% of the single pensioner minimum income guarantee. New technology, in particular, micro-CHP offers scope for further substantial reductions in energy bills. There are more difficult, though not intractable, problems where there is no gas supply.

7.114 We conclude that fuel poverty should be tackled as soon as possible, partly to open up new opportunities for pricing instruments in the domestic sector. With substantial energy efficiency programmes and likely rises in incomes, fuel poverty should be substantially diminished by 2010. Government should stage the introduction of policies which have an impact on costs in order to minimise the adverse effects on the fuel poor. However, timing is uncertain and Government should keep the scope for policy change of this type under constant review.

The aggregate costs of meeting a long-term carbon target

7.115 Looking further forward to 2050 it is worth asking how much it might cost the economy in aggregate terms to get to a 60% reduction in carbon emissions. The Inter-Departmental Analysts' Group (IAG) spent some time analysing this issue and, though there is much uncertainty so far into the future, some bounds can be put on to the likely cost. There are various ways of expressing this cost. The simplest is probably in terms of the loss of economic growth. On the assumption that economic growth will continue at the historic annual rate 2.25%, GDP would triple over fifty years. IAG estimates suggest that 0.02 percentage points might be lost from the growth rate – equivalent to a loss of only around 6 months' GDP growth over 50 years. In other words, we might lose only 1% of all the economic growth we expect over the next half a century. In return, the benefits would be a major contribution to the international effort to mitigate climate change. While achieving a 60% cut in carbon emissions by 2050 would be challenging, it could be done while still achieving economic growth rates of around 2.25%.

The Risks

7.116 The risks posed by these varied low carbon agendas are very different. For example, the renewables risk is that the main barriers to investment will not be overcome, so that deployment will be too low to offer a credible low carbon option. The move to a low carbon transport option requires the development of new technologies over the next 20 years.

7.117 While a continuing commitment to renewable generation, together with enhanced energy efficiency and a low carbon transport sector, is seen now as the primary means of moving towards a low carbon economy, what if this policy fails? While the prospects of success are good, it is prudent to be aware from the start of the continuing need to review progress, and to be ready with alternative approaches. The uncertainties are too large for us to be sure how much any one option might cost in 2020, let alone 2050. It will therefore be prudent to have insurance against the failure of these options to deliver in full. This can be provided by keeping open other low carbon power generation options.

7.118 DTI and DEFRA should monitor the extent to which energy efficiency, renewables and CHP achieve current expectations, so that fallback strategies can be developed if needed. In particular:

- what action should be taken if investment in new renewables is slow to come forward, perhaps because of continued difficulties in getting projects through the planning system, or because it is difficult to achieve a sufficiently large scale of activity? Chapter 10 considers how possible reactions to failure might change over time. In the event of the failure of renewables and carbon sequestration to deliver, new investment in nuclear power would need to be considered. The option will not have been closed if the right actions are taken today;

- what action should be taken if it the energy efficiency and CHP policies recommended do not deliver? The recommendations are designed to encourage the take-up of cost effective energy efficiency through self-sustaining energy efficiency markets, incentivised by targeted and market-based instruments. They need to be given time to work. But if after 5 years it is clear that the approach is not working, a new approach will be needed, possibly involving stronger elements of direct regulation; and
- what action should be taken if the potential of low carbon transport technologies is not realised? The progress of technologies needs to be carefully monitored and if concerns are real, greater emphasis will need to be placed on other policy tools such as land use planning, public transport infrastructure, congestion charging and support for low power alternatives such as cycling. In addition measures to control aviation demand should be pursued at EU level in case full international agreement is not reached.

Overcoming the inertia in the energy system

7.119 There are many differences between the conventional energy system and those envisaged in some of the energy scenarios. The energy systems which some people see for the future are very different from that of today in terms of:

- the small scale of new technologies;
- the greater variety of options;
- the ways in which generation is connected to the network;
- the way in which electricity flows through the network; and
- the way in which customers choose how much energy to use and where it comes from.

7.120 While the technologies and commercial possibilities have changed enormously, the energy system has significant inertia. Yet change will have to occur if many of the low carbon options are to come through.

Summary of Recommendations

Main Recommendations

21. **OST** should take steps to increase the level of funding for low carbon energy R&D. The priority areas of the Chief Scientific Adviser's Research Review Group represent a good starting point (7.3).

22. **DEFRA** should develop energy efficiency indicators, targets and monitoring mechanisms for each sector of the economy (7.9).

23. **DEFRA** should develop a Strategy for Home Energy Efficiency to set out a clear, long-term framework. This should include an aspirational target for home energy efficiency of 20% improvement by 2010 followed by a further 20% improvement by 2020 (7.11).

24. In order to encourage a range of renewable options, and maximise the chances of rapid and long-term learning and cost reductions, **DTI** should immediately set a firm target of 20% of electricity to be supplied from renewables for 2020 (7.63).

25. **DTI** should, by 2008, establish the renewable energy support mechanisms to ensure that the 2020 target of 20% is met (7.64).

26. In respect of NETA, **Ofgem** should develop transitional measures to be ready to be implemented by January 2003 in case current measures are unsuccessful in helping small generators. DTI should consider legislation to move this objective forward (7.67).

27. **Ofgem** should ensure that that the recommendations of the EGWG are implemented by 2005. **DTI** should consider legislation to move this forward in the event of obstacles to progress (7.67).

28. **Ofgem** should ensure that future changes to electricity trading and grid access arrangements do not discriminate unfairly against renewable and CHP generation (7.67).

29. **DTI** should take the necessary actions to keep the nuclear option open (7.78).

30. **DTI** should decide whether to support a programme for carbon capture and sequestration, and if so by what means (7.91).

31. **DTLR** should work with EU partners and motor manufacturers to secure further improvements in the energy efficiency of road vehicles and to open options for low carbon fuelling in the longer-term (7.96).

32. **DTLR** should prioritise discussion of taxation and other measures to manage aviation demand in EU and international fora (7.102).

Other recommendations

33. **DEFRA** and **DTI** should make an early commitment to extending the Energy Efficiency Commitment from 2005 to 2010, on the basis that it would, at a minimum, be kept at existing levels. Subsequently, and by the end of 2003, the Departments should review the scale of the Commitment for this additional period in the light of the initial experience (7.18).

34. **DTLR** should review the costs and benefits of moving to "near zero space heating" buildings well in advance of the next review of the energy efficiency component of Building Regulations (7.25).

35. **DEFRA** should take the lead in Europe in pressing for a more comprehensive programme of cost effective EU energy efficiency standards and negotiated agreements (7.28).

36. **DEFRA's** Strategy for Home Energy Efficiency should consider the option of a negotiated agreement with the finance sector to reduce the cost of financing energy efficiency measures by funding them as part of mortgage offers (7.29).

37. For contracts that include longer-term energy efficiency financing (but only for those contracts) **DTI** and **Ofgem** should modify the 28-day rule, with other approaches used to protect customers against excessive charging (7.32).

38. **DTLR** should develop Building Regulations to deliver a phased transition to low energy commercial buildings, including consideration of the use of renewable energy such as photovoltaics (7.37).

39. As part of Government's leadership role in energy efficiency, **HM Treasury** should include departmental energy efficiency targets in future Public Service Agreements, and the **Office of Government Commerce** should develop model energy services contracts for use in tendering throughout the public sector (7.45).

40. **DTI** should review the extent of the need for capital grants for renewable energy after 2005. This need should be assessed in time for the 2004 Spending Review (7.48).

41. **DTI** should undertake further analysis of the possibilities and benefits of mechanisms or schemes to promote renewable energy producing heat, plus household and/or community projects, especially those which in practice fall outside the Renewables Obligation (7.50).

42. **DTI** should contribute to the international process of developing radically improved nuclear reactor designs, engaging with others in the development of low cost, low waste designs (7.76).

43. **DTI** should ensure that UK regulators are adequately staffed to assess any new investment proposals, and are also pursuing opportunities to develop common international safety standards (7.76).

44. **DTI and HM Treasury** should ensure that any new nuclear build should benefit from any future methods that will be used to value carbon and internalise the externalities of fossil fuel use. In addition, new investment in existing stations that substantially raised nuclear capacity (and which would reduce carbon emissions) should be considered for similar treatment, subject to independent evaluation of any case made (7.78).

45. **DTI** should ensure, using independent evaluation, that the nuclear industry fully internalises its externalities, including risks such as waste cost escalation (7.78).

46. **DTI** and **DEFRA** should stimulate a public debate about nuclear power, and in particular on the trade-offs between nuclear-specific risks and carbon abatement potential, as part of a wider debate on future energy policies and needs (see Chapter 10) (7.79).

47. **HM Treasury** should ensure that electricity exported to the network from CHP schemes is, for fiscal purposes treated in the same way as power used on site (7.85).

48. **DTI** should ensure that policy towards Section 36 power station construction consents requires proposers to show they have considered alternative sites with heat loads, if Government is asked to approve a proposal not linked to CHP (7.85).

49. **Ofgem** should ensure for micro-CHP, that there are simple and standardised connection terms, that settlement profiles avoid recourse to expensive metering and in the medium-term, that advanced metering technology should be introduced (7.88).

50. **DTLR** and the Inter-Departmental Analysts' Group on Low Carbon Options should consider how best to address the lack of data on costs of energy efficiency and fuel switching in transport (7.95).

51. **DTI** and **DEFRA** should monitor the extent to which energy efficiency, renewables and CHP achieve current expectations, so that fallback strategies can be developed if needed (7.118).

APPENDIX TO CHAPTER 7

Institutional Barriers to the Deployment of Renewables Options

The New Electricity Trading Arrangements

7.121 NETA was introduced on 27 March 2001. Since then there has been rising concern over the impact of NETA on small generators, and in particular on intermittent or less predictable generation from wind farms and on some CHP units. A review of the first two months impact of NETA on small generators by Ofgem[48] showed that prices, income and output were all considerably lower, although prices for small generators did not appear to have fallen more sharply than prices for generators as a whole.

7.122 Because electricity is non-storable, centrally designed balancing mechanisms are required in competitive markets and these are necessarily complex. There are no easy answers to the design of these mechanisms and a wide range of approaches has been adopted in different countries. Increasing percentages of renewable generation could add costs to the running of the electricity system. The extent of any extra costs will depend on the proportions of the generation which are intermittent[49] (wind energy, wave energy and solar), predictable[50] (tidal energy) and flexible[51] (biomass, wastes)[52] and on the types of generation displaced. Intermittent power imposes greater costs than the others since more actions must be taken by the system operator, or some other party, to compensate for unpredicted fluctuations.

7.123 Additional flexibility of various sorts must be acquired in order to compensate for possible fluctuations in the level of wind generation. Costs may be incurred as follows:

- to keep additional generation capacity in readiness (to meet peak demand if wind is unavailable);
- to obtain additional flexibility from generators or on the demand-side to maintain energy balance in each metered period (half-hourly in the UK); and
- to obtain additional flexibility from generators or on the demand-side to maintain power balance continuously within half-hourly trading periods.

7.124 Small and intermittent generators are interested in three values:

- the cost imposed on the system by increasing percentages of intermittent generation;
- the balancing and other costs they face under NETA by virtue of their intermittence and scale; and
- the price discount that they actually face in the market.

7.125 The central question is the cost of back-up needed to cover for the periods when intermittent generators cannot generate (most obviously because there is a lack of wind) and whether NETA reasonably reflects those costs.

48 Ofgem (2001a).
49 Intermittent reflects generation which occurs in relation to the whims of nature.
50 Predictable reflects generation which occurs at predictable times but may not occur outside those times.
51 Flexible reflects generation which can be generated at any time.
52 CHP features in all three categories.

7.126 PIU has had a survey made of the current knowledge concerning the costs associated with intermittent generation.[53] Different assumptions produce different figures. It is clear that at current levels of penetration the system costs associated with intermittent generation are negligible: the small changes in output associated with individual plants are "lost" within the normal fluctuations in demand and supply within the network.

7.127 At some point, as the proportion of power derived from intermittents rises, some allowance will need to be made for back-up to cover unexpected fluctuations in supply. Other plants will need to be incentivised to hold themselves in readiness to meet shortfalls in supply, or electricity storage will need to be incentivised. The calculations done for the PIU assume that storage is used, and this may have tended to over-estimate the costs. As a rough rule of thumb, while the share of intermittents remains below about 5%, the system costs would be insignificant. With a share between 5% and 10% costs start to rise to about 0.1p/kWh. Costs continue to increase beyond 10%, with current estimates suggesting a cost of about 0.2p/kWh when intermittents provide 20% of electricity.[54]

7.128 Under cost-reflective trading arrangements one would expect the value of intermittent generation to be less than that of conventional generation by approximately these amounts. An important determinant of the NETA price for intermittents is the spread between system sell and system buy cash-out prices. The greater this spread, the greater the discount faced by intermittents. At the start of NETA the spread was very volatile but averaged around 5p/kWh for the first few weeks. It has subsequently fallen to around 2p/kWh in recent months.[55] Analysis undertaken for the PIU and estimates by National Wind Power[56] suggest that at this 2p/kWh spread, assuming no consolidation and 3.5 hour gate closure the NETA discount would lie around 0.4p/kWh. The DTI has put forward a 0.3p/kWh figure for consultation.[57]

7.129 A modification has been put forward to reduce gate closure of the Balancing Mechanism from 3.5 hours to 1 hour. This may reduce the NETA discount. Nevertheless, the figures in paragraph 7.128 are sufficiently above the **costs** derived in paragraph 7.127 to provide the basis for the claim that the Imbalance Settlement Prices of NETA provide inappropriate incentives for reliable power versus intermittent power, favouring the former over the latter to an extent greater than warranted by their underlying values to the system. Given these uncertainties, we recommend that further analysis is undertaken of these costs.

7.130 In addition, the price offered by suppliers to intermittent generators, and smaller generators in general, is further below this price.[58] The DTI is hoping that consolidation will reduce this problem. They have asked Ofgem to set up a Working Group to investigate the barriers to consolidation. Even if consolidation works well – and there are very serious obstacles to its progress – it will impose transaction costs and take some time to occur.

7.131 There is also a view that NETA undervalues small-scale generation relative to large-scale generation,[59] thus giving a double disadvantage to most intermittent generators which are small scale.

7.132 Thus, the evidence suggests that intermittent generation is suffering as a result of

[53] Milborrow (2001).
[54] Milborrow (2001).
[55] www.bmreports.com
[56] Moore (2001).
[57] DTI (2001e).
[58] BWEA (2001b).
[59] ILEX (2001).

a range of issues related to NETA. While intermittents are having particular problems, other smaller generators are also experiencing difficulties, as Ofgem has recognised.[60] Although measures are underway which are intended to address these difficulties, it is not clear that they will be successful or by when this might be. Furthermore, any transitional mechanism to help small and intermittent generators would probably take 6 months to a year to establish.

7.133 There are two **recommendations:**

Given this analysis, and the Government's goals for renewable energy and CHP, much of which is intermittent or produced in small units:

- there are sufficient grounds to recommend that Ofgem develops transitional arrangements which by-pass the particular difficulties imposed by the current electricity trading arrangements. Measures are underway which may help small generators. **Transitional arrangements should be developed in parallel to be ready to be implemented by January 2003 in case the current measures are unsuccessful in helping small generators.**[61] Consideration should be given for potential legislation to move the agenda forward.
- NETA was introduced to establish a trading mechanism that aims to be cost-reflective. However, it is not clear that NETA is properly reflecting the relative costs that small and intermittent generation impose on the system. To facilitate a move to a low carbon system, it is important that the trading arrangements develop in such a way as to ensure that renewables and CHP are treated in a non-discriminatory manner. While trading arrangements should not favour these options, they should ensure that intermittent electricity (such as wind energy), predictable but variable electricity (such as tidal power) and small-scale generation – of whatever sort – are not under-valued. Where there is real uncertainty as to what constitutes cost-reflective, or non-discriminatory pricing, options from within the range of possibilities should not be chosen without careful consideration of the environmental impacts of the alternatives.

Network connection and use of system charges

7.134 The electricity system has evolved to deliver power from large-scale remote generators to consumers. Several technologies that would lead to significant carbon reductions, including photovoltaic panels, CHP and wind farms, require a system able to accommodate small and intermittent sources on the distribution (as opposed to transmission) network. This requires the Distribution Network Operators (DNOs) to operate and design their networks differently, thereby accommodating more embedded generation.

7.135 A joint DTI/DETR/Ofgem Report of the Embedded Generation Working Group (EGWG)[62] looked at this problem and explained why the DNOs do not have an economic interest in connecting embedded generation. It made a number of recommendations about how to develop a new **approach** to designing and operating the network. These recommendations should be implemented as soon as possible. Unless this occurs, distributed generation will continue to have problems in connecting to the grid. Changes may, however, have to wait until the 2005 Distribution Price Control Review. But any further delay would put the 2010 renewables and CHP targets in jeopardy.

60 Ofgem (2001a).
61 Success could be measured in terms of MW installed.
62 DTI, DETR, Ofgem (2001). A Scottish Embedded Generation Working Group followed up the EGWG report by examining issues of particular interest to Scotland.

7.136 There are three recommendations:

- the EGWG recommendations should be implemented fully, no later than through the 2005 Distribution Price Control Review;
- while it will be difficult to implement the EGWG recommendations before 2005, in the interim, alternative policies should be prepared so that they would be ready for implementation in 2007 if it became clear that the changes laid out by the EGWG were not coming into effect; and
- network access charges and use of system charges must change if renewables and CHP are to be deployed. Given concerns that the EGWG recommendations will not provide the necessary impetus for DNOs to alter their attitude to embedded generation, even with new regulatory incentives, early consideration should be given to the scope for legislation to move the agenda forward.

A move to Active and Intelligent Distribution Networks

7.137 Technologies are available which allow distribution networks to provide new services and operate in different ways. "Smart metering" and information technology may facilitate greater use of energy services and demand side management. This area was touched on by the EGWG. PIU would recommend that the Distributed Generation Co-ordinating Group (DGCG)[63] examines this issue further and makes recommendations in its report in 2002.

Investment in Scotland

7.138 The Scottish Executive co-ordinated a Scottish Embedded Generation Working Group (SEGWG).[64] Except in a few policy areas related to Scotland, SEGWG supported the recommendations of the EGWG. Scotland has a very large potential renewable energy resource, so that a substantial portion of new renewable generation is likely to be in Scotland. Scotland already has a surplus of generation, and it exports power to England. Consequently, SEGWG considers that the network operators in Scotland are concerned with the impact of a distributed generation scheme not only on the local distribution network, but also on the transmission system.

7.139 Given Scotland's rapidly increasing wind energy deployment and large resource of other renewable energy technologies, there are three issues:

- is the investment in transmission necessary;
- if so, how should it be paid for; and
- if so, who should pay for it?

7.140 It has been argued that there might be the need for a "strategic" investment project, aimed at opening up a new transmission route for Scottish renewable energy southwards. This project would be so large that it would not easily fit the regulatory mechanism. The criteria for "strategic" and "standard" investment would have to be very carefully defined.

7.141 As the SEGWG makes clear, additional transmission system costs should not fall disproportionately on Scottish customers, if they are incurred in part to meet renewables targets for England and Wales. The EGWG put forward a number of charging options.[65]

[63] The EGWG recommended that a Group should be set up to oversee the implementation of the EGWG recommendations. This has now occurred and has been named as the DGCG.
[64] SEGWG (2001).
[65] These charging options were based on the current NGC system and combined with shallow connection charges and entry and exit charges on all actors with distribution networks.

Levying an exit charge on all customers would be a fair and transparent way to pay for such a scheme, if it were decided that it were strategic.

7.142 The **recommendation** is that:

- Analysis of the potential need for strategic projects should be added to the remit of the DGCG.

Difficulties in obtaining planning permission

7.143 The planning system, and attitudes to infrastructure development, will have a key impact on the development of a low carbon energy system. The broader discussion of these issues takes place in Chapter 8. Renewable energy faces particular difficulties.

7.144 There have been several surveys concerning public attitudes to renewable power plants. Most have been surveys done either for renewable developers or for opposition groups- and the results have tended to support the position of the sponsor. Those surveys which have been undertaken by independent institutions, such as the BBC, the Scottish Executive, academics, RSPB and local councils, have generally been supportive to renewable energy.[66] The surveys also suggest that support increases once a power plant has been built.[67]

7.145 Nevertheless, the business of obtaining planning permission for renewable investments, particularly onshore wind in England and Wales, remains costly and time-consuming, and success rates for some technologies are lower than the national average.[68] Unless success rates increase targets will not be met. Chapter 8 discusses potential means for overcoming these difficulties.

[66] RSPB (2001), BWEA (2001b).
[67] Scottish Executive (2000b).
[68] Hartnell (2001).

8. INSTITUTIONS

Summary

This chapter examines the institutional requirements of a low carbon future. The main conclusions are:

- despite the strengths of existing government institutions, institutional changes will be needed to take the UK towards a low carbon future while balancing the economic, social and security impacts of energy policy;
- the UK should continue strongly to champion liberalisation in the EU energy markets and support the European Commission in playing an effective and appropriate role;
- in the long-term, the Government should aspire to bring together responsibilities for energy, transport and climate change policy in one department. In the short-term, a new Sustainable Energy Policy Unit should be established. Responsibility for energy efficiency and CHP should be brought together with other aspects of energy policy;
- it is essential that the Devolved Administrations are involved with the implementation of this report and the on-going development of UK energy policy;
- Ministerial guidance to Ofgem on environmental objectives should be more specific about the outcomes Government wishes to acheive;
- a review should be undertaken to ensure that activities of national agencies that deliver low carbon policies are fully co-ordinated;
- central Government needs to support local authority and voluntary sector activities in facilitating local activity in energy efficiency and clean, small-scale power generation; and

- **national planning guidance should set out clear arguments when there is a national case for new investment in energy-related facilities. Greater prominence should be given to energy developments in regional guidance and sub-regional plans.**

Introduction

8.1 This review develops a challenging agenda. There is no single correct path towards a low carbon economy: there will be an on-going need to balance objectives; the risks which beset energy systems must be managed; and the requirements of policy implementation will be extensive and complex. Some of these tasks fall directly to government and regulators, others will be tackled by market participants within the framework developed by government. How far can we rely on existing institutions to do the job?

8.2 Our conclusion is that, despite the strengths of existing institutions, changes are needed. These would improve the process of resolving conflicts between objectives and the delivery of policy. This Chapter considers institutions at international, national and regional/local levels, and concludes with a discussion of the planning system.

International institutions

Climate change

8.3 As previously discussed, energy policy will increasingly be set within the framework of international commitments and negotiations on climate change. The international response to the problem of climate change is negotiated and taken forward under the auspices of the United Nations Framework Convention on Climate Change. The most significant documents produced to date under the UN-FCCC are the Kyoto Protocol, which sets targets for developed countries, and the Marrakesh Accords which set out in detail the way in which the Protocol will be implemented. Negotiations on post-Kyoto targets must begin in earnest by 2005, and will deal with targets post-2012. This next stage of negotiations may also try to bring more countries into the target-setting process. The UK will maintain the current approach of negotiating officially through the EU, with its own individual target decided through a burden-sharing process.

The European Union

8.4 While there are no treaty powers specific to energy policy, the European Union already has a significant influence on UK energy policy through areas such as internal market provisions, competition policy and environmental policy.

8.5 Two European developments are likely to be of growing importance over the next ten years:

- *enlargement* – there could be up to ten additional member states by 2004, changing the EU's political and economic centre of gravity. Russia and the Middle East will become immediate neighbours and, with increased import dependence, relations with these countries will rise up the political agenda. The accession countries will extend the EU infrastructure, increasing the need for regulation and investment; and
- *greater European Parliamentary involvement* will increase democratic representation but will also add a further layer of complexity to the policy-making process.

8.6 As a result of these factors, alongside the growing importance of climate change and the liberalisation of European energy markets, the European Commission seems likely to play an increasingly important role in energy policy.

8.7 Current EU priorities include the completion of the energy single market and increasing the diversity of gas suppliers to create greater competition in the gas market. These priorities are important for the achievement of UK energy policy goals, including maintaining competitive pressures on energy prices and providing diversity of fuel sources for energy security. As discussed in Chapter 4, the UK should continue to champion the liberalisation of EU energy markets and support the European Commission in pressing forward with the relevant directives. The EC also has a role in the completion of European energy networks.

8.8 The European Climate Change Programme[1] proposes a range of policies and measures to deliver the EU's climate change targets under the Kyoto Protocol. The EU's status as a signatory to the Protocol provides impetus to Union-wide measures to reduce greenhouse gas emissions. The most significant of these is the proposal for an EU emissions trading scheme. It would feature mandatory caps on the power sector, and could significantly affect the economics of new generating capacity. While individual member states should retain authority on the approaches used to achieve carbon reductions, in line with the principles of subsidiarity, the principle of emissions trading between member states is to be welcomed.

8.9 The Commission has also recently produced a Green Paper on security of supply which is currently under debate (its recommendations are discussed in Chapter 4). The Commission has proposed the need for a "consistent and coordinated energy policy at Community level". The UK consultation on the Green Paper has not revealed a pressing demand for treaty powers for energy. The UK should therefore continue to oppose a change in the treaty base: an energy chapter or other further treaty powers are unnecessary as competition issues can be dealt with under single market measures, and most other matters can be handled by national energy regulators.

8.10 There is no need for a European energy regulator: each member state will have its own regulatory authorities. Some coordination of approaches is likely to be necessary as liberalisation proceeds: this can be achieved through EU forums and is to be welcomed.

8.11 In conclusion, while there is no need for a change in EU treaty powers, the European Commission will have an increasingly important influence on UK energy policy through its role in development of climate change policy, pushing through energy market liberalisation, coordinating energy security concerns and managing an enlarged EU. Effective action in these areas is important for UK energy objectives and the UK should continue to support the Commission in playing an effective and appropriate role.

National institutions

Whitehall departments and agencies

8.12 In reviewing options for institutional change, the following principles were considered. Any new structure should:

- provide clarity of responsibilities without duplication;
- support public accountability;
- balance the collation of related policy areas against institutional size;
- improve the policy-making process, with appropriate expertise and minimal bureaucracy;

[1] Commission of the European Union (2001) and other documentation available at http://www.europa.eu.int/comm/environment/climat/eccp.htm

- ensure the separation of roles while handling potential conflicts of interests; and
- justify the cost and disruption of restructuring through improved performance.

8.13 The existing structure of institutions involved in UK energy policy making and delivery lacks coherence. At a departmental level, transport policy is located within DTLR, climate change policy along with energy efficiency and CHP policy/sponsorship in DEFRA, and the remainder of energy policy with DTI. It has been suggested that one route to greater unity would be to return to a Department of Energy, but such an approach would fail to bring together the range of interests involved in energy decisions. While the interests connected to energy are so wide that there is no obviously correct organisation of departments, the **Government should aspire in the long term to bring together in one department responsibilities for climate change, energy policy and transport policy.** Sponsorship of energy industries should remain in DTI. This recommendation would require fundamental change to existing departmental structures and significant forward planning. In the shorter term, there are actions that could be taken to enhance the current departmental arrangements.

8.14 An enhanced central capacity is required to support energy policy by permanently monitoring key developments in energy use and supply, and assessing implications for policy on energy, transport and climate change. This analytical centre should co-ordinate a forum within which those interested in energy outcomes can engage in the analysis of the impact of new policy initiatives. In addition to those with direct responsibilities for energy, transport and climate change, the Treasury should have an integral role particularly because of the future importance of carbon valuation and, given the growing influence of imports and international markets, FCO should be more fully integrated into the energy policy-making process. Given the range of devolved powers, close contacts would have to be established with the Devolved Administrations.

8.15 **It is recommended that a Sustainable Energy Policy Unit (SEPU) is established** to undertake this role. The Unit would report directly to Ministers and also to the Ministerial Sub-Committee on Energy Policy (DA(N)). Initially the Unit could be based within the DTI, but its position should be considered on the same time-scale as the organisational review of the DTI Energy Group (discussed further below). While the Unit will have to remain formally linked to one department (a fully independent body would require legislation which is not justified at the current time), the Unit should stand apart from individual departmental interests and be driven by a cross-Whitehall responsibility for sustainable energy. Proposals for the SEPU are set out in Box 8.1, but further consideration will clearly have to be given to the Unit's policy responsibilities, structure and staffing. There is no direct precedent for a Unit of this sort and imagination will be required in setting it up. Its future position will depend on the development of the roles of climate change, energy policy and transport policy within Government.

8.16 This proposal is made at a time when the DTI is reviewing the organisation of its Energy Group. The group currently performs a number of different functions – policy-making, policy analysis, industry sponsorship, regulation, licensing and policy delivery. DTI is seeking to achieve greater clarity, with less mixing of roles. We support this, especially if the result can be a clearer and more objective focus on policy-making. Industry sponsorship and energy policy-making should, so far as possible, be separated. Separation of these functions will minimise the risk of regulatory capture and conflicts of interest.

8.17 Alongside the Energy Group reorganisation, some streamlining of various executive functions may be possible, for example in the granting of licenses for all fossil fuels both on and offshore. Further thought might be given to the possibilities for establishing a composite Fossil Fuels Authority outside the DTI. This body would have the authority to license and encourage the efficient extraction of UK fossil fuel resources.

8.18 The review considered a further element of Whitehall organisation: the location of responsibility for energy efficiency and CHP policy, and sponsorship of the energy efficiency and CHP industries. Responsibility for these areas was given to the Department of the Environment when the Department of Energy was disbanded, as there were considerable synergies from placing the responsibility within a department responsible for construction, including building regulations. The link to transport was also helpful since there is considerable potential for increasing the energy efficiency within this sector. But, with the creation of DEFRA and DTLR, these synergies have been lost.

8.19 There are good reasons why responsibility for energy efficiency and CHP could be in either DEFRA or the DTI. There are gains from having energy efficiency pursued alongside the general responsibility for the UK climate change programme. But it can also be argued that responsibility for both the use and provision of energy should be placed together as there are increasing links between demand and supply side technologies. It will also be increasingly important to pursue energy efficiency policy in the light of a thorough understanding of the

Box 8.1: A new Sustainable Energy Policy Unit (SEPU)

Analytical capability. The Unit would have a strong analytical capability responsible for monitoring key developments in energy use and supply and for assessing implications for policy on climate change, energy and transport. The Unit would be responsible for ensuring greater co-ordination of energy-related analytical work across Government. It should ensure that the necessary long-term analysis is carried out and that this analysis is open and inclusive. It would provide a forum where different interests across Whitehall could debate key issues.

Strategic policy. The Unit would lead on the development of strategic policy, drawing on the evidence of its analytical work. It would be important that the Unit work closely with the Devolved Administrations. The Unit would not be responsible for policy issues relating to specific industries, sponsorship or policy delivery.

Staffing. The Unit would be staffed by officials on loan from government bodies (including DTI, DEFRA, DTLR, HMT, FCO, the Devolved Administrations, Ofgem and the Environment Agency) and external secondees. Staff should be recruited in the most part through open competition, with an appointment board consisting of people from both across Whitehall and outside. A Unit of about 50 people is envisaged, including specialists, administrators and support staff.

More inclusive working methods. It would be vital for the Unit to adopt an open and inclusive method of working: establishing new networks, drawing on inputs from the full range of stakeholders and making maximum use of web-based communications.

It would be for consideration as to how the existing **DTI Energy Advisory Panel** would relate to this Unit. The Unit would probably create more than one advisory group, for example on energy modelling, demand side projections, and gas and oil market developments.

workings of liberalised markets. Therefore it is recommended that, in light of experience with the Sustainable Energy Policy Unit, **consideration should be given to locating responsibility for energy efficiency and CHP policy with the other aspects of energy policy.**

8.20 The proposal for a Ministerial Group on Low Carbon Vehicles and Fuels, announced in the draft Government strategy *Powering Future Vehicles*, is welcomed. The Ministerial Group will work alongside DA(N), focusing on the implementation of the strategy for promoting the development, introduction and take-up of low carbon vehicles and fuels, and the full involvement of the UK automotive industry in the new technologies.

8.21 The Chief Scientific Adviser's review of energy research recommended that consideration should be given to setting up a national **Energy Research Centre.** This would facilitate a multi-disciplinary approach which could take account of the environmental, social and public acceptability aspects of energy technologies, as well as the basic science which underpins them. It could be a "networking" centre and play a role in co-ordinating UK research, facilitating collaboration between government, academia and industry, and UK participation in international projects. A national Energy Research Centre could fulfil a valuable function in contributing to enhanced and improved energy R&D and innovation. **It is recommended that more detailed proposals be developed.**

Devolved administrations

8.22 As set out in Box 1.1, energy efficiency and (to some extent) support for renewable energy are devolved matters in Scotland and Wales. (Northern Ireland is outside the remit of this review.) Given the importance placed on these two aspects of energy policy, it is essential that the Devolved Administrations are involved with the implementation of the review's finding and the on-going development of UK energy policy. This will include both close liaison with Whitehall, in particular through direct participation in the Sustainable Energy Policy Unit, and the development and implementation of policy on devolved issues.

Energy regulators

8.23 The Sustainable Energy Policy Unit should involve experts from both Ofgem and the Environment Agency. The SEPU should be involved in major new initiatives by either regulatory body, ideally helping in the wider analysis and co-ordination of new proposals.

8.24 We recognise the importance of preserving the independence of economic regulators whose main objective is to protect the interests of consumers by promoting competition and ensuring that prices are no higher than needed to deliver the services required. This independence is an essential means of providing investors with the assurance that their decisions will not be undermined by political intervention in regulatory matters. However, it was recognised in the Utilities Act 2000 that it is appropriate for DTI to give guidance to Ofgem, given that its activities can contribute to or conflict with Government objectives in the areas of social and environmental policy. Ofgem should have "due regard" to the guidance. This means that Ofgem would modify its actions to take account of the guidance so long as this did not contravene its statutory duties.

8.25 Guidance serves a useful purpose by enabling Government to give Ofgem a clear statement of its social and environmental objectives, and the weight it attaches to them, so that Ofgem can carry out its duties in a manner that is alert to the wider policy picture and, where possible, supportive of it. However **we do not think the existing draft guidance on environmental concerns[2] is sufficiently specific about the outcomes**

[2] DTI (2001b).

Government wishes to achieve and when it wishes to achieve them. For example:

- The draft says that "the Government encourages the Authority to assess the impact of the New Electricity Trading Arrangements on CHP and renewables generators". However, it does not say what an environmentally desirable outcome from this assessment might be.
- The draft says that Ofgem should have regard to a number of environmental issues when considering how competition might be promoted through embedded generation. However, it does not indicate how urgent these issues are.

Given its duties, Ofgem may or may not be able to respond to the Government's priorities, but at least the context within which it is operating will be clear. Given the purpose of the guidance, it should be reviewed more frequently than the 5 year intervals proposed by DTI.

8.26 The review has not argued for a fundamental change in the relationship between Government and Ofgem. However, Chapter 3 concluded that the Government can only deliver many environmental objectives, especially climate change objectives, through the energy system. This means there are very likely to be tensions between Government environmental objectives and the duties of Ofgem. Where these tensions cannot be resolved through guidance the alternative is to use legislation. It will be for Government to decide in each case whether the circumstances justify the legislative route, but more frequent resort to legislation is likely to be a consequence of using energy policy to achieve environmental objectives.

8.27 Detailed recommendations concerning Ofgem's approach to network regulation and NETA are contained in Chapter 7. Further to this, our work has led us to believe that **Ofgem should always produce comprehensive analyses of significant regulatory proposals, taking full account of costs falling on the energy industry and consumers.**

8.28 Finally, there has been a debate on whether the separation between Ofgem's regulation of onshore gas pipelines and the DTI's role in regulating offshore infrastructure is the best approach. Submissions to the PIU show a general feeling that the present arrangements for offshore regulation are broadly satisfactory, and that companies of all sizes are able to obtain the pipeline capacity they need at competitive market prices. There is, however, a continuing need for consultation between the DTI, Ofgem and the industry to ensure that actions affecting onshore and offshore investments are co-ordinated appropriately.

National non-departmental delivery agencies

8.29 There are currently a large number of bodies involved in the delivery of low carbon policies. Examples of the main institutions are listed in Figure 8.1, focusing on those promoting energy efficiency.

8.30 In general, energy efficiency and low carbon programmes are best delivered via market and regulatory mechanisms, for example the Energy Efficiency Commitment, building regulations, standards and the emissions trading scheme. The key role for institutions is to overcome information failures, and relevant activities are therefore to provide information, advice, advocacy, capacity building and supporting innovation. These roles are currently played primarily by the Energy Saving Trust and the Carbon Trust. The main exceptions are the current fuel poverty programmes. These should be integrated with other energy efficiency programmes at a local level so that funds are used effectively. There is a new initiative – Warm Zones – which is attempting to do this.

Figure 8.1 Main low-carbon institutions

Institution	Funding (annual 2001 unless otherwise explained)	Key areas of expenditure
Sources of funding		
Carbon Trust - Enhanced Capital Allowance scheme	Worth £70M depending on take-up, in the form of a tax allowance	Encourages businesses to invest in approved energy efficiency technologies
DEFRA – Emission trading	£215M (over 5 years on a UK wide basis)	The scheme aims to sign business up to beyond business-as-usual reductions of greenhouse gases
Ofgem – Energy Efficiency Commitment	Currently around £50M. Will rise to the equivalent of around £150M in EEC4 (2002–5), for which Ofgem will have operational responsibility. Overall obligation is set by Government.	Sets energy efficiency targets for energy suppliers through household energy efficiency installations. Funded by energy suppliers, who may pass the costs on to their consumers (max. £3.60 per customer per fuel per annum for the £150m figure)
Delivery Bodies		
Carbon Trust	Around £50M from CCL revenues and the Energy Efficiency Best Practice programme (UK total)	Will accelerate the takeup of cost effective, low-carbon technologies and other measures by the business and public sector
Climate Change Projects Office	Joint funded by DTI and DEFRA – £0.3m	Advises business on opportunities for reducing carbon overseas
DEFRA – Energy Efficiency Best Practice Programme	£18M (UK total)	Domestic and business best practice. Due to be split and given to the EST and the Carbon Trust to manage
Energy Agencies	Receive funding through the EU Save programme for the first 3 years	The Agencies promote the use of renewable energy and energy efficiency in non-domestic buildings

Figure 8.1 Main low-carbon institutions – continued

Institution	Funding (annual 2001 unless otherwise explained)	Key areas of expenditure
Energy Efficiency Advice Centres	Part funded through the EST, local authorities and private organisations	Advice mainly to households on energy efficiency measures and grant availability
Energy Saving Trust (EST)	£49M (UK Total) for 2001-02	Energy efficiency for households, SMEs and cleaner fuelled vehicles – information, grants, accreditation, training, networks
FCO – Climate Change Challenge Fund	£0.5M per annum to date	Provides funding to help business and developing countries meet the challenges of climate change
Government Offices		Provide a link to other programmes
Home Energy Efficiency Scheme	£75M old HEES up to 1 June 2000 £150M per annum 2000-04 (England only)	New HEES provides a package of insulation and heating measures tailored to the householders' needs and the property type
Joint Environment Management Unit	Joint funded by DTI and DEFRA	Encourages the development of a strong, competitive UK environmental industry

Source: DEFRA

8.31 Where schemes are directed towards different clientele there is a case for institutional separation. This is one of the justifications for the current structure, with the Carbon Trust having a stronger focus towards industry and innovation than the Energy Saving Trust, whose main activities centre on domestic users and on the transport sector. However, there are areas of overlap between both sectors, for example SMEs and technologies like micro-CHP and fuel cells. There would be advantages in merging the EST and the Carbon Trust over the medium term to maximise the synergies between the different sectors and ensure that there is no overlap.

8.32 There is also a more general lack of coordination between the various sources of funds. For example, the relationship between the funds available for the emissions trading scheme and the sources of funding available for business from the Carbon Trust is unclear, and this creates confusion among businesses, local authorities and others seeking to exploit them. Given the importance of energy efficiency and the proposal to "re-launch" all existing schemes and activities, there is a need for an **in-depth review of low carbon delivery activity to ensure that delivery** organisations are arranged in the most effective manner and that there is no overlap in activity. The review should look not simply at existing programmes but at future requirements, and further consideration should be given to the Royal Commission's recommendation for a single agency to promote energy efficiency in all sectors.[3]

Regional and local decision-making

8.33 Increased use of small-scale and decentralised technologies is expected in a low carbon future. This will place a greater focus on regional and local activity in the energy sector, so that regional and local institutions will have to play a larger role.

8.34 Local authorities already provide services and regulate some energy activities, but their key future role in the energy sector will be as leader and facilitator in their local communities. In this context they will have five important functions:

- leading by example, as an energy and transport user and a land owner;
- setting the local framework through land use and transport plans in light of the recent Green Paper about fundamental changes to the planning system (discussed below);
- building consensus for local action via Community Plans and Local Strategic Partnerships;
- facilitating local action, working with other statutory agencies (e.g. health authorities), businesses (such as energy suppliers) and the community; and
- ensuring information and advice is provided to homes and that small businesses are directed to the most appropriate sources of advice.

8.35 Local authorities' existing duties under the Home Energy Conservation Act (HECA) focus on a target for improvement of the whole housing stock and reporting to Government on progress. These are being reviewed in the light of the changing role of local government. These duties need to be modernised to emphasise building local partnerships, providing advice and coordination of local programmes to address fuel poverty and energy efficiency.

8.36 Voluntary groups are widely trusted and involved in community action. They can therefore play a number of roles. Specialist voluntary organisations may prove the most effective way to provide energy efficiency advice and to initiate innovative community projects. Local authorities should encourage community groups and local groups of national organisations to play a bigger role in local partnerships, for example in fuel poverty programmes.

8.37 **Central Government should consider additional resources for capacity building in local authorities and the voluntary sector to play a more active role in the energy sector, in particular in support of energy efficiency** (discussed further in Chapter 7).

[3] Royal Commission on Environmental Pollution (2000), recommendation 12

Planning

8.38 A persistent theme of the review has been the problems, either experienced or perceived, that energy projects have in gaining planning permission. Examples presented to us include: renewable energy generation, in particular wind and biomass; new coal mining developments; gas storage plans; electricity generation using coal-bed methane; energy from waste developments, and individual household measures, such as PV, solar hot water heating and external wall insulation, especially in conservation areas. Nuclear projects raise planning issues of particular complexity. Problems are often the result of the different concerns of potential developers and local residents. However, if the UK is to meet environmental, social and economic objectives then a range of new supply- and demand-side measures will have to gain planning permission.

8.39 The Government is reviewing the operation of the planning systems in England and has recently issued a Green Paper.[4] DTLR has also released a consultation document[5] on the treatment of major infrastructure projects by the planning process and is committed to reviewing its national planning guidance on renewable energy[6] as soon as possible. The National Assembly for Wales is also currently reviewing its planning policy guidance and has commenced the process of developing a Wales spatial plan,[7] and the Scottish Executive has recently revised its national planning guidance[8] for renewable energy developments and is currently also carrying out a review of strategic planning.

8.40 The main challenge that planners face is to balance the national costs and benefits of a development against the local costs and benefits. Energy projects must often be sited at or near the primary resources, whereas the energy produced may be consumed elsewhere. The result is that one part of the country may resent bearing what it sees as a cost in order to bring advantage to others. Public participation is an integral part of the planning process. The attitude of local communities to proposals for new energy development is a material consideration and they must continue to have their say in the planning process. (The process of engaging the public in the energy policy debate is discussed further in Chapter 9.)

8.41 A range of actions can help immediately:

- national planning guidance currently only covers renewable energy facilities. As part of the review of all national planning policy guidance announced in the recent Green Paper, **Government needs to make clear when there is a national case for new investment in any energy-related facilities where planning decisions are made by local authorities.** This should be done by establishing the relevant national context for each type of development, whether it be the production of primary energy, energy storage, energy production and distribution, or demand-side measures; and
- given the pace of technical change, information given on technologies within the guidance or in technical annexes to the guidance needs to be continually updated.

8.42 Energy developments are gradually receiving an increased profile in regional guidance and sub-regional plans. However, more rapid progress is required: as we move towards more renewable and decentralised generation and a greater emphasis on demand-side technologies, energy developments should

4 DTLR (2001c).
5 DTLR (2001b).
6 Department of the Environment (1993).
7 National Assembly for Wales (2001).
8 Scottish Executive (2000a).

be given greater prominence within these documents. This should be achieved by:

- **regional planning bodies placing greater prominence on energy issues in regional planning guidance** including incorporation of the results of the recent regional renewable energy studies[9] in England. Regional Development Agencies should set regional targets for renewable energy production in their Regional Sustainable Development Frameworks. These targets should be set initially at indicative levels following the conclusion of the DTI's current review of the studies; and
- placing **greater emphasis on pro-active planning for energy developments at a sub-regional level.** This should include identifying areas that could be appropriate for specific types of developments. If the Local Development Frameworks proposed in the DTLR revision of the planning system are implemented, it will be important that energy developments are well represented within the frameworks.

Planning is a devolved issue (see Box 1.1) and it is for the Devolved Administrations to consider the most appropriate policy for Scotland and Wales.

8.43 Some promising renewable options involve harnessing energy in, or over, the sea. Offshore energy projects could also ease the pressure for land use in the UK. This is beginning to happen for wind projects, and there is potential for wave and tidal stream generation in the future. Currently there is no authorisation process offshore comparable to the planning process onshore: offshore developers must gain a series of consents in order to proceed. There is also no clear vision of how developments will progress offshore over the next few years.

Therefore, the Government should consider the following:

- the onshore planning agencies and the bodies that grant offshore consents need to work closely together. The DTI/Scottish Executive proposal to coordinate the process of gaining a number of different consents for offshore wind is a good example; and
- since, over the next few years, the number of offshore energy developments is likely to increase, there are likely to be conflicts with other offshore activities such as fishing, transport, defence activities, and oil and gas infrastructure. **DTI should develop a policy on strategic offshore issues to inform Government decisions.** While it is the duty of Crown Estates to lease sea-bed rights to potential developers, there is a need for Government to develop appropriate policies on a number of issues, drawing for example on DTI experience with the oil and gas industries. Issues to be addressed include: site selection (this will be primarily for developers, however, Government will need a policy on this); size of offshore developments for which consents can be grante; grid access and rules for developments outside the 12-mile territorial waters zone. This will be particularly important to ensure that the growing momentum behind offshore wind is not lost.

Section 36 & 37 Applications

8.44 Generation projects over 50MW apply for planning permission direct to the DTI/Scottish Executive in accordance with section 36 of the Electricity Act; this covers applications for much of the generation plant currently in existence in the UK. Overhead transmission lines must gain permission under Section 37 of this Act.

[9] All the Government Offices in England and Wales were asked to undertake regional renewable energy studies to assess the potential for renewable energy developments within each region. These studies are now complete and the results are being assessed by DTI and DTLR.

8.45 Some of the larger and more complex generation and infrastructure projects, for example Sizewell B and the North Yorkshire transmission line, have historically suffered from having very long and expensive public enquiries. DTLR are currently consulting on proposals to streamline the planning process for major infrastructure projects[10] and it is likely that these proposals will benefit future projects of this scale.[11]

8.46 In particular, we support the principle set out in these proposals that it is useful to debate common themes of a type of development, such as its technical ability and cost and the establishment of a national policy statement around that type of development, before and separate to an enquiry on the local siting aspects of a project. However, any debate on common themes must seek early and active engagement with a wide range of stakeholders, and must involve the local communities which may be affected.

Summary of Recommendations

Main recommendations

52. **Government** should aspire in the long-term to bring together in one department responsibilities for climate change, energy policy and transport policy (8.13).

53. **Government** should set up a cross-cutting unit (initially based in DTI, described above as the "Sustainable Energy Policy Unit" (SEPU)) to oversee the future direction of energy policy; to implement the findings of the PIU report; and to provide an enhanced energy analytical capability (8.15).

54. **DA(N)** to consider whether responsibility for energy efficiency and CHP policy should be located with other aspects of energy policy (8.19).

55. **SEPU/OST** to develop more detailed proposals for a national Energy Research Centre (8.21).

56. **DTI** to sharpen Ministerial guidance to Ofgem on environmental issues (8.25).

57. **Ofgem** to produce analyses of significant regulatory proposals, taking full account of costs falling on the energy industry and consumers (8.27).

58. **DEFRA/DTI** to carry out a review of low carbon delivery organisations (8.32).

59. **DTLR/DEFRA** to consider additional resources to build capacity in local authorities and the voluntary sector, in particular for energy efficiency activities (8.37).

60. **DTLR with DTI** to update national planning guidance, making it clear when there is a national case for new investment in energy-related facilities (8.41).

61. **Regional planning bodies** to give greater prominence to energy developments in regional planning guidance (8.42).

62. **Local authorities** to ensure that greater emphasis is placed on proactive planning for energy developments in sub-regional plans (8.42).

63. **DTI** should develop a policy on strategic offshore issues for new technologies to inform Government decisions (8.43).

[10] DTLR (2001b).

[11] Projects that may qualify under the new proposals include nuclear plant, thermal power stations with a heat output of 300MW or more, renewable energy generation over 150MW in size, overhead lines with a voltage of 220kV or more, crude oil refineries, some gas storage and large open cast mines. A full list of projects that may qualify is in DTLR's consultation document.

Other recommendations

The European Union

64. An EU energy chapter or other further treaty powers are unnecessary (8.9).

65. There is no need for a European energy regulator (8.10).

National Institutions

66. Industry sponsorship and energy policy-making should, so far as possible, be separated (8.16).

67. DTI should give further thought to the possibilities for establishing a composite Fossil Fuels Authority outside the DTI (8.17).

68. It is essential that the Devolved Administrations are involved with the implementation of the report's findings and the on-going development of energy policy (8.22).

69. There is a continuing need for consultation between the DTI, Ofgem and the industry to ensure that actions affecting onshore and offshore investments are co-ordinated appropriately (8.28).

Regional and local decision-making

70. Local authorities' duties under the Home Energy Conservation Act (HECA) should be modernised to emphasise building local partnerships, providing advice and co-ordinating local programmes (8.35).

71. Local authorities should encourage community groups and local groups of national organisations to play a bigger role in local partnerships (8.36).

Planning

72. Information given on technologies within planning guidance or in technical annexes to the guidance needs to be continually updated (8.41).

73. Energy developments should be given greater prominence within regional guidance and sub-regional plans. Specific measures by which this should be achieved are (8.42):

- Regional Planning Bodies should incorporate of the results of the recent regional renewable energy studies in England.
- Regional Development Agencies should set regional targets for renewable energy production in their Regional Sustainable Development Frameworks.
- If the Local Development Frameworks proposed in the DTLR revision of the planning system are implemented, it will be important that energy developments are well represented within the frameworks.

9. CONCLUDING THEMES

Summary

Binding international commitments for UK GHG emission reductions can only be met through action in the energy system. An overarching statement of energy policy could therefore be "the pursuit of secure and competitively priced means of meeting our energy needs, subject to the achievement of an environmentally sustainable energy system".

The case for significant government intervention in markets on security grounds appears weak at this point in time. The present role of government should instead be in assessing the security risks and taking steps to ensure markets are able to make effective choices on security.

Government should create powerful incentives to create low carbon options that would put the UK in a favourable position to move to a low carbon future.

Innovation needs to play a central role in meeting the low carbon future.

Energy policy should be kept under regular review: in particular, the Government needs to be aware of the need for contingency plans if present policies seem not to be working as expected.

The Government needs to conduct an open public debate about energy systems, covering the issue of security, the shift to a low carbon economy and the role of the various low carbon technologies, including nuclear power.

This radical agenda implies substantial change and widespread public acceptance. The timescales are long, but the time for action is now.

Framework

9.1 In setting future energy policy, the guiding policy principle for government should be sustainable development, requiring the achievement of economic, environmental and social objectives. It is also vital to maintain adequate levels of energy security at all points in time. There will be tradeoffs and synergies between these objectives.

9.2 There is no simple guide to resolving trade-offs, but because greenhouse gas abatement is particularly important among sustainable development objectives and can only be delivered through the energy system, energy policy is likely to give preference to this objective. An overarching statement of energy policy could be "the pursuit of secure and competitively priced means of meeting our energy needs, subject to the achievement of an environmentally sustainable energy system".

Security

9.3 The basic approach adopted in this review is to start from a belief in the power of markets to make effective choices in energy system. The success, within the UK, of the process of liberalisation confirms this. While the review questions whether markets can address all security issues, it gives general endorsement to the market-based approach. The case for significant intervention in markets on security grounds appears weak at this point in time. Rather, the present role of Government is in carrying out assessments of the potential risks to the energy systems and to ensure that the market has taken adequate measures to manage these risks. Some residual intervention is needed. Policy-makers and regulators will need to be constantly alive to the possibilities for under-investment in networks, and for distortions in the incentives to invest in new generation capacity in electricity markets, though the present position is satisfactory.

9.4 Some people may consider that this review takes too relaxed a view of future oil and gas supplies. There is a difficult balance to be struck between a hasty response to new concerns and inaction. The UK will become more dependent on trade for its oil and gas supplies, just as we are already dependent on trade for imports of other basic needs. Trade is generally a means of increasing diversity of supplies. Nevertheless, such a shift brings with it new risks and challenges, and it is not something to which we can be indifferent. It means, for example, that the Government must give greater attention to relations with the countries that we will depend on for supplies.

9.5 So far as gas supplies are concerned, risks may in part be managed by reliance on backup – storage or LNG – in part the answer may be to ensure that we do not become over-reliant on imports from just one country, which may require new international interconnections. But though these problems should be confronted now, they are not pressing, particularly since there is still a lot more production to be had from the UKCS. There are already international mechanisms in place to increase oil security, and growing attention is being paid to ways of securing gas networks. The liberalisation of EU gas markets will add to security since it will increase the ease with which fluctuations in European demand and supply can be accommodated. UK policy should continue to offer active support to this process.

9.6 The review has not been convinced by the argument that, in order to secure diversity of electricity supplies, purchase obligations should be used to carve the market up into pre-determined shares for gas, coal, nuclear, CHP and renewables. The review takes the view that the risks can be managed in other ways. This is not a popular view: there are many interests opposed to what may be seen as an excessively *laissez-faire view*. The approach does not mean that the Government or the regulator can withdraw from active involvement in the development of the market. But the losses from constraining the market in this way would be likely to out-weigh the gains, and the potential risks can be managed. The case for a renewables obligation is special, and relates to the need to develop new low carbon options.

Low carbon policies

9.7 This review identifies a programme of change to be delivered through a new institutional structure. It does not develop a programme of legislation – though it is possible that some legislation might be needed. Nevertheless, it presents a radical agenda. Keeping the UK on a path towards a low carbon economy could not be otherwise.

9.8 The roots of the programme are already contained in existing policy approaches. What is new is the priority accorded to climate change objectives. If big cuts in carbon are required this will require focused attention.

9.9 The RCEP target of 60% reductions in carbon emissions covers a period of some 50 years, which will be characterised by great uncertainty. Nevertheless, if there was to be a target of this kind, a number of important tasks would need to be to be undertaken as soon as possible, some within the next five years. These tasks would comprise detailed policy analysis, the creation of new policy instruments and the reordering of R&D priorities.

9.10 Some of the tasks reflect changes in the framework for decision-making. Policy should:

- move more quickly to determine the right balance of policy instruments – taxes, permits, regulation – in order to create powerful incentives for long-term carbon reduction, particularly where substantial capital investment and technical change are involved. Good policy will normally require a mix of different instruments including actions that directly tackle specific market failures, but the Government should prepare for greater future use of economic instruments that enable the wider environmental costs of carbon to be incorporated into market prices;
- consider the central role of innovation. Innovation often needs to be seen in an international context, but in some cases a UK specific approach may be required;
- consider which measures would most appropriately be taken by the UK unilaterally, or collectively on an EU (or wider international) basis. In this context, decisions would need to be compatible with safeguarding the UK's international competitiveness; and
- consider the appropriate institutional arrangements to deal with the size and complexity of the task involved.

9.11 In establishing the basis for long-term policies, three considerations stand out:

- given the size of the task, involving the transformation of UK energy supply and use, the RCEP objective could not possibly be achieved except as a prolonged, cumulative process, involving, among other things, the progressive adaptation or replacement of most of the existing capital stock;
- adverse underlying long-term trends mean that, even if the measures in the latest Climate Change Programme achieved all the planned CO_2 savings by 2010, at some point thereafter emissions would once again resume an upward trend in the absence of further measures; and
- many of the measures to reduce CO_2 have inherently long lead times as a result of the large-scale capital projects involved, the preparatory work needed to remove technological uncertainty and market barriers and distortions, or the lengthy international negotiations required.

9.12 The timeline for action is set out in detail in Chapter 10. However, immediate priorities include:

- **energy efficiency should be prioritised** at the highest levels of government and a new aspirational target set for improvements in domestic energy efficiency. Ministers should extol the prospects, and throughout the public and private sectors investors should review the possibilities;
- **innovation**, including in energy saving. If the UK can focus on technical challenges – like the challenge of improving efficiency in older homes – then we may make some real breakthroughs. These are potentially major new opportunities for British business;
- **the renewables programme needs to be reaffirmed** and Government needs to be sure that it has in place all the mechanisms needed to meet the targets set for 2010. Some institutional barriers still need to be removed. Thereafter a further target of 20% for 2020 is needed;
- three institutional barriers to renewables have been identified in this review: the treatment of small and intermittent generators in **NETA**; the need for new approaches to **charging for** and running, **local electricity distribution networks;** and the workings of the planning system. An immediate task for the Sustainable Energy Policy Unit should be to monitor progress in removing these barriers. If change is not possible within existing structures, then the use of legislation to remove the barriers will need to be considered; and
- **transport** may not be the most cost-effective area in which to make major new improvements now, but in the longer-term the world as a whole needs to be trying to move away from oil-based transport. As proposed in the *Powering Future Vehicles* consultation, the Government should set targets for and monitor progress towards a low carbon transport sector. Handling the projected growth in aviation energy use and CO_2 emissions must become a priority for the transport community.

Fuel poverty

9.13 Achievement of the social objective to overcome fuel poverty is an important government objective, particularly in the short term. The UK Fuel Poverty Strategy target is that no vulnerable household will be in fuel poverty by 2010, with other households being tackled once progress has been made in the priority vulnerable groups. The recommendations in this review will influence the factors determining the number of households in fuel poverty (see Annex 4). Additional improvements in energy efficiency will further reduce the numbers suffering from fuel poverty though some of the recommendations in the review will raise costs and probably prices. This establishes the importance of early progress towards fuel poverty targets as a means of reducing the constraint on environmental and security policies. Government should consider other means to tackle residual fuel poverty in a world where energy prices may be higher than today.

Managing risk: responding to uncertainty and new information

9.14 It is central to our recommendations that governments should accept the uncertainties surrounding energy policy interventions. We cannot know for sure how successful given policy initiatives will be. Government can set the framework within which markets operate, but it cannot determine precisely which technologies will work best or which opportunities will prove most commercial. Although the review is generally opposed to picking winners, some generalised preferences are necessary in order to get low carbon technologies on the move. Similarly, security concerns mean that some interventions are needed now and further intervention could be needed later if adverse trends become apparent.

9.15 Government's aim should be to create options for the future and, so far as possible, to preserve some flexibility of response. This must not be taken as a recipe for inaction: quite the reverse. Action is needed to assist innovation and to create new options, and action is also needed to manage risk.

9.16 Some decisions that are recommended for the present must be reviewed through time to ensure that they are working as planned. If they are not, then various means of mitigation need to be considered. The likelihood that particular mitigation measures would be adopted changes over time. Thus, while the initial reaction to the apparent failure of a policy should generally be to try to improve the original policy framework, longer-term signals that things are not working as planned are likely to call forth more drastic remedies, until finally the original approach should be abandoned. These ideas are developed further in Chapter 10.

9.17 One consideration is the time taken to respond, once a decision has been taken to change direction. Some indication of response times is given in Annex 7.

Opening the debate

9.18 The implementation of an ambitious low carbon policy would be a demanding task. The public should be in no doubt about the political commitment behind the proposals. Changes like these could not be produced as a result of quick technical fixes: technology has a large part to play, but just as important are changes in attitudes and assumptions. Commitment to a low-carbon energy policy would imply a general shift in perception. A wide range of actors within and outside the energy industry would need to evaluate their energy policy decisions, and gradually move towards low carbon use. Given the inertia in the energy system, and the fact that the most low carbon technologies are barely part of the current conventional energy system, a change of direction would be difficult to achieve. It would be wrong to imagine that everything can be "win-win": there are some hard choices and there will be losers as well as winners. For this reason the Government needs to take the issues to the public soon.

9.19 The PIU review has, to the extent possible, been conducted in the open. A wide range of contacts has been made with representative bodies, NGOs, the energy industry and, by correspondence, with members of the public. But it has not engaged fully with members of the public. This was deliberate: the review was conducted against a rapid timescale and contacts were inevitably compressed into about four months. A proper process of public consultation and debate would take longer and be much more intensive. During the review, proposals were made to the PIU for a process of public engagement. This should constitute a central part of the implementation of the findings of the review (see Chapter 10).

9.20 This debate has several facets:

- one is the potential role of nuclear energy in future energy systems. This is a difficult and polarised debate. It will be interesting to see how far more information can resolve the differences but ultimately different values are at stake;
- there is an equivalent debate about the future contribution of renewable resources: this will be big, but quite how big is a matter of dispute. Again some of these differences can be resolved by more information and analysis; and

- more active involvement of consumers and communities, coupled with greater understanding by customers of the impacts of, and the potential for, altering their energy choices would be a valuable tool in meeting the objectives of sustainable development. In part this involvement can be brought about by new technologies, like metering, but it would also reflect a different process of public discussion and debate about energy options, for example in the planning system.

9.21 This review has not outlined a blueprint for a new energy economy. It establishes the first step only. Sustainable energy is vital for the UK in the medium to long run. It needs to be championed within government. But the new agenda will take all the participants in energy markets – producers and consumers – into new realms. This review will be the start of a debate rather than its conclusion.

9.22 A radical agenda implies substantial change, and widespread public acceptance of the need for change. The nation must not be lulled into inaction by the focus of much of the expert debate on long time scales, and on energy systems in a future that will belong mainly to our grandchildren. The time for action is now and all players in the energy system have a role to play. Given that there is considerable inertia in the system, and that most low carbon technologies are not part of the conventional energy system, a change of direction will be difficult to achieve. It would require considerable clarity of purpose in all parts of the Government.

10. IMPLEMENTING THE RECOMMENDATIONS

Introduction

10.1 The challenge of this review was to develop a vision for energy policy for the next fifty years and a strategy and practical steps towards it. The aim of this Chapter is to set out the timing of the action required to implement the main recommendations. It does not cover all the recommendations made. The full list of recommendations can be seen at the end of each Chapter.

10.2 Given the remit of the review, the recommendations relate predominately to the central government departments. However, as discussed in Chapter 1, a number of key areas relating to energy policy are devolved matters in Scotland and Wales. Given the importance placed on these aspects of energy policy, it is clearly essential that the Devolved Administrations are involved with the implementation of these recommendations. This will include close liaison with Whitehall, in particular through direct participation in the Sustainable Energy Policy Unit, and the development and implementation of policy on devolved issues.

Timeline for action

10.3 Some of the main recommendations, if they are accepted, need to be acted upon immediately; others are pointers to future action. It is important to recognise issues of timing. The review emphasises the importance of allowing energy policy to evolve as new information arrives. In some cases, given the long lead times associated with energy market investments, action should not be delayed. In others, given uncertainties – about international co-operation, technologies, costs and demand – it makes sense to wait until more information has accumulated with the passing of time

10.4 The main recommendations are divided into three time scales: those that require immediate action; those that need to be implemented over the next three to four years; and those that can afford a slightly longer time scale, taken here to be between five to ten years. Each main recommendation has a lead department and implementation date identified; and we would expect the Ministerial Sub-Committee on Energy Policy (DA(N)), chaired by the Deputy Prime Minister, to take an active role in ensuring that these recommendations are implemented within the time scales set out below.

Immediate action required in the follow-up to the review

10.5 There is some immediate action required by Government in response to this review:

- Following the publication of this review, the **DTI** should start a process of full public consultation and engagement in energy policy. The debate on long-term energy policy was started by the publication of the RCEP report in June 2000. The debate should now be starting to move towards a conclusion. This means that the Government should publish its response to this report, and separately to that of the RCEP, well before the end of the year. These responses, which should have been informed by public views on energy and environmental issues, should follow a process of public engagement that must be set in train soon. By **March 2002,** the **DTI** should start to involve the wider public in these debates.

One technique that might be used is that of the Citizens Panel and the Consensus Conference.[1] This first round of public debate should be completed **by August 2002.**

- Following this public consultation, the **DTI** should publish a response on behalf of the Government by **October 2002.** This response could take the form of a Government statement to Parliament or a White Paper. It would foreshadow any new legislation and would indicate whether the general statement of the overall objective of energy policy should be redefined.
- **Government** should set up a cross-cutting unit (initially based in DTI, described above as the **"Sustainable Energy Policy Unit"** (SEPU)) to oversee the future direction of energy policy; to implement the findings of the PIU review; and to provide an enhanced energy analytical capability. A shadow unit needs to be in place by **May 2002,** with the unit being fully operational by **October 2002**.
- The Unit, initially located in the DTI, would report to the Energy Minister and through him to DA(N), chaired by the Deputy Prime Minister, which should have responsibility for overseeing the implementation of this review. The Committee should formally review the progress of implementation 12 months after the Government statement on the review (and, if required, 24 months after the Government's statement).
- The Ministerial Group on Low-Carbon Vehicles and Fuel, should be responsible for overseeing the implementation of the final Powering Future Vehicles strategy, working alongside DA(N).

Main recommendations that should be implemented over the next three years

10.6 There are some main recommendations that should be implemented almost immediately, and in any case within the next three years:

2002-5

Framework recommendations

- Where energy policy decisions involve trade-offs between environmental and other objectives, then environmental objectives will tend to take preference over economic and social objectives. The **DTI** should redefine its general energy policy objective. The new objective could be "the pursuit of secure and competitively-priced means of meeting our energy needs, subject to the achievement of an environmentally sustainable energy system" **(by end 2002)** (3.35 and 3.37).
- There is no simple way to resolve residual trade-offs. Each case will demand separate analysis. It is recommended that to assist this process **HMT** should establish, and keep under regular review, shadow prices for key environmental externalities and other non-economic policy objectives **(by end 2002)** (3.44).
- **HMT and DEFRA** should give early consideration to expanding the use of carbon valuation through taxes or tradable permits to cover as much of the energy market as possible. This could involve expansion or modification of the current Emissions Trading Scheme and should ensure that UK companies could participate in international carbon trading schemes,

[1] A consensus conference is a forum at which a citizens' panel, selected from members of the public, questions experts (or witnesses) on a particular topic. The Panel then assesses the responses, discusses the issues raised, and reports its conclusions at a press conference. A distinctive feature of this approach is that the citizens' panel is the main factor throughout. Consensus conferences are especially suited to dealing with controversial issues of public concern at a national level which are often perceived as being too complex or expert dominated. Source: *UK Consensus Conference on Radioactive Waste Management, Executive Summary.*

including the draft EU scheme, as soon as these are introduced **(by end 2004 and on-going thereafter)** (3.79).

Security recommendations

- The recently established **DTI/Ofgem Working Group on Security of Supply** (WGSS) should expand its existing activities to take on responsibility for monitoring all of the risks to security of the energy system discussed in Chapter 4. In order to do this effectively it will need to:
  - expand its membership to include representatives from the FCO, since many of the risks have an important international element **(immediate);**
  - build on the Group's existing monitoring indicators to monitor all risks to security of supply discussed in Chapter 4 – one completely new area for the group will be risks to oil supplies **(by the end of 2002);** and
  - conduct ongoing monitoring of all of these indicators, in order to establish how the risks alter over time **(ongoing)** (4.112).
- **FCO** should ensure that foreign policy is more fully integrated into the energy policy process (**ongoing**, but to start immediately with their integration into the WGSS) (4.60 and 4.65).
- **DTI** should continue to champion the liberalisation of European energy markets and support the European Commission in pressing forward with the relevant Directives (**immediate and ongoing**) (4.60).
- There is no case for restricting the share of gas in the power sector at this time. However, the **WGSS** should monitor this situation, in particular to assess the market signals surrounding gas prices (**ongoing, but to have started by end December 2002**) (4.27).
- **DTI** should carry out an assessment of the cost-effectiveness of policy responses that could enhance security of the system, some of which are suggested in Chapter 4. These results should inform decisions on any contingency action taken in response to the monitoring (**by end 2003**) (4.28).

Low Carbon recommendations

- **DTI and OST** should take steps to increase the level of funding for low carbon energy R&D. The priority areas of the Chief Scientific Adviser's Research Review Group represent a good starting point (**immediate and ongoing**) (7.3).
- **DEFRA** should develop energy efficiency indicators, targets and monitoring mechanisms for each sector of the economy (**by end 2003**) (7.9).
- **DEFRA** should develop a Strategy for Home Energy Efficiency to set out a clear, long-term framework and the policy instruments that might be used in this strategy. This should include an aspirational target for home energy efficiency of 20% improvement by 2010 followed by a further 20% improvement by 2020 (**by September 2002**) (7.11).
- In order to encourage a range of renewable options, and maximise the chances of rapid and long-term learning and cost reductions, **DTI** should set a firm target of 20% of electricity to be supplied from renewables for 2020 (**immediate**) (7.63).
- In respect of NETA, **Ofgem** should develop transitional measures in parallel to be ready to be implemented (**by January 2003**) in case current measures are unsuccessful in helping small generators. **DTI** should consider potential legislation to move this objective forward (**for immediate consideration, but process to have finished by end 2003**) (7.67).

- **DTI** should take the necessary actions to keep the nuclear option open (**ongoing**) (7.78).
- **DTI** should decide whether to support a programme for carbon capture and sequestration, and if so by what means (**by end 2003**) (7. 91).
- **DTLR** should work with EU partners and motor manufacturers to secure further improvements in the energy efficiency of road vehicles and to open options for low carbon fuelling in the longer-term **(ongoing)** (7.96).
- **DTLR** should prioritise discussion of taxation and other measures to manage aviation demand in EU and international forums (**immediate and ongoing**) (7.102).

Institutional framework recommendations

- **DA(N)** to consider whether responsibility for energy efficiency and CHP policy should be located with other aspects of energy policy (**by end 2003**) (8.19).
- **SEPU and OST** to develop more detailed proposals for a national Energy Research Centre to take forward co-ordinated low carbon R&D (**by September 2002**) (8.21).
- **DTI** to sharpen Ministerial guidance to Ofgem on environmental issues (**by end 2002**) (8.25).
- **Ofgem** to produce comprehensive analyses of significant regulatory proposals, taking full account of the costs falling on the energy industry and consumers (**immediate and ongoing**) (8.27).
- **DEFRA** and **DTI** to carry out a review of low carbon delivery organisations (**by end 2003**) (8.32).
- **DTLR** and **DEFRA** to consider the need for additional resources to build capacity in local authorities and the voluntary sector, in particular for energy efficiency activities (**by end 2002**) (8.37).
- **DTLR** in liaison with **DTI** and others, to update national planning guidance, making clear the circumstances where there is a national case for new investment in energy-related facilities (**by end 2003**) (8.41).
- **Regional planning bodies** to give greater prominence to energy developments in regional planning guidance (**immediate and ongoing**) (8.42).
- **Local authorities** to ensure that greater emphasis is placed on proactive planning for energy developments in sub-regional plans (**immediate in current planning arrangements, then subject to DTLR reform of planning**) (8.42).
- **DTI** should develop a policy on strategic offshore issues for new technologies to inform Government decisions **(by end 2002)** (8.43).

Main recommendations that should be implemented over the next ten years

10.7 There are other main recommendations that will require a slightly longer time-scale to implement:

2005-10

Security

- **SEPU** and **WGSS** to continue to monitor the indicators of security of supply (**ongoing**) (4.112).

Low carbon recommendations

- **DTI** should establish the renewable energy support mechanisms to ensure that the 2020 target of 20% is met **(to be in place by the end of 2008**) (7.64).

- For network investment for embedded generation, **Ofgem** should ensure that that the recommendations of the EGWG are implemented (**by end 2005**). **DTI** should consider legislation to move this forward in the event of obstacles to progress (**start considering legislation early in 2005 if necessary**) (7.67).
- Ofgem should ensure that future changes to electricity trading and grid access arrangements do not discriminate unfairly against renewable and CHP generation **(ongoing)** (7.67).

Institutions

- **Government** should aspire in the long-term to bring together in one department responsibilities for climate change, energy policy and transport policy **(ongoing)** (8.13).

Next Steps

- **DA(N)** to oversee the 2007 Energy policy review (discussed below).

Involving the Devolved Administrations

10.8 As policy evolves, Whitehall departments will need to ensure that their actions are co-ordinated with the parallel development of policy in the Devolved Administrations. This can partly be done through the SEPU, but other continuing contacts are also needed. Since the energy situation in the territories of the Devolved Administrations is distinctive, it seems inevitable that there will differences in timing and emphasis. For example, Scotland's electricity balance is currently highly dependent on nuclear power, while there is potentially a huge capacity for renewable generation. These factors are likely to influence the focus of the Scottish policy debate. In Wales too there are distinctive views about the balance between renewables and other options. Energy policy in Northern Ireland is fully devolved, but new policies will need to be related to parallel GB, and indeed EU, developments.

The need for periodic reviews

10.9 This review and its recommendations have focused on the steps needed to start the process of change, within the context of a fifty-year period. It does not present a detailed plan for energy systems to 2050. The uncertainties inherent in the energy markets dictate that such a review could not have been otherwise. Maintaining the drive towards a low carbon future will require constant monitoring of the energy system by the SEPU. It will also require a series of periodic reviews to take stock of the progress made in relation to the overall goal and to see what, if any, changes to policy are required.

10.10 **We recommend that the first of these reviews should be carried out in 2007. Within the time scale to 2007**, a number of main events are likely to have happened and sufficient time will have elapsed to allow for the trends since the review to be observed. These key events are described in Box 10.1.

10.11 2007 would therefore seem a natural point at which to carry out a full review of the progress made. An important element of the 2007 review will be a re-assessment of the issues highlighted in this review. In many cases, the passing of time will have brought a greater level of certainty.

10.12 The **main questions for the 2007** review will be:

What have been the main developments, both in the UK and globally, since the 2001 review in each of the following areas:

- *International climate change agreements;*
- *low-carbon technologies:* energy efficiency; CHP; renewables; nuclear, carbon sequestration and transport;

- *fuel mix:* the share of each fuel in the primary fuel mix;
- *liberalisation of the European energy markets;*
- *security of supply;* and
- *institutional events?*

Have the policy recommendations from the 2002 review been successful? And if not, has this been a fault with the policy? Or is there a more fundamental problem inherent in the energy system?

What future policy recommendations are appropriate in relation to the low carbon technologies, fuel mix and fuel sources?

10.13 A major theme of this review has been the risks and uncertainty inherent in the energy market. Uncertainty about government policy can itself add to market uncertainty. If Government periodically sets out a vision for energy policy, and restricts major changes in policy to these reviews, this should help to reduce some of the uncertainty. Thus, an important function of the 2007 review will be to re-state the long-term vision for energy policy. It should also set the date for the next periodic review.

Ad hoc reviews

10.14 In an ideal world there would be no need for changes in energy policy between each periodic review. However, events can happen that mean that the path on which energy systems are moving has to be temporarily, or even fundamentally, changed.

10.15 Although, by their very nature, such events are impossible to predict, the continuous assessment of long-term trends in the energy market carried out by the SEPU will put the UK in a better position to spot quickly the fundamental shifts to the energy system. Further, continuous analysis will put the UK

Box 10.1: Events that are likely to have happened by 2007

Events related to the low carbon agenda:

- the shape of post-Kyoto agreements will have become clearer;
- the impact of latest EU directives on acid rain will be more apparent;
- the EU carbon emissions trading scheme should have been introduced;
- the Renewables Obligation will have been subject to a review;
- more of the Magnox stations will have closed; and
- DEFRA's review of nuclear waste will have reached its conclusions.

Security related events:

- the European energy markets should have been liberalised; and
- the UK may have moved from a position of net exporter to that of net importer for gas and, will be moving much closer to that position for oil.

Institutional events

- the DTLR ten-year plan for transport will be reaching its final stages;
- the DTLR review of the planning mechanisms will have been implemented; and
- further progress will have been made to reduce fuel poverty.

Government in a better position to react in a timely and appropriate manner to adverse events, or trends, when they occur.

10.16 In the event of such adverse developments there may well be a case for ad hoc reviews of the basis for policy. Examples of the type of events, or trends, that might warrant such ad hoc review include:

Low carbon technologies

- a low carbon future is rejected by the international community;
- the take up of low carbon technologies, in particular energy efficiency and renewables, has been slow and/or much more expensive than anticipated at the time of this review; and
- the development of new low-carbon technologies, for example new transport fuels and renewable energy technologies, is much slower than envisaged in this review.

Security

- EU liberalisation fails to proceed at the speed set out in the EU gas directive, and hence there is a lack of a large and deep liquid market for gas;
- there is a sustained period of high and volatile energy (especially oil and gas) prices;
- there are increasing signs that the investment required to maintain the systems, including the networks, are not likely to be made; and
- there is a fundamental shift in the reliability of the oil and gas exporting countries.

Engaging the public

10.17 Monitoring the system and carrying out reviews are only part of the story, and will not in themselves be enough. If the UK is to meet the vision set out in this review, there needs to be a fundamental change in the way that we view, and use, energy. In pursuing a new approach to energy policy, the Government needs to understand the views and concerns of the general public. The Government has a duty to explain its own approach to the public, but it also needs to gather feedback. Following the publication of the PIU review, there will be a period of debate on the recommendations. However, this is only the beginning. And the consultation carried out in the aftermath of this review should be seen as only the beginning of a longer programme of public engagement in energy issues.

ANNEX 1. THE ROLE OF THE PERFORMANCE AND INNOVATION UNIT

The Performance and Innovation Unit

1. The creation of the Performance and Innovation Unit (PIU) was announced by the Prime Minister on 28 July 1998 as part of the changes following a review of the effectiveness of the centre of government by the Cabinet Secretary, Sir Richard Wilson.

2. The PIU's aim is to improve the capacity of government to address strategic, cross-cutting issues and promote innovation in the development of policy and in the delivery of the Government's objectives. The PIU is part of the drive for better, more joined-up government. It acts as a resource for the whole of government, tackling issues that cross public sector institutional boundaries on a project basis.

3. The unit reports direct to the Prime Minister through Sir Richard Wilson. A small central team helps recommend project subjects, and manages the unit's work. Work on projects is carried out by small teams assembled both from inside and outside government. About half of the unit's current project team staff are drawn from outside Whitehall, including from private sector consultancies, think tanks, NGOs, academia and local government.

4. Comprehensive information about other PIU projects can be found on the PIU's website at http://www.piu.gov.uk

ANNEX 2. PROJECT TEAM, SPONSOR MINISTER AND ADVISORY GROUP

The report was prepared by a multi-disciplinary team, drawn from the public and private sectors, and guided by a Ministerial Sponsor and Advisory Group with Government and non-Government representation.

The Team

The team was led by Nick Hartley, on secondment from OXERA Consulting Ltd. Catriona Laing, Team Leader for the Resource Productivity and Renewable Energy project (on secondment from Department for International Development), worked with Nick Hartley on managing the integration of the energy aspects of the two projects.

The project team consisted of the following:

- Stephen Aldridge – PIU, Chief Economist
- Sam Armstrong – on secondment from Environmental Resources Management Ltd
- Allan Brereton – PIU
- Jake Chapman – part-time team member, National Energy Services Ltd
- Ian Coates – PIU, Government Economist
- Emily Corsellis – on loan from the Department of Trade and Industry (DTI)
- Nick Eyre – on secondment from the Energy Saving Trust
- Robert Gross – on secondment from Imperial College Centre for Energy Policy and Technology
- Alison Kilburn – PIU, Government Economist
- Gordon MacKerron – on secondment from National Economic Research Associates
- Catherine Mitchell – on secondment from the Centre for Management under Regulation, Warwick Business School
- Bill Nickerson – on secondment from the Massachusetts Institute of Technology (June to August 2001)
- Richard Penn – on loan from DTI
- Alison Sharp – PIU
- Iain Tomlinson – PIU
- Shane Tomlinson – PIU

Consultants to the project team provided expert input on a part-time basis during the course of the analysis. The project team itself is responsible for the report's finding and final recommendations.

- John Chesshire, Freelance Consultant
- Malcolm Eames, Policy Studies Institute
- Malcolm Fergusson, Institute for European Environmental Policy
- David Milborrow, Freelance Consultant
- Robin Smale, OXERA Consulting Ltd
- David Smol, ILEX Energy Consulting Ltd
- Goran Strbac and Nick Jenkins, University of Manchester Institute of Science and Technology

Sponsor Minister and Advisory Group

The team was greatly assisted by being able to draw on the expertise and advice of its Sponsor Minister and Advisory Group. The team gratefully acknowledges the advice and time given by each Advisory Group member.

Brian Wilson Minister for Industry and Energy, DTI (Sponsor Minister)

Michael Meacher Minister for the Environment, DEFRA

Paul Boateng Financial Secretary, HM Treasury

Peter Hain Minister for Europe, FCO

David Jamieson Parliamentary Secretary, DTLR

George Foulkes Minister of State, Scotland Office

Don Touhig Parliamentary Secretary, Wales Office

Anna Walker DTI (replaced by **Geoff Dart**, November 2001)

Richard Bird DEFRA

Harry Bush HM Treasury

Chris Segar FCO

Geoffrey Norris Senior Policy Adviser, No 10

Callum McCarthy Chairman of GEMA and Chief Executive of Ofgem

David King Government Chief Scientific Adviser

Sir Tom Blundell Chair, Royal Commission on Environmental Pollution

Paul Jefferiss RSPB

Tony Cooper Prospect

Sir John Collins Chief Executive, the Vestey Group and Chairman of the DTI Energy Advisory Panel

Ann Robinson energywatch

Geoff Mulgan Director, PIU

ANNEX 3. ORGANISATIONS CONSULTED AND SUBMISSIONS RECEIVED

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AES Limited

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Akintewe, Maureen

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Allday, Con

All Party Parliamentary Coalfield Communities Group

Allsobrook, Christopher

Alstom UK

Alun L Shaw

Amalgamated Engineering and Electrical Union

Amerada Hess

Amos, J H

Architects & Engineers for Social Responsibility

Arthur D Little

Ash, Sir Eric, et al

Assirati

Association for the Conservation of Energy

Association of Coal Mine Methane Operators

Association of Electricity Producers

Atkinson, Sean

Atomic Energy of Canada Ltd

Audland, Sir Christopher

Babtie Group

BAE Systems

Baker, Elizabeth

Baker, Emma

Ball, Alex

B & Q plc

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Berry, Andrew and Frances

Beuker, Jenny

BG Group

Biddulph, Tim

Biox Consultants

Bitor

Bizz Energy

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Bloodsworth, Colin

Blundell, Neil

British Nuclear Energy Society - Young Generation Network

BNFL

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BOC Group

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Bodenham, Paul

Bond, Graham
Bond, John
Border Biofuels
Borman, Michael
Bowman, A I
Bowman, Graeme
BP
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Bradley, Stephen
Braid, Dr Neil
Brake, Joe
Brake, Tom
Brassington, A R
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Bringing the Climate Criminals to Justice
British Association for Biofuels and Oils
British Association of Colliery Management
British Biogen
British Cement Association
British Energy
British Energy Association
British Energy Nuclear Industry Forum
British Nuclear Energy Society
British Sugar
British Wind Energy Association
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Brown, Mark
Brown, Hilary
Brownlow, Julia
Bruley, Clive
Brutton, Florence
Buckley, Carolyn
Buckley, David
Butler, Kelly
Button, John
Buxton, John
Bywater, Lucy
Cabinet Office European Secretariat
Cain, Anthony
Cairns, Professor R A
Callaghan, Sue
Calvert, Jack and Ann
Campaign for the Protection of Rural Wales
Carbon Trust
Cargill plc
Carpenter, Chris
Carroll, Malcolm
Castagnera, Christopher
CBI
Centre for Better Homes plc
Centrica plc
Channell, Oliver
Chatham House
Chatfield, David
Chemical Industries Association
Chown, Katie
Christian Ecology
City and Council of Swansea
Clarke, Tasha
Clearvision International
Cloot, Peter and Sheila
Coal Authority
Cobb, Rosanne
Combined Heat and Power Association

Commission for the European Union, Directorate General for Energy and Transport

Communique PR

Confederation of UK Coal Producers (COALPRO)

Conoco

Confederation of Renewable Energy Associations

Confederation of UK Coal Producers

Consumers Association

Conway, Vida

Cook, Lindsey

Coombe, Miles

Coppice Resources Ltd

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Cottenden, Karen

Cottrell, Sir Alan

Countryside Agency

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Cowell, Charlotte

Cowper-Lewis, Meg

Cox, Nicholas

Cumbrians Opposed to a Radioactive Environment (CORE)

Corus

Country Land and Business Association

CPRE

CREA

Cresswell, P S

Crown Estates

Crozier, Richard

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Edwards Energy Limited

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Energy Action Scotland

Energy Advisory Panel

Energy Club

Energy from Waste Association

Energy Intensive Users Group

Energy Saving Trust

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Environment Agency

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EURATOM-UKAEA Fusion Association

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Fellowes, Brian

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Finnegan, Sarah

First Renewables

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Forestry Commission

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Forward Strategy Unit, Cabinet Office

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Fox, John

Fraser, Barbara

Friends of Eden, Lakeland and Lunesdale Scenery (FELLS)

Friends of the Earth

Friends of the Earth (S D Eades)

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Fremlin, J H

Fryer, Andy

FT Energy

Fuel Cell Power

Fuel Cell World

Gaffney Cline Consultants

Gammon, Christopher and Linda

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Gas Forum

Gas Industry Emergency Committee

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Gilroy, Dr K S

Global Commons Institute

Global Oil Watch

GMB

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Gomersall, Fiona

Goodwin, Jenny

Grainger, Anne

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Grimshaw, Jane

Haines, Professor M G

Hackney, Janet

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Hayles, J M

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HM Treasury

Holland, Catherine

Holland, Philip

Holliday, Professor Sir Frederick

Hondros, John

Hopcraft, Keith

Horsler, Andrew

Hubble, Dr David

Hughes, Dick and Angela

Hugill, Jan

Hyder

ICCEPT

Iddon, Mike

Impax Capital Corporation Limited

Incoteco (Denmark) ApS

Independent Chief Executive's Forum

Industry Leadership Team

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Inglis, Graham

Innogy

Institution of Civil Engineers, The

Institute of Energy

Institution of Professionals, Managers and Specialists

Institute of Energy and Sustainable Development

Institute of Energy

Institute of Nuclear Engineers

Institute of Physics

Institute for Public Policy Research

Inter-Department Analysts Group

International Energy Agency

Intronic

Ireland, D E

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JM Associates

Joels, Judith

Jones, Catherine

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Jukes, Martin

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Kemp, Jonathan

Kemp, Martin

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Kirk, Dr Andrew

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Lattice Group

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Lawrence, Rachel

Lehman, Peter

Lewis, David

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Linnegar, Simon

Livingstone, Steven

Llewelyn, John

Local Government Association

London Electricity

Lonsdale, Jane

Lord Brook, Chairman, House of Lords Select Committee on Energy

Lord Ezra

Lord Hardy of Wath

Ludwig, Blake

Lyon, Stephanie

Mackenzie, Elspeth

Mackey, Kate

Macnee, Lorna

Major Energy Users Council

Marathon Oil UK Ltd

Marsden, Heather

Mathieson, Jennifer

Matthews, Roy

Maybank, Janda

McGovern, Donna

McNeill, Paula

Mears, Laura

Melzack, Geneva

Merritt, A

Micro Power

Middlemiss, Nigel

Middleton, Andrew

Milborrow, David

Millar, June

Miller, Emma

Miller, Patrick

Mills, R B

Mining Scotland Ltd

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Morrison, Jean

Moulton, Anna

Mulhall, Peter

National Assembly for Wales

National Association of UK Licensed Opencast Operators (NALOO)

National Energy Association

National Farmers Union

National Grid

National Lotteries Opportunities Fund

NEMEX 2001

NERA

Newbery, Professor David

Newell, Christopher

Nirex

NGC

NNC Ltd

NOF

No Opencast

Northern Electric

Northern Ireland Department of Enterprise, Trade and Industry

Norwegian Embassy

Nottingham and Derbyshire Local Authorities Energy Partnership

Nuclear Free Local Authorities

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Octagon Energy Ltd

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OFREG

Office of Science and Technology

Oil Depletion Analysis Centre

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Powergen

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Royal Society

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Scotland Office

Scottish and Southern Energy

Scottish Coal

Scottish Conservative MSP Group

Scottish Council for Development and Industry, The

Scottish Environment Protection Agency

Scottish Executive

Scottish Natural Heritage

Scottish Opencast Action Group

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Social Exclusion Unit

Society of Motor Manufacturers and Traders

Solar Century

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Solomon, Justin

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Stokes, Susan

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Stuart-Anderson, J

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Sustainable Energy Task Force (CAN-UK and LINK)

Sustainable Development Commission

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Talbot, Viv

Talisman Energy

Tamaris Energy

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Targett, Anthony

Tasker, Samantha

Teearu, Tina

Teeside Power

Tickell, Sir Crispin, et al

Thompson, Dr K

Thompson, Neil

Thorp, David

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TXU Europe Group plc
Uglow, P
UK Advanced Power Generation Task Force
UK Coal Mining
UK Coal plc
UK Offshore Operators Association Ltd
UK Permanent Representation, Brussels
UK Petroleum Industry Association
UK Power Sector Group
UNISON
United Utilities
Universities Nuclear Technology Forum
University of Manchester
Upton, Anne
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US Department of Energy
US Embassy London
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Valentine, Gilbert
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Waring, Kit
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Warrington, Julie
Waterson, Joan
Watson, L C
Welsh Anti Nuclear Alliance
Wenke, Stefanie
Whittle, Kate
Wilenius, Mr and Mrs
Williams, Chris
Williams, Clive
Williams, Mark
Williamson, Gillian
Willis, Helen
Wills, Helga
Wilson, Helen
Wilson, Paul
Wilson, Richard
Windsor, Colin
Witt, Nicholas
Wolff, Gerry
Woodlands Trust, The
World Fuel Cell Council
World Nuclear Association
Wright, Sarah
WWF
Yorkshire Coal Task Force
Zadurian, Natalie
ZEPG Group

ANNEX 4. IMPACT OF ENERGY REVIEW RECOMMENDATIONS ON FUEL POVERTY

1. A fuel poor household is one that cannot afford to keep adequately warm at reasonable cost. The most widely accepted definition of a fuel poor household is that it is one which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth. This is generally defined as 21°C in the living room and 18°C in the other occupied rooms (temperatures recommended by the World Health Organisation).

2. The Government launched its UK Fuel Poverty Strategy on 21 November 2001. This sets out how the Government and the Devolved Administrations will tackle fuel poverty in the UK and sets a target for vulnerable households to ensure that by 2010 no older householder, no family with children, and no householder who is disabled or has a long-term illness, need risk ill health due to a cold home.

3. Recommendations for policy change made in the energy review have been analysed for their potential impact on the number of households in fuel poverty. Fuel poverty is caused by a combination of factors including:

- energy efficiency in the home;
- fuel costs; and
- household income.

4. There are significant difficulties in estimating the impact of changes to 2010, 2020 and beyond due in particular to wide potential variations in fuel prices. For the purposes of estimating the effects of price changes on future numbers of households in fuel poverty, the Fuel Poverty Strategy proposes that a reasonable range of price movements between 1999 and 2010 would appear to be:[1]

- for domestic gas prices – plus 15% to minus 10% in real terms
- for domestic electricity prices – plus 5% to minus 2%

5. These figures include:

- the rising trend in fossil fuel prices in international markets;
- the downward pressure through competition and regulation;
- a potential 4% increase to electricity prices to 2010 due to the Renewables Obligation; and
- a 1.2% increase in gas and electricity prices due to the Energy Efficiency Commitment to 2005.

It is emphasised that possible price movement may fall outside these ranges, primarily because of uncertainty about the future path of fossil fuel prices and, to a lesser extent, the impact of regulation on distribution and transmissions costs.

6. If these extremes were realised, the DTI estimates that the number of households in fuel poverty could either increase by 0.8 million or fall by 0.3 million.[2] These figures do not include the impact of energy efficiency improvements in the housing stock or growth in income levels, so any increases could be significantly lower. The uncertainties in fuel price projections make more detailed analysis unproductive.

[1] DTI, DEFRA (2001), para 3.30. The range of possible price movements identified takes account of plausible changes in fossil fuel prices and the Energy Efficiency Commitment to 2005. For electricity they also take account of distribution and transmission price controls and the Renewables Obligation, whilst for gas they take account of efficiency improvements.

[2] DTI, DEFRA (2001), para 3.32. The figures cover the two definitions of fuel poverty discussed in the Strategy (including and excluding Housing Benefit and Income Support for Mortgage Interest) to give the widest possible range of changes.

7. Within this context of wide future uncertainty, three sets of energy review recommendations were analysed for their potential impact on the number of households in fuel poverty: support for energy efficiency, support for renewables and infrastructure changes. These were the areas thought most likely to influence fuel prices and fuel poverty.

8. An extension of the **Energy Efficiency** Commitment from 2005 to 2010 could lead to an increase in fuel prices of approx 1%.[3] Average fuel bills for low income households over the same period could reduce by around 1.2%[4] due to the energy efficiency improvements provided through the Commitment. The net result for fuel poor households may be a small fuel bill reduction to 2010 with benefits continuing to accrue beyond that date.

9. The proposal for extension of the **Renewables Obligation** to 20% to 2020 would not create an additional price effect to 2010 but could increase electricity prices by around 5-6% to 2020.[5] Based on the DTI estimates referred to above, this price change could today result in up to about 1/2 million additional households falling into fuel poverty. When looking to 2020, it is reasonable to assume that improved energy efficiency will reduce the vulnerability of households to falling back into fuel poverty (noting the difficulty of improving energy efficiency in households without cavity walls and not linked to the gas network), and so the impact will most likely be smaller.

10 The proposals for developments in **infrastructure** are not considered to have a significant impact on fuel prices to 2010. However, the implications of issues raised in the review, including carbon valuation, could lead to fuel price increases in the longer term. (The energy review has not considered the issues surrounding extension of the gas network and its potential impact on the number of houses in fuel poverty as these are being considered by a working group established by Government.[6])

11. Thus, it is estimated that the additional actions proposed by the energy review could result in a small fall in fuel bills to 2010 but could lead to increases to 2020. The impact on the number of households in fuel poverty will be reduced by improvements in energy efficiency and staging of future policy action should be considered to minimise adverse effects. However, the uncertainties surrounding future fuel prices emphasises the need for regular monitoring of fuel poverty measures and being ready to review policies and programmes to take account of new circumstances, as set out in the UK Fuel Poverty Strategy.

[3] DEFRA (2001a).

[4] The benefit of a 2-year period of EEC is estimated to be equivalent to approximately a 1.6% fall in average bills. However, low income households usually take on approximately 70% of this benefit in increased comfort (i.e. the real fuel bill fall will be approx 0.5%). Therefore an EEC extension for 5 years would result in a fall of approximately 1.2%.

[5] Derived from OXERA (2001).

[6] DTI, DEFRA (2001), paras 3.34 and 9.13.

ANNEX 5. ENERGY EFFICIENCY – THE BASIS FOR INTERVENTION

Introduction

1. Improving energy efficiency is broadly consistent with all the major objectives for energy policy. An increase in the pace of improvement is very likely to be needed if we are to achieve a low carbon energy system, certainly if we are to do so at a low cost.

2. The technical and economic potential for improved energy efficiency has been examined in detail in the course of the PIU's work.[1] It is summarised in Annex 6 and is broadly consistent with the analysis of the Inter-Departmental Group on Low Carbon Options.[2]

3. Energy efficiency will clearly benefit from the proposals that the costs of climate change should be reflected in the price of fossil fuels. However, this is not all that needs to be done. Many energy efficiency opportunities are already cost-effective. In these cases the market failures and barriers that constrain early adoption need to be addressed. But if improvements in energy efficiency are to be sustained, policy also needs to encourage innovation in the technology and marketing of energy efficiency.

4. The following sections consider:

- the nature of the barriers to energy efficiency,
- the benefits of innovation for energy efficiency, and
- the broad principles for policy that flow from these considerations.

Barriers to energy efficiency

5. The current, apparently cost effective, potential for energy efficiency is approximately 30% of final energy demand. The potential financial benefits in reduced costs to consumers (net of taxes) are £12 billion annually. And the potential carbon reductions are 40 MtC/year (see Annex 6). This is a very significant potential. It is broadly consistent with estimates for other countries[3] as well as the analysis that underpins the UK Climate Change Programme.[4]

6. There is a broad consensus across the energy efficiency professionals who have been consulted. They agree that the key barrier can be described as follows. Energy users do not seek to optimise the economic efficiency with which they use energy. In a complex world, people have many concerns and most have a higher priority than energy efficiency. So projects that are primarily about energy efficiency are often not even considered. And in investment decisions and purchases that involve energy use, energy efficiency is usually a minor consideration.[5] This underpins and reinforces the other barriers described in the box.

7. There are some exceptions. A few industrial energy users are very energy intensive. And in fuel poor households, energy costs are a large part of disposable income. For them energy costs and energy efficiency are important. But, energy bills average less than 3% of costs in households as a whole and only 1.3% in businesses. Even quite substantial price rises would not make energy costs a major issue for most energy users.

[1] PIU (2001c).
[2] DTI (2002).
[3] Intergovernmental Panel on Climate Change (2001).
[4] DETR (2000).
[5] The practice of limiting the number of issues that are considered in making a decision is commonly referred to as 'bounded rationality'.

Barriers to Energy Efficiency

Some of the barriers to investment in improved energy efficiency that have been identified are:

- Many energy users have imperfect information about energy efficiency opportunities and distrust of information available from what they see as vested interests.
- There is often better information on capital costs of investments than on their running costs, leading to adverse selection of inefficient goods.
- Capital markets are incomplete for many borrowers, for example low income households may find it difficult to borrow, even for very cost effective projects.
- Inadequate contractual relationships with builders and other traders result in sub-optimal design, and the risk that that projects may not be implemented correctly.
- Tenancy arrangements provide no incentives for either landlords or tenants to make cost-effective energy efficiency investment in rented properties.
- Regulatory arrangements discourage potentially beneficial long-term contracts between licensed energy suppliers and domestic customers.
- Some fiscal measures treat energy efficiency less favourably than energy supply.
- The price of energy, in most cases, fails to take into account the environmental costs associated with its supply and use, i.e. there are externalities.

8. Of the barriers listed above only the environmental externalities lend themselves to correction through energy pricing. Increased prices might also increase the demand for information. The remainder are more rooted in the structure of the market.

9. There are two possible analyses of these barriers to cost-effective options. Either:

- there is some form of market failure; and/or
- not all the costs have been identified.

10. There can be costs not fully accounted for in the calculation of the potential. The “hidden costs” of management time and personal time involved in decision-making are probably the most important. But there may be others including:

- disbenefits such as intrusion of builders into homes; and
- risks of unforeseen cost increases or reduction in benefits due to fuel price falls or product under-performance.

The alternative explanation is that energy efficiency markets are imperfect. All of the barriers identified in the box can be thought of in this way.

11. Both explanations are plausible. Doubtless both are part of the truth. The extent to which there is genuine market failure cannot be determined theoretically – it is an empirical issue. The best evidence we have comes from Government energy efficiency programmes that have been carefully monitored.

12. In the domestic sector, the National Audit Office has confirmed that the predecessor programmes of the Energy Efficiency Commitment (EEC) were highly cost effective.[6] They saved electricity at less than half the avoidable cost of supply. The “hidden” implementation and management costs of the

[6] National Audit Office (1998)

energy suppliers are included in the assessment. In this case, the time costs for the customer are largely removed by supplier activity. In business, the investments stimulated by the Energy Efficiency Best Practice programme (EEBPp) have typical payback periods of 2 to 4 years. EEBPp has provided targeted information and advice to reduce the costs of management and the perceived risks of these investments.

13. There are, therefore, genuinely cost effective investments that are not adopted in all sectors. The key point for policy-making is that Government intervention can reduce these costs. Both EEC and EEBPp do this, in different ways. The implementation costs in the absence of the programmes can be conceptualised as either "hidden costs" or "market failure". But the implication is the same – it points to Government intervention in the market in a manner that reduces implementation costs.

14. Whether the barriers to energy efficiency are "hidden costs" or market failures has implications for the cost effectiveness of carbon saving using energy efficiency. This has been studied in considerable detail.[7] If the whole explanation is market failure, energy efficiency investment is extremely cost-effective and there are major economic benefits associated with carbon reduction (costs of saving carbon are – £300/tC to -£100/tC). If the whole explanation is hidden costs, the costs are positive (£30-£50/tC), but still lower than typical supply side options for carbon reduction. Given our analysis, that Government intervention can reduce hidden costs, the lower end of the cost range may be more probable. So, economic benefits, possibly significant ones, are associated with carbon reduction through energy efficiency.

Looking to the Future – Innovation

15. The technical and economic potentials for energy efficiency outlined in Annex 6 are a snapshot taken at the current time. The potential is not fixed. Innovation can both increase the potential and improve the economics substantially. This is what has happened over recent decades. Since 1970, decreased energy intensity has contributed twice as much as changes in the energy supply mix to reductions in carbon emissions (see Chapter 2). But the scope for further progress in energy efficiency has not been used up. Innovation has increased the potential at about the same rate that cost effective measures have been adopted. The result is that the "current cost effective potential" has remained largely unchanged. Innovation is critical to this process.[8]

16. Most of the potential for future advances in energy efficiency will rely on technological improvements in materials technology, design and control. These are the types of change where the pace may accelerate in the knowledge economy. In this way, improved energy efficiency is expected to be an integral part of economic modernisation. Specific intervention may be needed in some areas. But the priority is to ensure that the importance of innovation is designed into other energy efficiency policy instruments.

17. In the buildings sectors the slow turnover of the stock prevents very rapid improvements. Even if the scope for currently cost-effective technology is exploited over the next decade, new technologies will continue to add to the technical and economic potential. These include new construction techniques, micro-CHP, heat pumps, super-insulating windows and high efficiency appliances, as well as design improvements to use solar energy.[9]

[7] DTI (2002).
[8] DTI (2002) Appendix D.
[9] Chief Scientific Adviser (2001).

18. In the industrial sector, significant improvements have been made in recent years. But a very large potential remains, especially through more fundamental changes to products and processes. Technologies that are already known, but currently not widely used, include membrane and crystallisation separation, process intensification, advanced refrigerants, absorption heat pumps, high temperature CHP and advanced motor controls.[10] And technologies that might be in common usage by the middle of the century may yet to be discovered.

19. In the transport sector, most potential lies in redesign of the car. Electric traction based on hybrid technology is already in commercial production. Fuel cell technology is the focus of major R&D programmes. Both offer large "well-to-wheel" efficiency improvements.[11] With advanced controls and battery storage they could facilitate other improvements including braking energy recovery, individual wheel control and engine capacity reduction. Combined with lightweight materials and aerodynamic design improvements, these can yield major efficiency improvements. Vehicles with fuel consumption of 3.4 litres/100 km (83 mpg) are already on the road. Design concepts could deliver 2.5 l/100km or less.

20. Energy efficiency innovation needs to be understood more broadly than changes in technology. Social and institutional change may be just as important. Liberalised energy markets may be a driver. To date the focus in supply markets has been on competition on commodity price. But as the scope for further reduction in supply costs falls, suppliers may increasingly look to commercial innovation and a wider package of products. In this context, there is the prospect for greater activity in energy services. There may well be systemic innovation with synergies between technical and commercial changes. For example, there are important potential linkages between micro-CHP, new metering technology and energy services marketing.[12]

Policy Principles

21. Three broad approaches can assist the adoption of socially cost-effective energy efficiency:

- raising the marginal cost of energy to account for its external costs;
- targeting barriers to reduce hidden costs or overcome market failure; and
- encouraging energy efficiency innovation.

22. Pricing environmental externalities has implications for all low carbon options. It needs to be used in a context of wider international action and attention to the distributional implications, in particular fuel poverty (see Chapter 3). It is important for long term energy efficiency policy. But energy pricing is not the only policy tool that can make a substantial difference. On the contrary, the existence of market failures and importance of innovation point to the use of a range of targeted interventions.

23. The analysis points to the importance of reducing high transaction costs that act as a barrier. In this context, the best policy instruments need to incentivise activity by organisations with the potential for the lowest costs, increase their capacity to deliver, and reduce transaction costs. The role of Government is to:

- identify the organisations best placed to deliver in each sector;
- incentivise (or regulate) them to deliver more energy efficiency investment; and
- reduce their information and transactions costs through targeted advice and capacity building.

[10] See, e.g. the results of the Atlas Project, Commission for the European Union (1997).
[11] Fergusson, M. (2001).
[12] PIU (2001c) – Annex 4.

24. Government has already made a start on the agenda of defining responsibilities:

- for vulnerable and low income households, the Government and Devolved Administrations have fuel poverty programmes supported by public expenditure;
- for the wider range of households, the Energy Efficiency Commitment is a regulatory requirement on licensed gas and electricity suppliers;
- in new buildings, Building Regulations require energy efficiency action by the builders;
- for household and commercial appliances, EU standards and negotiated agreements place responsibility on manufacturers;
- in some industrial sectors the Climate Change Negotiated Agreements give a strong fiscal incentive;
- in the public sector, Government departments have energy efficiency targets; and
- for cars, there are EU voluntary agreements with vehicle manufacturers.

Other policies and programmes give supporting information and incentives.[13]

25. This type of approach needs to be used with care. Whilst it cuts through the raft of barriers that restrict energy efficiency investment, it is important that it is cost-effective and does not discourage innovation. To this end, long timescales and tradable mechanisms are preferable.

26. There remain energy use sectors where there are no strong incentives, in particular in the commercial sector and those industries outside negotiated agreements. The Climate Change Levy provides a price incentive. But if price elasticities are low, the energy saving impact is limited and this is reflected in the relatively low contribution these sectors make to the UK Climate Change Programme. This points to new policy interventions in commerce and SMEs.

27. Product regulation addresses information barriers directly by excluding low efficiency products from the market. It is particularly effective where barriers are strong and energy costs are small, e.g. for buildings and consumer products. Long regulatory timescales are needed to minimise business uncertainty. Where products are internationally traded, the EU is the appropriate level for regulation, although Government can actively encourage agreement on appropriate intervention by the EU.

28. Negotiated agreements may be used as an alternative in some cases. These can have more flexibility. However, it is important they are transparent to Government, business and third parties, through independent monitoring and verification. They are most likely to be effective where Government indicates that alternative policy instruments will be used in the event of no agreement.[14]

29. Energy efficiency regulation and market mechanisms are not in conflict. New forms of regulation seek to create new markets. Key examples are the Emissions Trading Scheme and trading of Energy Efficiency Commitments. Both allow a given target to be delivered more cost-effectively, and thereby potentially allow more ambitious obligations than non-tradable constraints.

30. Public expenditure is most appropriate where energy efficiency goals have a strong social component, in particular to address fuel poverty amongst low-income households. It allows vulnerable households to be targeted with minimum deadweight.

31. Financial incentives (e.g. subsidies, tax reductions and enhanced capital allowances)

[13] DETR (2000).
[14] Green Alliance (2001).

reduce investment costs. Where there is information asymmetry, they are best applied at the point of capital investment or product purchase. They need to be carefully scrutinised for cost-effectiveness and to minimise deadweight loss. They are most effective where cross-price elasticities are high, e.g. to differentiate efficient products from others providing the same energy service.

32. Our analysis has found little evidence to support general information campaigns. Targeted advice is more effective, along the lines for example provided to industry and buildings professionals through the EEBPp, to households by Energy Efficiency Advice Centres (EEACs) and to consumers by clear labelling and branding. Government has a role, working with other players, to ensure these activities are delivered.

33. Capacity building through training and support is necessary where organisations that can play a useful role do not have the resources required, for example in the energy efficiency installer sector that is dominated by SMEs. Local authorities and the voluntary sector will also need additional resources to play a bigger role in advising households.

34. Government already supports energy education through the National Curriculum. This has a key long-term role in improving understanding of the principles of energy use and its relationship to environmental problems. In the short-term, compulsory education has limited impact. But, the practical involvement of adults can be fostered through community groups.

35. Government has a major role through the public sector, not only in direct improvements in energy efficiency, but also in setting an example in the wider economy. This will require addressing the barriers that affect public sector energy efficiency, by setting targets for energy efficiency, then allocating the resources to deliver them. Procurement policy will play a key part in this.

36. Government has a major role in supporting and incentivising innovation in environmental technologies. Evidence from the USA indicates that Government funded R&D on energy efficiency can be highly cost effective compared to other energy R&D.[15] In the UK, per capita energy efficiency R&D expenditure is very much less than in some other countries and significantly lower than on the supply side.[16] This has been exacerbated by the privatisation of key energy industries that previously undertook most energy efficiency R&D.[17] The Government's Chief Scientific Adviser's advisory group on energy research has identified energy efficiency R&D as a key priority. The Carbon Trust plans to use a significant portion of Climate Change Revenues to increase low carbon R&D (including energy efficiency).

37. Government can play a key role as a promoter of energy efficiency innovation, through its own procurement policies, incentive schemes to develop niche markets and by building partnerships between market players in the (generally rather weak) energy efficiency sector.

38. In the context of a long-term, low carbon economy, market transformation is a useful concept for addressing innovation. It involves fundamental change to the nature of goods and services on the market. It tends to require a number of different instruments working together, for example regulatory mechanisms to remove the lowest efficiency goods from the market, fiscal or other incentives to shift the mass market and niche market creation mechanisms to encourage new high efficiency designs. Energy efficiency policy instrument analysis needs to include implications for long-term market transformations as well as immediate effects.

[15] US National Academy of Sciences (2001).
[16] Chief Scientific Adviser (2001).
[17] PIU (2001b).

ANNEX 6. THE POTENTIAL FOR COST REDUCTIONS AND TECHNOLOGICAL PROGRESS IN LOW CARBON TECHNOLOGIES

Introduction

1. A number of low carbon technologies are available. Technical potentials are large.[1] But what is technically feasible is often not economically viable and many options are currently more expensive than fossil fuel-based alternatives. The relative merits of the different technologies change over time, with costs falling with technological progress and market growth.

2. In order to compare the costs per tonne of carbon saved, based on expected future technology costs, the PIU undertook a detailed analysis of each of the main low carbon options, in collaboration with the DTI-led Interdepartmental Analysts Group on low carbon technology (IAG) and independent experts.

3. Full detail of the PIU's work on cost reduction potentials for the leading electricity generation options is provided in PIU (2001f), (2001h) and (2001i); for transport technologies in Ferguson (2001); and for energy efficiency in PIU (2001c). Key findings are summarised in Chapter 6. Future changes are difficult to predict in advance, as the uncertainties are large. This Annex outlines the techniques used, and the main findings for each low carbon option.

Approach

4. The work focuses on an assessment of potential changes in costs between now and 2050. Energy markets will tend to favour the least-cost mix of technologies. Relative costs will change, as a result of technological development and changes in fuel prices. Given the uncertainties over a long time horizon, the PIU's quantitative assessments focus on 2020, with a qualitative assessment of likely *trends* from 2020 to 2050.

5. The analysis uses two broad approaches:

- engineering assessments, based on expert judgement of likely reductions in costs, placing technologies on a spectrum from "infant" or "emerging", to "mature"; and
- extrapolation and interpretation of historic relationships between cost reductions and cumulative production, so called "learning curves".

Engineering Assessment

6. Mature technologies are those that are well established and near the limit of incremental technological development. Emerging technologies are those with considerable potential for further development and cost reductions through innovation.

7. "Technology stretch" is the potential for further technological development and refinement – for continued innovation. This is based upon detailed assessment of the potential for refinement and development of the technologies, and of manufacturing processes. Cost reductions already achieved in closely related technologies, or those using similar production techniques, are often used as a "benchmark" against which potential cost reductions may be assessed.

[1] Discussion of technical potentials is provided in PIU (2001h).

8. The main advantage of engineering assessments is that they need not rely upon previous trends in cost reduction. The main disadvantage is that they depend upon expert judgements, which may differ.

Learning curves

9. The main alternative method is to use experience curves, based on "learning-by-doing".[2] They are widely used in business, but have not been used extensively for the assessment of UK energy policy. Evidence from a very wide range of technologies and sectors demonstrates a clear relationship between production and cost; put simply, as cumulative production increases, costs fall. This is not to underplay the complexity of the drivers of cost reduction – technological innovation, economies of scale, improved utilisation of labour and capital, etc. – but the conclusion is that most "learning" and cost reduction come through production and market experience.

10. "Learning rates" – the proportionate cost reductions that occur with every doubling of cumulative production – vary by technology and at different stages of development of a given technology. They tend to be steeper in the early stages of technology development. Typically, for industrial products, the learning rate is in the range 10 to 30%, which means that for each doubling of cumulative production, costs fall by between 10 and 30%. For all of the technologies under consideration here, markets, and learning rates, are for the most part global, thus cumulative world production, rather than UK application alone, is the key variable for learning assessment – though some technologies are more appropriate for UK conditions than others, and many have UK specific attributes.

11. Learning curves have proved a robust tool for assessing cost reductions in a wide range of products and sectors, though they have a number of limitations as a tool for estimating future costs:

- in the case of new technologies it can be difficult to use early experience to predict longer-term developments; and
- cost reductions can only be predicted on the basis of projections of production growth-sensitivity analysis may be used to assess the impact of different market growth rates.

12. The PIU uses both learning curves and engineering assessments. Both approaches support the following conclusions:

- newly emerged technologies that have a small market share have much larger potential for cost reduction than more established products;
- established technologies can "lock out" less developed alternatives that are initially more expensive, even if such technologies have the potential to become much cheaper in the longer term;[3] and
- uncertainties about the potential for cost reduction decrease as market experience increases.

Cost ranges

13. An overview of what both approaches suggest for each low carbon option is provided below. In all cases a range of costs is provided. In many cases the range reflects uncertainty about capital costs, and in some, about future fuel and O&M costs. In the case of renewables, site specific aspects, such as wind regimes and cost of installation and connection, also have a profound affect on costs, the PIU's analysis

[2] The energy policy applications of learning curves were recently examined at length by the IEA (2000b), the findings are discussed in more depth in PIU (2001 h).

[3] The rate and means by which innovations progress into established markets has been explored for many technologies and markets. Typically new technologies progress through high value niche markets. In highly capital intensive markets with limited product differentiation, such as electricity, this process can be slow. See Utterback (1997).

therefore takes in a range from high cost to low cost sites. The intermittent nature of some renewables is reflected in the load factors they achieve and is built into these costs. System costs due to intermittency are discussed below.

14. These ranges also reflect different assumptions about financing conditions, in particular the impact of different discount rates and amortisation periods. Where possible, the PIU have undertaken sensitivity analyses that take in both high and low discount rates (8% and 15%, real) and amortisation periods that reflect financing conventions (15 or 20 years), in addition to different capital cost estimates. Full details may be found in the relevant working papers.

The technologies

15. There are many energy technologies covering every stage of the energy chain from fuel extraction, transportation and refining through generation, transmission and end use. New energy vectors, particularly hydrogen, and energy storage technologies are also considered separately. The technologies that we consider are:

- energy efficiency in power generation and end use, including fuel cells and combined heat and power;
- renewable energy;
- nuclear power generation;
- carbon capture and sequestration;[4] and
- fuel switching and energy efficiency in transport.

16. Low carbon options cannot be considered in isolation, as "conventional" fossil fuels will also be expected to experience cost reductions. The PIU have therefore also assessed the potential for progress in;

- natural gas fired power generation ; and
- oal fired power generation.

Low carbon options

End use energy efficiency: summary of current potential

17. The current cost effective potential for energy efficiency in all sectors is summarised in Table 1. It amounts to approximately 30% of final energy demand. The potential financial benefits in reduced costs to consumers (net of taxes) are £12 billion annually.

Table 1

Summary of Current Economic Potential for Energy Saving

Estimated Potential for Currently Economic Savings

	Energy (Mtoe/year)	Per cent	Financial (£M)
Domestic	17.4	37.2%	5000
Service	3.8	21.0%	1190
Industry	8.6	23.8%	1380
Transport	19.3	35.0%	4700
Total	49.1	31.4%	12300

[4] The separation of CO_2, either pre- or post-combustion, and the engineered sequestration of this, deep underground. This technology is considered separately from the individual fossil fuelled power options because of its potential importance in reducing carbon emissions, because of its relative novelty, and because it is essentially an "add-on" that can remove carbon from a range of power generation options and fuels for other purposes, such as transport.

18. This is a very significant potential. The extent to which all of this potential is cost-effective is still disputed. However, there is a consensus on the broad conclusion that much of it is, both from empirical work on existing programmes and studies of future potential, as well as amongst the stakeholders that we have consulted. It is broadly consistent with estimates for other countries summarised by the Intergovernmental Panel on Climate Change.[5]

19. Historical empirical evidence for cost-effective energy efficiency is from reliable sources. In the domestic sector, the National Audit Office has confirmed that existing regulatory programmes are highly cost-effective.[6] They save electricity at 22% of the purchase price (and less than half the avoidable cost of supply). In the business sectors, the investments stimulated by the Energy Efficiency Best Practice Programme are now estimated to save over £800 million annually, with a typical payback period of 2 to 4 years.

20. Studies by and for Government form the basis of the future energy efficiency programmes that are central to the UK Climate Change Programme – both the Energy Efficiency Commitments in the domestic sector and the Climate Change Negotiated Agreements in industry.

21. This scope for significant economic benefits is an important conclusion of our work. It is widely understood that improving energy efficiency can assist in delivering environmental and energy security objectives. The large potential for cost-effective investment makes improving energy efficiency a key part of the economic and social dimensions of energy policy as well. And, in the longer-term, it is part of the agenda for an efficient, innovative and sustainable energy system.

Energy efficiency in energy provision – Combined Heat and Power

22. Medium and large scale combined heat and power (CHP) (with typically 30kWe to 30MWe output) is a well – established technology. These technologies are already cost-competitive with conventional power – typically **less than 2.0 p/kWh**. Smaller scale CHP-often known as mini-CHP – has become available for smaller commercial buildings. The smallest scale products, micro-CHP (MCHP) – suitable for individual homes – is an emerging technology with the first units on commercial trial now.

23. The electrical efficiency of CHP tends to reduce with the size of plant, the best achieving 45% and the current micro-CHP units 10% to 15%. However, in all cases, because of the association with a heat load, the effective power generation efficiency (the efficiency with which additional gas use is converted to power) is typically 80%-90%.

24. The economics of CHP are complex. Compared to the current alternative of CCGT from centralised power plants, there are additional costs associated with the distribution of heat, but savings from increased efficiency. However, there are also different costs associated with the locations and scale at which gas is used and electricity is produced. The economics are, therefore, crucially dependent on the gas-to-electricity price difference, which is a function of real cost and market structures.

25. The greatest potential for growth by 2050 is in micro-CHP; a direct replacement for a conventional gas boiler at an additional cost of a few hundred pounds.[7] Several manufacturers have units based on Stirling engines. At these capital costs, the effective generating cost is around **3.5 p/kWh, perhaps falling to**

[5] IPCC (2000).
[6] National Audit Office (1998).
[7] Early units are expected to have a premium of £600 which is expected to fall to £400 once mass production starts. This can be expected to reduce further, to £200-300 once the market matures.

2.5 p/kWh as the market grows. Within a decade it is expected that units based on fuel cells will become cost effective, these will have a significantly higher electrical efficiency.

Energy efficiency in energy conversion – Fuel cells

26. Fuel cells use electrochemical processes to convert hydrogen (or a hydrogen-rich fuel stream) and oxygen into electricity. They combine high efficiency with very low emissions. If run on hydrogen the only emission at the point of use is water. If run on hydrocarbons (or hydrogen derived from hydrocarbons), local emissions are near zero, with CO_2 emissions dependent upon the hydrogen source. If hydrogen is derived from zero carbon sources such as renewables, nuclear, or C&S (see below), then fuel cells offer the prospect of "zero emission" power. Fuel cells are also modular, and potentially suitable for application at a wide range of scales from micro-generation (tens of kW) to large scale power generation.

27. Interest in fuel cells in currently focused upon two areas of application:

- road transport, where zero emissions of local air pollutants, combined with high efficiencies and high power density (high power from small units), is driving considerable R&D activity;
- stationary power generation – primarily for small scale decentralised (less than 1 MW) applications – where fuel cells offer considerable efficiency gains over combustion technologies. Quiet operation and availability of waste heat for CHP[8] make them particularly suitable for CHP installations in commercial and residential buildings.

28. Some analysts argue that combined cycle fuel cell plants could eventually displace combustion-based CCGT for large-scale power.[9]

29. There are several basic designs of fuel cell; some are commercially available for niche market applications, others remain at the laboratory stage. Different types of fuel cells have different characteristics. At present, fuel cells are not cost competitive with combustion technologies in most applications. Estimates of current costs suggest a range from $2000/kW (£1600) to $10,000/kW (£7500) – however it should be noted that the commercial market for fuel cells is very small and many designs are effectively prototypes (which tend to be high cost).

30. The speed with which fuel cells will achieve cost reductions is not yet clear. It has not proved possible to provide estimates of costs in 2020. There is widespread agreement, based on engineering assessment, that fuel cells will become competitive in many applications,[10] with decentralised stationary CHP as the first market, followed by transport applications. The central uncertainty is how quickly this will happen.

Transport

31. Carbon emissions from transport may be reduced in three ways:

- shifting to less energy intensive modes;
- improving the efficiency with which conventional fuels are used; and
- switching to lower carbon fuels.

32. The PIU's work on technologies has focused on the latter two options. However a key conclusion from the scenario work is that managing demand growth in the more energy

[8] Fuel cells are often divided into "high temperature" (<500C) and "low temperature" (>100C) designs, generally speaking high temperature designs are further from commercial application and better suited to larger-scale stationary applications, they are also able to operate on a wider range of fuels. Interest in transport applications has focussed more upon low temperature designs.

[9] UNDP/WEC (2000).

[10] UNDP/WEC (2000), ICCEPT (2001), Brandon and Hart, (1999).

intensive modes is likely to be essential if deep cuts in emissions are to be achieved.

33. Both road and air transport are almost entirely dependent on oil. These are the sectors expected to experience the highest growth rates. Analysis undertaken for the PIU suggests that the potential for fuel switching in the road transport sector is limited in the period to 2020, and that aviation may remain oil-fuelled even until 2050. Efficiency gains will therefore play a key role for both sectors. The potential for technological advances in this area is large for road transport, but appears to be more limited for the aviation sector.[11] Hybrid vehicles and weight reductions could deliver 50% improvements in fuel efficiency for road vehicles by 2020. Estimates of costs are not available.

34. In the longer term most analysts expect more fundamental shifts in both fuel sources and motive power units for road vehicles, though this appears less likely for aviation. Much attention is focussed on the potential of fuel cells for road transport, with substantial industry R&D efforts underway, driven in large part by legislative pressure in the US and elsewhere to reduce local air pollutants radically.

35. The potential of these developments to reduce carbon emissions depends upon fuel source. Although fuel cells are more efficient than internal combustion engines, this advantage is lost if petroleum based fuels are used, as on-vehicle reformation of petroleum (to produce hydrogen) absorbs considerable energy. The role of the fuel cell in securing significant carbon emissions advantages is therefore intimately bound up with the development of low carbon supplies of hydrogen and the infrastructure, including on-board storage, that might be needed to facilitate this. Again, the long-run costs of such a transition are difficult to quantify, particularly given uncertainties about fuel cell costs.

Renewables

36. There are many renewable energy technologies that can make some contribution to meeting UK energy demand. The PIU's analysis has focussed on those options that have the potential to provide the largest amounts of energy in the long term – those with the largest technical potential.[12] Details of the UK's renewable resources are provided in PIU (2001h). The technologies considered are:

- solar photovoltaics;
- wind (onshore and offshore);
- wave and tidal stream; and
- energy crops.

37. With the exception of the last, these generate electricity. Energy crops may be used for power, heat or liquid fuels. This list excludes some important technologies that are already cost competitive, considered technologically mature, or have more limited potential for expansion in the UK.[13]

38. New renewable energy technologies currently contribute less than 1% of global energy demand, and less than 3% of electricity, but collectively have the potential to deliver orders of magnitude more. The scope for cost reduction is therefore very large. Current costs differ substantially, from 2.5–3.0 p/kWh for onshore wind in good sites, through 5–6 p/kWh for offshore wind, around 8p/kWh for energy crops, to around 70p/kWh for PV.

[11] Studies by the IPCC and others suggest that efficiency gains in aviation are likely to be dramatically outstripped by demand growth. Prospects for transport technologies and new fuelling infrastructure are discussed in Ferguson (2001).

[12] Based upon estimates of technical potential derived from DTI (1998).

[13] In particular solar hot water, hydropower (large and small), biomass wastes, geothermal. This is not to suggest that technologies not listed do not have a valuable current or potential role, either in the UK or elsewhere. We focus on a limited number of technologies in order to develop a broad picture of the potential of renewables to provide cost-competitive power on a large scale over a long time horizon.

39. With the exception of energy crops, renewables are intermittent. This, together with site specific aspects such as local wind regimes affects load factors and is built into the costs quoted above, and the projected costs summarised below. Renewables that are both intermittent and to some degree unpredictable also impose additional system costs – the system must be able to cope with unpredicted fluctuations in output. Not all intermittent renewables are unpredictable: tidal energy is completely predictable; wave is more predictable than wind; and predictive capacity for wind is improving. The costs to the system of coping with unpredictable intermittency have been explored in detail with NGC and independent experts – see Milborrow (2001). These costs are small in comparison to generating costs and are discussed in the final section of this annex.

40. Detailed conclusions of the PIU's work on renewables are as follows:

- there is good evidence, based on detailed assessment of learning curves and market growth rates, that onshore wind is likely to become amongst the cheapest of all generating technologies within 20 years – **less than 2 p/kWh in good wind speed locations, with a typical range of 1.5–2.5 p/kWh;**
- there is equally robust evidence that PV is likely to continue to experience sustained and substantial cost reductions over the next 20 years.[14] However, though PV will become cost competitive in many applications in sunnier climes, it will still **be some way from being generally cost competitive in the UK – 10 to 16 p/kWh –** even taking into account the value of being a decentralised source of power. PV is widely expected to continue to secure cost reductions after 2020, and could become cost competitive with retail electricity in the UK around 2025;
- though we can be less certain about developments in offshore wind, where world experience is limited, engineering assessment of offshore technology issues suggests that offshore wind is likely to fall to **2 to 3 p/kWh**;
- advanced combustion technologies for energy crops also have considerable potential for cost reduction, with capital costs projected to fall by around 50% once demonstration plants move into commercial deployment. Whilst market and learning rate data are available for conventional combustion technologies, they are not available for advanced technologies. Reductions in crop production and processing will also be required if energy crops are to become **cost-competitive. This makes cost reductions in biomass more difficult to assess. Best estimates lie in the range 2.5–4 p/kWh**;
- more uncertainty surrounds wave and tidal technologies, with many competing devices currently at an early stage of development. Commercial markets do not exist, and a learning curve based approach is not possible. Estimates of potential costs suggest figures of the order of **4 to 8 p/kWh** for the first commercial-scale device.[15] The UK is currently at the forefront of wave and tidal power.

Nuclear Power

41. Nuclear power (fission) is a well-established technology and currently supplies around a quarter of UK electricity needs. Designs for current nuclear stations are in the 1GW to 2GW range and in principle nuclear power could

[14] The PIU's analysis is based upon a learning rate of 18% and market growth of 25% per year, and discount rates of 8% and 15%. See PIU (2001h). Other analyses using both engineering assessment and learning curve approaches suggest similar results, see UNDP/WEC (2000).

[15] Based upon assessment of figures produced for the DTI in Thorpe (1999) and House of Lords (2000): see also PIU (2001a).

supply very large amounts of virtually zero carbon power in the future. Uranium is plentiful, easy and cheap to store, and likely to remain cheap. This means that nuclear power is essentially an indigenous form of energy. Any limits to nuclear power growth are likely to come from siting problems (it will be much easier to use existing nuclear sites than move to greenfields) and from public acceptance issues, including resolution of nuclear waste strategy.

42. No new-build nuclear has been financed in liberalised markets. In the UK, the costs of Sizewell B, the most recently constructed nuclear unit, was around 6p/kWh (2000 prices, 8% discount rate),[16] while the nuclear industry's expectation of generation costs for a twin PWR at the time of the Government's Nuclear Review in 1995 was 3.5p/kWh (same basis as Sizewell B figure above.) The proposal from the nuclear industry is now for a programme of the AP-1000 design (owned by BNFL/Westinghouse), expected to cost between 3p/kWh for the first unit, and 2.5p/kWh, across a large programme of 10GW, even at a higher discount rate. It is clear that, whether through "learning" in the narrow sense, or wider processes of cost reduction, the nuclear industry consider the costs of new nuclear generation in the UK are on a steep downward path.

43. The industry also expects, as is implied by the range of 2.5p/kWh to 3p/kWh, that there will be substantial learning and scale effects from a standardised programme, so that a fourth double unit might cost almost a quarter less than the first such unit. Strict learning effects are difficult to measure in the nuclear power case because more stringent regulation has often counteracted learning effects. However in the right regulatory conditions there is every reason to expect learning to take place in nuclear power as in other technologies. The pace and extent of learning may however be slower for nuclear than for renewables because:

- relatively long lead times for nuclear power mean that feedback from operating experience is slower;
- relicensing of nuclear designs further delays the introduction of design changes; and
- the scope for economies of large-scale manufacturing of components is less for nuclear because production runs are much shorter than for renewables, where hundreds and even thousands of units may be installed.

44. The nuclear industry argues that it can build the AP1000 in the range 2.5p/kWh to 3p/kWh. Such a result will depend on achieving construction costs below the bottom end of the range in the IEA's recent report on nuclear power in the OECD;[17] on the achievement of very high operating availability; on a series build of 10 identical reactors; on short construction times; and on regulatory stability. Such an outcome is clearly possible.

45. On the other hand, AP1000 technology (though based on established components) is yet to be built anywhere in the world, with associated first of a kind risks; there has been no ordering of new nuclear plant in OECD Europe since 1993; it seems unlikely that construction cost and performance guarantees can be as firm for nuclear as for CCGTs; operating performance wil be difficult to guarantee at the levels suggested; there is no certainty that a 10GW programme could be completed in an orderly way; and the economic results are sensitive to changes in several of the above parameters.

46. Making minor adjustments for some of the issues in paragraph 44, and applying the PIU 8% and 15% discount rates and a 20 year

[16] Most of the numbers in this section are explored in more detail in PIU (2001i).
[17] IEA (2001c).

amortisation period, the central inter-quartile range of nuclear costs is **3p to 4p/kWh**, with both lower (industry) and higher outcomes possible. Such a result still represents a major decrease in costs compared to all previous nuclear construction in the UK, including Sizewell B.

47. Such costs are likely to apply in 2020, given that an AP1000 programme could not be completed any earlier than twenty years from now. Beyond that date, new designs of smaller, more modular reactors with inherently safer characteristics could become available. Capital costs might be reduced to $1000/kW (£690/kW), and in such circumstances nuclear costs could fall further beyond 2020. Commercial nuclear fusion is not predicted to appear within this timeframe.[18]

Capture and engineered sequestration of CO_2 (C&S)

48. There is growing industrial interest in removing CO_2 from fossil-fuels before it is released into the atmosphere, sequestering the carbon in deep repositories (or beneath the ocean bed) so that it is "locked up" and does not enter the atmosphere. There are two discrete steps: first, the CO_2 must be captured, secondly, the CO_2 must be transported to a geologically appropriate repository. The technique of carbon capture is well known, and likewise there is already some experience of sequestering CO_2 – indeed, CO_2 is already injected into some oil fields for enhanced oil recovery. But the two halves of the process have yet to be brought together and demonstrated on a large scale.

49. C&S would allow fossil fuels, including high carbon fuels such as coal, to continue to contribute to energy supplies without precluding deep cuts in CO_2 emissions. C&S can in principle be applied to any fossil fuelled power station or large combustion plant. It is also feasible to extract hydrogen from fossil fuels and sequester the waste CO_2. The hydrogen could then be used in transport applications.

50. C&S allows CO_2 emissions to be reduced by around 80%. The size of the potential CO_2 reservoirs available is uncertain. Estimates of the global potential of deep saline aquifers range from 10 years global emissions at current rates to twice the carbon content of estimated recoverable fossil fuel reserves.[19] Estimates of the potential of depleted oil and gas reservoirs also vary. However, suitable sites are not evenly distributed around the world, and the UK has access to potentially large CO_2 repositories under the bed of the North Sea.

51. Engineering estimates suggest that gas-fired and coal-fired generation with C&S would cost **between 3.0 and 4.5 p/kWh**, if development succeeds.[20] Considerable uncertainty surrounds these figures. These costs represent "first commercial" application and, as such, could be secured before 2020 if development proceeds rapidly, though the pace of development is uncertain. As the technologies involved in C&S are mature, dramatic cost reductions by 2020 appear unlikely. In the longer term it appears probable that costs could continue to fall as experience is gained and technology improves. Uncertainties about the scale and speed of development make this difficult to quantify.

52. Uncertainty still surrounds C&S, in particular as to the safety, environmental risks and public acceptability of sequestration. These aspects, as much as the technologies themselves, will have a profound impact on the development of this technology.

[18] PCAST (1995).
[19] The main source of this wide variation is uncertainty about the integrity of geological formations – if only capped aquifers are suitable then the resource is much more limited UNDP/WEC (2000).
[20] UNDP/WEC (2000).

Combined cycle gas turbines (CCGT)

53. CCGT technology is currently the cheapest generating option in all locations with well-developed natural gas supply infrastructure, and is the least-cost option in the UK. CCGT plant combines low capital cost and relatively short build times (2 to 3 years) with high thermal efficiency relative to coal-fired plant.

54. CCGT offers a number of additional advantages: it is economic at a range of scales from around 300MW to 1500MW, and, in the UK at least, the widespread availability of gas means that CCGT plant may be located where it is needed on the national grid, close to demand. In addition, gas-fired power stations face relatively few planning constraints. By contrast coal, nuclear, wind and some other renewable energy face considerable constraints upon where they may be located.

55. Current capital costs of a modern CCGT plant are around £270 /kW and delivered energy costs around 2.2 p/kWh. Capital costs are widely projected to continue to decline marginally – **falling to around £260/kW by 2020.** Engineering assessments suggest that future development will be focused on continued efficiency improvements. Today's CCGTs deliver electricity at around 55% thermal efficiency. The next generation are widely predicted to raise efficiency to around 60%.[21] These capital cost reductions and efficiency gains would reduce costs to around **2.0 p/kWh by 2020, given today's gas price**, a decrease of around 10%. Possible increases in gas prices (by 20 – 30% to around 1.0 p/kWh) would increase CCGT power prices to around **2.3 p/kWh**.

56. Important though these efficiency gains undoubtedly are there is little doubt that the days of rapid cost reductions in gas turbine technology are over. Learning rates of around 20% were typical in the period to 1980, but figures of 3% to 10% are commonly cited for the period 1980-95.[22] Gas turbines are widely considered to be mature. However continued innovations in combined cycle plants are predicted, in the longer term many analysts suggest that gas-turbine technologies will give way to fuel cells in combined cycle stations.

Coal technologies

57. Current coal-fired generation, based upon steam-cycle pulverised coal technologies, with flue gas desulphurisation (PC-FGD) are not cost-competitive with CCGT in the UK or most countries with well-developed natural gas infrastructures. Coal plant is more capital intensive, has longer build times and offers lower efficiencies than gas. In addition, current coal technologies produce much higher emissions of all air pollutants than CCGT, and flue gas desulphurisation results in large quantities of solid or liquid waste.

58. There is considerable world-wide interest in advanced coal technologies, to raise efficiencies and reduce pollutant emissions, compared to current designs. Interest in coal is driven primarily by the widespread availability of coal compared to gas, with particular interest in countries with cheap coal and limited access to gas, like India and China.

59. Leading options for 2020 include super-critical pulverised coal steam cycle plants and integrated gasification combined cycle plants (IGCC). Examples of both technology types are operating in many countries, and though IGCC is not yet considered fully commercial it is considered by many analysts to offer the best prospects for the long term.[23] We therefore take IGCC technologies as the "benchmark" for 2020.

[21] UNDP/WEC (2000)
[22] IEA (2000a), UNDP/WEC (2000)
[23] UNDP/WEC (2000)

60. IGCC technologies gasify coal (or indeed other solid or liquid fossil fuels) to produce "syngas" – essentially hydrogen and carbon monoxide – which is then burned in a combined cycle gas turbine. The main advantages of IGCC are improved efficiency, 43–45% for current designs, with 50% estimated for new designs. By comparison 35% is typical for PC-FGD. IGCC plants also offer much lower emissions of local air pollutants, and somewhat lower CO_2 emissions. IGCC is also well suited to CO_2 separation and sequestration, as a relatively pure CO_2 stream can be removed from the syngas pre-combustion, rather than extracting highly diffuse CO_2 from the exhaust gases.

61. IGCC technologies are currently more expensive than conventional PC-FGD designs, with capital costs of the order of £900–£1200 /kW and £700–£900 /kW respectively.[24] As yet, though many commercial scale IGCC plants are in operation around the world, the technology has yet to be deployed on a fully commercial basis. Commercial IGCC designs with efficiencies of around 50% and lower capital costs are predicted to be available post-2010- such designs would have capital costs of around £750–£900 /kW, and, if coal prices remain similar to today's levels, would deliver energy at a range of approximately **3.0–3.5 p/kWh. This appears to be a reasonable** estimate of costs for 2020. In the longer term, efficiencies as high as 65% appear possible. Continued cost reduction in the gasification cycle is also believed to be achievable.

Costs per tonne of carbon saved

62. The costs per tonne of carbon saved that flow from these cost projections are summarised in table 5.1 of the main text. The assumptions that underpin this table are as follows:

- costs per tonne of carbon saved for all supply technologies are in comparison with CCGT generation. Cost range for CCGT in 2020 is 2.0–2.3 p/kWh as discussed above;
- emissions saved by displacing CCGT are assumed to be approximately 0.1 kgC per kWh;
- emissions savings per kWh are assumed to be 1 (100%) for renewables, nuclear and energy efficiency, 0.8 (80%) for C&S and 0.4 (40%) for CHP;
- cost ranges for all power generation technologies include grid connection charges, but do not include any additional locational charges – which range from positive to negative and cannot be generalised;
- additional system costs due to intermittency for renewables are not explicitly included. At very low penetrations (<5% of peak demand) these are negligible, at modest levels (5–20%) these are uncertain and vary by technology but could add between 0.1 and 0.2 p/kWh. If borne solely by renewables generators this would result in an increase of 5 to 10% at the low end and 1 to 3% at the upper end of renewables cost ranges. Given the wide range of inherent uncertainty indicated in the table (50–200% variation in costs), these effects are lost in the "noise" of the uncertainty inherent in these cost ranges.

[24] UNDP/WEC (2000), AEAT (2001)

Summary of key findings				
Technology	**2020 cost**	**Basis for assessment**	**Confidence in estimate**	**Cost trends to 2050**
End use efficiency	Low[25]	Engineering assessment	High	Decrease, but variable[26]
Fuel Cells	Unclear	Engineering assessment	NA	Sustained decrease
Large CHP	Under 2 p/kWh	Engineering assessment	High	Limited Decrease
Micro CHP	2.5–3.5 p/kWh	Engineering assessment	Moderate	Sustained decrease
Transport efficiency	Low	Engineering assessment	NA	Unclear – fuel switching
PV	10–16 p/kWh	Learning rate and market growth rate	High	Sustained decrease
Onshore wind	1.5–2.5 p/kWh	Learning rate and market growth rate	High	Limited Decrease
Offshore wind	2.0–3.0 p/kWh	Engineering assessment and onshore learning rate	Moderate	Decrease
Energy crops	2.5–4.0 p/kWh	Engineering assessment and learning rate	Moderate	Decrease
Wave	3.0–6.0 p/kWh	Engineering assessment	Low	Uncertain
Fossil generation with CO_2 C&S	3.0–4.5 p/kWh	Engineering assessment	Moderate	Uncertain
Nuclear	3.0–4.0 p/kWh	Engineering assessment	Moderate	Decrease
CCGT	2.0–2.3 p/kWh	Engineering assessment and learning rates	High	Limited decrease
Coal (IGCC)	3.0–3.5 p/kWh	Engineering assessment	Moderate	Decrease

25 Energy efficiency measures are usually cost effective (see Annex 5) and therefore costs of saving energy are below the costs of supply to the relevant final user.

26 Costs of individual technologies are expected to decrease with innovation, but much of the lowest cost potential will progressively be deployed.

ANNEX 7. TIMELINES AFFECTING DECISIONS

1. The purpose of this Annex is to consider the timescales associated with the energy system. These timescales will affect the timing and the impact profile of energy policy decisions. Figures quoted in this Annex are all broad approximations made by PIU based on a range of sources.

2. The following timescales are important:

- How long does energy producing and using equipment last?
- How long does it take to construct key items of energy infrastructure?
- How long will indigenous UK energy supplies last?
- How long does it take to create new energy options?
- What will happen to UK carbon emissions?

3. Energy assets, like other assets, have no clearly defined lifetimes. How long they last will depend on developments during their lives which could on the one hand lead to early obsolescence or on the other to life extension.

How long does energy producing equipment last?

4. Many energy producing assets have long lifetimes compared to other assets. Table 1 gives an approximate indication of how long some sorts of assets might last.

5. To some extent, all the above are composites of various pieces of equipment with different lives. During the life of the overall asset, some pieces of equipment may be replaced several times. Gas pipeline and electricity transmission and distribution systems are characterised by rolling programmes of capital replacement. The systems as a whole are not replaced but rather they evolve over time. The figures in Table 1 indicate the periods over which the whole of these systems might be renewed.

6. The key messages to take from Table 1 are:

- a high proportion of the energy infrastructure will be replaced over a 50 year timescale, but:
- developments to gas and electricity networks

Table 1: Lifetimes of energy producing assets

Asset Type	Years
Gas pipelines and terminals	60
Electricity tranmission and distribution wires	50
Nuclear Power stations	40
Conventional Fossil Fuel Power Stations	40
Combined Cycle Power Stations	30
Wind Power Stations	20
Hydro Power Stations	100
Oil refineries	50

undertaken in the next few years, together with some kinds of power stations built in the near future, could still be operational in the middle of this century; and

- almost all assets built from now on could still be operational in 2020.

7. Existing assets: whilst Table 1 gives a general idea of assets lives, it is also necessary to consider the probable lives of the existing asset stock. It is particularly important to concentrate on power stations since the turnover of power stations can have significant impacts on carbon emissions and the diversity of fuel sources.

8. Most existing *coal and oil* stations are already 30 years old or more. Future levels of operation will come under increasing pressure from tightening limits on acid gas emissions unless substantial sums are spent on refurbishment.[1] Some of the stations are likely to close by 2010 and most that do not carry out major refurbishment seem likely to close by 2020. Coal stations that have refurbished to meet strict acid gas emission limits, and those that do so in future, could continue operating to 2020 or even beyond.

9. *Nuclear*: the Magnox stations are expected to close by around 2010 and little prospect for life extension is foreseen. Most of the AGR stations are expected to close in the period 2010–2020, although some life extensions may be possible, whilst the one existing PWR should last to beyond 2030.

10. All the existing *gas* capacity has been built since 1990 and should last until at least 2020. But by 2020, some of the earliest stations will be approaching the end of their lives.

11. The current level of electricity generating capacity in Great Britain is about 70 GW. In very broad terms, we would expect about one fifth of this to need replacing by 2010, one half by 2020; three quarters by 2030 and almost all by 2040.[2]

How long does energy using equipment last?

12. Lifetimes of most energy using equipment are a good deal shorter as shown by the approximate figures in Table 2. The main message from the table is that over a 50 year time-scale, the bulk of energy using equipment is likely to be changed two or three times and that most of it will be changed at least once before 2020.

13. Building design and construction is a very important determinant of the amount of energy needed to light and heat them. Houses last 100 years or more and many commercial buildings can also have very long lives. It is probable that about half the existing building stock will still be in use 50 years from now, as will almost all new buildings.

Table 2: Lifetimes of energy using equipment

Asset Type	Years
Cars and motor vehicles	10-15
Electrical appliances	5-20
Household boilers	15

[1] For example, installing flue gas desulphurisation equipment.
[2] Assumes that electricity demand remains at least at current levels. If demand falls, plant can be retired without replacement.

How long does it take to build key items of energy infrastructure?

14. The focus is mainly on power stations for the reasons given in Paragraph 7. Construction times vary considerably and will also be greatly affected by the time taken to obtain the relevant planning permissions. Table 3 gives approximate indications of build times, on the assumption that the projects concerned do not face major planning obstacles.

15. Table 3 suggests that significant amounts of gas and renewable generating capacity can be built within 5 years or less but that build times are longer for clean coal with carbon sequestration or for nuclear. A key message is that the process of learning and cost reduction can happen more quickly with renewables than with nuclear or coal sequestration, because the turnaround time for projects is faster.

How long will indigenous UK energy supplies last?

16. **Gas:** At present, the UK is a net exporter of natural gas. DTI estimates are that by 2010, the UK may need to import up to one-third of its gas requirements and by 2020 it may need to import over 80%. Future production figures[3] take no account of output from as yet undiscovered reserves. However, DTI consider such contributions are likely to be small and could be offset by lower output from known reserves. DTI projections are summarised in Table 4. The demand projections are based on the central growth scenarios of Energy Paper 68[4] and may be on the high side since they do not allow for the effects of the Climate Change Programme.[5] The projections also assume that all new electricity generation capacity, except that needed to meet the 10% renewables target, is gas fired.

Table 3: Build times for energy assets

Asset	Years
Nuclear power station	10 *
Clean coal station with carbon capture and sequestration	7
Gas fired power stations (including large CHP)	3
Renewable generating stations	1-3 **
Micro-CHP and domestic photovoltaic	Days / weeks
Gas/electricity link to Europe	5
Gas storage facility	3
LNG terminal	5

* Could be less with already licensed designs.

** Range reflects wide range of renewables technologies. Would be longer for large hydro projects.

[3] Based on proven plus probable plus possible reserves
[4] DTI (2000b).
[5] DETR (2000).

Table 4: Future Production and Demand for Gas

Mtoe	2000	2010	2020
Production	108	70	20
Demand	95	109	125
Net Imports	(13)	39	105

Table 5: Future Production and Demand for Oil

Mtoe	2000	2010	2020
Production	138	70	20
Demand*	86	97	107
Net Imports	(52)	27	87

* including non-energy use

Table 6: UK Production and Use of Energy

Mtoe	2000	2010	2020
Production	290	183	70
Demand	244	257	266
Of which gas:	95	109	125
Imports	(46)	74	196
Imports as % Demand	(19%)	29%	74%
Gas as % Demand	39%	42%	47%

17. **Oil**: At present, the UK is a significant net exporter of oil. DTI projections, once again based on known discoveries, suggest that production levels in 2010 may be only half current levels and may fall to less than 20% of current levels by 2020. As well as oil for energy needs, the UK currently uses some 12 mtoe per annum for non-energy purposes. The demand projections in Table 5 assume non-energy oil use will remain at current levels. They indicate that the UK could be a modest net oil importer by 2010 and a large importer by 2020. Energy demand for oil is again based on Energy Paper 68.

18. **Coal**: At present coal accounts for about 15% of the UK energy mix, but its use seems likely to drop over the next 20 years in almost all scenarios. UK production of coal also seems likely to drop, as existing deep mines' reserves are progressively exhausted and as falling local demand, and competition from imported coal, threaten the commercial viability of new deep mines.

19. **Nuclear and Renewables:** By 2020, nuclear output is expected to fall to about one-third of its current level, but renewables output, on current targets, would reach 10% of electricity.

20. Combining the figures for the individual fuels, Table 6 shows projections of the overall energy balance.

21. The key messages from Table 6 are:

- by 2020, imports reach about three-quarters of UK energy needs;
- gas accounts for close to half overall UK energy needs.

22. **Uncertainties**: It should be recalled that the above projections for UK oil and gas production are very uncertain and that the historical trend has been for projections of this sort to turn out to have been too pessimistic.[6] The extent to which this happens in future will depend partly on future oil and gas prices. The projections may also overstate energy demand. Taking these uncertainties into account suggests that the UK might still be broadly self-sufficient in energy in 2010. However, it would take a substantial divergence from the projections for the UK to remain close to self-sufficiency in 2020. It is also possible that oil demand, mainly from transport, will grow less than anticipated, and that coal use will decline faster, perhaps from stronger carbon reduction pressures – in such cases gas use could well exceed 50% of total energy needs by 2020.

How long does it take to create new energy options?

23. There is no easy answer to this question. As already noted options which can be quickly deployed, such as some renewables, can be developed more quickly than those which take a long time to deploy, such as a new type of nuclear reactor.

24. Options which need considerable further technical work, such as new nuclear reactors, some types of renewables (e.g. wave and tidal energy), and ways of storing electricity or hydrogen, will probably need longer to become established than those where the main barriers are economic or institutional (e.g. greater take up of energy efficiency).

25. Development of some options may be related to the regulatory cycle for the natural monopolies, currently 5 years. Options in this category include significant changes to the design of electricity distribution systems and, related to this, greater take up of small scale onshore renewables and CHP. Significant development of larger renewable resources in Scotland (onshore and marine) could be influenced by electricity transmission regulation as well.

26. It is extremely hard to predict when major technological advances may arrive which could be highly disruptive to existing systems. An example from history is the internal combustion engine which revolutionised the style and availability of transport. Not only are such innovations very hard to predict, but once made, they can have very long lasting impacts. Our transport system today is still dominated by the internal combustion engine and likely to remain so for several years to come.

What will happen to UK carbon emissions?

27. The DETR Climate Change Programme shows UK greenhouse gas emissions falling by 14.9% from 1990 levels by 2010, but then rising by around 3% over the subsequent decade.[7] These estimates were before taking account of the additional measures announced by the Government in that Programme.

[6] For example, IEA (2000a) takes a more optimistic view of UK oil production prospects.
[7] DETR (2000). Table 1 page 53.

28. Estimates including the impact of these extra measures show greenhouse gas emissions down by 23% from 1990 levels in 2010, with emissions of carbon dioxide down by 19%.[8] Further small reductions are possible from measures set out in the programme but whose impact was not quantified. Reductions on this scale would be comfortably within our Kyoto limits which require reductions of 12.5% in greenhouse gas emissions over the period 2008-2012.

29. The Climate Change Programme does not quantify how emissions might develop beyond 2010 once account is taken of the extra measures. However, if it were supposed that these measures had no extra impact after 2010, then 2020 emissions of greenhouse gases would still be some 20% below 1990 levels.

30. In broad terms, the above projections are similar to PIU projections for World Market and Provincial Enterprise scenarios (see Chapter 5 of the main report). PIU projections for Global Sustainability and Local Stewardship scenarios show considerably lower emissions by 2020, driven by differences in the assumed policy background.

[8] DETR (2000), page 124.

ANNEX 8. CHIEF SCIENTIFIC ADVISER'S ENERGY RESEARCH REVIEW – SUMMARY AND RECOMMENDATIONS

Executive summary

1. This report has been prepared by the Chief Scientific Adviser and a group of twelve experts assembled to assist him in a review of Government support for research, development and demonstration activities. The review was commissioned by the Secretary of State for Trade and Industry to inform the wider review of energy policy being undertaken by the Performance and Innovation Unit.

2. The group was asked particularly to consider whether the overall level of expenditure on research, development and demonstration (RD&D) was sufficient, whether it was being targeted at the right areas and who should in future maintain an overview of expenditure.

3. The group agreed that increased RD&D effort was crucial to identifying new energy options which would deliver a secure and sustainable supply of energy with substantially lower carbon emissions. It welcomed the steps the Government was already taking to encourage innovation and the transition to a low-carbon economy.

4. The group concluded, however, that the UK's spending on RD&D should be raised to bring it more in line with that of its nearest EU competitors. The group laid particular emphasis on the importance of building a strong base of fundamental research activity. It felt that energy was still an insufficiently high priority for academic research and that the leading edge science was now going on elsewhere in the world. Consequently, UK companies could lose out on the opportunity to capitalise on publicly funded research and take advantage of the growing export market for energy and low carbon technologies.

5. The Group put down a marker that work is required to assess, quantify and seek remedies to any skills gaps in the UK energy sector.

6. The group called for more socio-economic research into the various factors that determine the uptake and successful commercialisation of new technologies, including the regulatory climate, the impact of fiscal incentives and public perception of environmental effects and lifestyle changes.

7. The group identified six broad areas of scientific research which it felt had the strongest case for being treated as priorities, based on criteria which included the degree of technological potential or "headroom" for research to yield step-change benefits. These were: CO_2 sequestration; energy efficiency; hydrogen production and storage; nuclear power; solar photovoltaics; and wave and tidal power. With regard to nuclear power, the group considered that, whether or not there is any commitment to new nuclear build, the priority for publicly funded research should be research into the handling and storage of nuclear waste. More generally, it emphasised the importance of exploring how different technologies could interact and the centrality of infrastructure issues to the commercialisation of alternative energy options.

8. The group noted the difficulties it had encountered in obtaining data on precise levels of spending in particular areas. It recommended that a suitable body be given the task of collecting and co-ordinating such data.

9. It also called for the establishment of a dedicated national research centre to boost the profile of energy research and attract high-calibre scientists into the field. The group

emphasised that such a centre should be based on a multidisciplinary approach and would need to stimulate research into a range of cross-cutting technologies in order to support advances in the six key areas it had identified during the course of its work.

10. Finally, the group concluded that its review had raised many relevant issues which it had not had time to explore fully in the short time available for its work. It recommended that the Government find means to continue a strategic exploration of such issues, including the legislative and regulatory drivers for research, energy storage technologies and infrastructure, and socio-economic research. More detailed recommendations could then be developed.

The full set of the group's recommendations and all supporting documentation can be found in a Working Paper on the Chief Scientific Adviser's Energy Research Review Group report at www.piu.gov.uk

ERRG recommendations

ERRG recommendation 1: Given their importance in determining the level and type of energy research being undertaken in the private sector, as well as the commercial uptake of technologies, there should be further strategic investigation and appropriate research into non-technical policy drivers, including regulatory as well as social, commercial and economic drivers. Particular attention should be paid to understanding the market context into which new technology is deployed.

ERRG recommendation 2: Government should have regard to the impact which different accounting treatments have on how the environmental costs and benefits are assessed when evaluating different energy options.

ERRG recommendation 3: In allocating funding for publicly supported energy research programmes, the Government should ensure that there is a sufficient focus on basic research activities.

ERRG recommendation 4: Government should encourage and support more cross-boundary research to look at how different technologies might be optimised to deliver overall energy policy objectives.

ERRG recommendation 5: Energy research and its proper co-ordination should be key priorities for Government. Spending, over time, should be brought more in line with that of our nearest industrial competitors in Europe. The opportunities for increasing co-operation with the European Commission and other EU Member States in jointly funded programmes and projects should also be considered.

ERRG recommendation 6: Further work is required to assess and quantify the extent of skills gaps in the UK energy sector, and seek remedies to them.

ERRG recommendation 7: Research is needed to support the continuing development of all the relevant technologies and practices, including the underpinning sciences. The following were identified as key areas:

- CO_2 sequestration;
- energy efficiency;
- hydrogen production and storage;
- nuclear power (nuclear waste);
- solar PV; and
- wave and tidal power.

ERRG recommendation 8: There should be increased support for important cross-cutting energy efficiency technologies such as innovative software and hardware for energy management systems, sensors and controls, and for research into energy strategies and systems analysis. Projects which combine several energy efficiency technologies to demonstrate their cumulative impact and improve understanding of their relative contributions and interactions may be particularly advantageous.

ERRG recommendation 9: The Government's research programme has thus far incorporated research on hydrogen into its work on fuel cells. It is now appropriate to establish a dedicated hydrogen research programme which would complement the continuing work on fuel cells. Research priorities should include storage technologies, particularly those which could lead to a step change in performance, and sustainable methods of hydrogen production. There should also be a limited demonstration programme.

ERRG recommendation 10: The key priority for publicly funded research in relation to nuclear fission should be to improve the methods by which nuclear waste and spent fuel can be safely and cost-effectively handled and stored. Even if there were to be no new commitment to nuclear build, the need to deal with legacy wastes argues strongly for a research programme aimed at finding innovative ways of treating them.

ERRG recommendation 11: With regard to nuclear fusion, priority should be given to work on materials capable of withstanding the heat and plasma fluxes in an operating fusion reactor for a sufficient length of time. Without such materials, realising nuclear fusion's potential as an energy source may not be possible.

ERRG recommendation 12: R&D on novel emerging PV material systems such as organics/polymers could provide step-change decreases in the cost of production. Given that this is the case, it may be advantageous for the UK to focus efforts more on these innovative "next generation" technologies and the associated systems.

ERRG recommendation 13: A suitable body should be entrusted with the mission of collecting and co-ordinating information, so that policy makers and research planners in this area are able to avoid unwittingly funding activity which is already adequately supported elsewhere, or neglecting a strategic requirement because of inadequate or mistaken information about what others are doing. The body carrying out the task would need to be seen as independent and have access to the necessary data, or the powers to collect such data. Such a body need not be located in government, although if it were, it ought to be placed so as to access the relevant expertise.

ERRG recommendation 14: Consideration should be given to setting up a dedicated national energy research centre. We welcome the proposals for such a centre currently being developed jointly by the Research Councils in collaboration with others. We also welcome the interest being shown by universities, business, the Energy Saving Trust and the Carbon Trust. Such a centre should be the hub of a wider network encompassing new and existing centres of excellence in specific areas.

ERRG recommendation 15: The Government should find means to continue a strategic exploration of a wide range of relevant issues, including those raised by the review's original terms of reference as well as issues such as legislative and regulatory drivers for research, energy storage technologies and infrastructure, and socio-economic research. This would enable those charged with the task to work up more detailed recommendations based on the outline which we have set in place.

ANNEX 9. GLOSSARY

28 day rule	Domestic customers are entitled to change their gas or electricity supply at 28 days notice and contracts are not allowed to preclude this right.
AGR stations	Advanced Gas Cooled Reactor nuclear power stations
BAU	Business As Usual
Biofuels	A fuel produced from dry organic matter or combustible oils produced by plants. Examples of biofuel include alcohols (from fermented sugar), black liquor from the paper manufacturing process, wood and soybean oil.
Biomass	The total dry organic matter or stored energy content of living organisms. Biomass can be used for fuel directly by burning it (e.g. wood), indirectly by fermentation to an alcohol (e.g. sugar) or extraction of combustible oils (e.g. soybeans).
Carbon abatement	Reducing/diminishing carbon produced; measures to prevent CO_2 emissions
Carbon C&S	Carbon capture and sequestration (see below)
Carbon capture	Removal of CO_2 from fossil fuels either before or after combustion. In the latter the CO_2 is extracted from the flue-gas.
Carbon sequestration	The long-term storage of carbon in the forests, soils, ocean, or underground in depleted oil and gas reservoirs, coal seams, and saline aquifers (see engineered sequestration).
Cash-out prices	The price paid to/by generators and suppliers to remove imbalances from the electricity network. Cash-out prices are paid as part of the financial settlement of Balancing Mechanism trades to deal with those whose generation or consumption of electricity is out of balance with their contracted position.
CHP	Combined Heat and Power
CCL	Climate Change Levy
CCGT	Combined Cycle Gas Turbine
CO_2	Carbon Dioxide (a greenhouse gas)
CSA	Chief Scientific Adviser
DEFRA	Department for the Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions (Note: DETR ceased to exist after the 2001 General Election. Its responsibilities were split largely between DEFRA and DTLR.)
DGCG	Distributed Generation Co-ordinating Group
Distributed generation	Synonym for embedded generation

Decentralised generation	Synonym for embedded generation
Diversity (in the energy system)	Having primary or secondary energy provided by a range of fuels or sources of fuel.
DTI	Department of Trade and Industry
DTLR	Department of Transport, Local Government and the Regions
EC	Commission for the European Union
EU	European Union
Embedded generation	Embedded generation covers smaller power plants connected to a regional electricity company's distribution network (as opposed to the high voltage transmission network where most current power plants are connected).
EGWG	Embedded Generation Working Group
Emissions/ carbon trading	A scheme introduced to cut down on greenhouse gases in the atmosphere and also complement other climate change measures.
Engineered Sequestration	Carbon sequestration achieved artificially by piping carbon dioxide into geological strata or the deep ocean.
EST	Energy Saving Trust
Equity	Fairness; use of principles of justice/fairness to supplement/implement law
Exogenous	Independently determined. A variable in an economic model (e.g. crude oil deposits) is said to be exogenous if it is not a function of any other variable in the model (e.g. the price of oil). The opposite of exogenous is endogenous.
Externality	An action by any producer/consumer that directly impacts on another producer/consumer, which the latter has not chosen to accept and so is not reflected in the market price of the action. Externalities can be either positive (i.e. beneficial) or negative (i.e. adverse).
FCO	Foreign and Commonwealth Office
Fuel cells	An energy conversion device which produces electricity from the electrochemical reaction between hydrogen and oxygen.
Fuel poverty	The most widely accepted definition of a fuel poor household is: one which needs to spend more than 10% of its income on all fuel use and to heat its home to an adequate standard of warmth.
GEMA	Gas and Electricity Markets Authority
GW	Giga Watt – a measure of power, one billion Watts.
Greenhouse gas	Atmospheric gases that partly absorb and re-emit downwards infrared radiation emanating from the earth's surface.
HSE	Health and Safety Executive
IEA	International Energy Agency
Interconnectors	A pipe or other means of transportation of fuel between countries for example there is

a pipeline connecting England and Belgium.

Intermittents Intermittent power plants harness energy from unpredictable natural sources (for example, wind or waves). Output is therefore not reliable, in the sense that it cannot be turned on and off as required.

IPPC Intergovernmental Panel on Climate Change

Liberalisation Occurred in the UK energy utilities over 15 years from the mid-1980s onwards and entailed the privatisation of gas, electricity and coal industries and a gradual increase in the level of competition.

kWh kilo Watt hour. Unit of electrical energy – one thousand Watts of electrical power provided for one hour. The basic unit of electrical sales.

LNG Liquified Natural Gas

Market failure Used by economists to describe the situation where the unconstrained operation of markets leads to a situation in which society is less well-off than it should be, using some objective measure. An attempt to rectify the failure is usually made through some form of Government intervention, such as regulation, economic instruments or some other policy tool.

Micro-generation Generation of electricity on a small (e.g. domestic scale), for example by photovoltaics or fuel cells.

Micro-turbines Gas turbines operating on a small scale, one of the technologies associated with micro generation

MW Mega Watt – one million Watts

MWh Mega Watt hours – one thousand kWh

NETA New Electricity Trading Arrangements

NGC National Grid Company

NGO Non-Governmental Organisation

NO_x Nitrogen Oxides (local and regional air pollutants)

Ofgem Office of Gas and Electricity Markets

OPEC Organisation of the Petroleum Exporting Countries

OST Office of Science and Technology

Photovoltaics (PV) Apparatus which transforms light directly into electricity.

PIU Performance and Innovation Unit

p/kWh Pence per kWh – the common form of pricing energy sold to consumers.

RD&D Research, Development and Demonstration

R&D Research and Development

RCEP The Royal Commission on Environmental Pollution

Renewables Energy production using natural resources in an inexhaustible manner.

Renewables Obligation The obligation placed on licensed electricity suppliers to deliver a specified fraction of their electricity from

	renewable sources or pay a penalty to Ofgem.
Resource productivity	Measures the ratio of economic output to natural resource input and thus the efficiency with which we use energy and material in power generation, manufacturing, services and households.
Scenarios	Internally consistent descriptions of possible future states of the world that set a framework in which social, economic and technological developments (in our case energy systems) may be analysed.
SEPU	Sustainable Energy Policy Unit (proposed new body within Government)
SMEs	Small and Medium-Sized Enterprises
SO_x	Sulphur Oxides (local and regional air pollutants)
Strategic (or fuel-related) risk	The risk of interruption to the supply of fuel from overseas. The origin of the problem may be market power, or political instability, or lack of investment in overseas infrastructure.
Sustainable development	Development that meets the needs to current generations without reducing the ability of future generations to meet their needs. The concept of sustainable development integrates the three conventionally separate domains of economic, environmental and social policy.
Synergy	Occurrence or policy which is mutually beneficial to more than one party
Domestic risk (to an energy system)	The risk of interruption to the flow of energy within the UK. The origin of the problem may be low or inappropriate investment in energy equipment (production, transportation or storage), technical failure, terrorism or civil unrest.
TENS	Trans-European Networks
TWh	One billion (1,000,000,000) kWh
TWh/yr	Units of electrical energy produced/consumed in a year
UKCS	United Kingdom Continental Shelf
UNFCCC	United Nations Framework Convention on Climate Change
Vesting	The moment (1st April 1990) when the switch was made from the old electricity industry structure in England and Wales (comprising the Central Electricity Generating Board and the Area Electricity Boards) to the new market structure (comprising a range of companies carrying out the functions of generation, transmission, distribution and supply, together with the wholesale market known as The Pool). Most of the new companies were privatised in the subsequent 12 months.
Watt	The conventional unit to measure a flow rate of energy. One Watt amounts to 1 joule per second.

ANNEX 10. REFERENCES

AEAT (2001), Database on Energy Technologies (corporate data source of AEAT Ltd)

BP plc (2001), BP Statistical Review of World Energy

Brandon and Hart (1999), An Introduction to Fuel Cell Technology and Economics

Building Research Establishment (2001), Domestic Energy Fact File

British Wind Energy Association (2001a), Notes of Meeting Between OFGEM and BWEA, 15 October

British Wind Energy Association (2001b), Review of Surveys

BTM Consult (2001), International Wind Energy Development, World Market Update 2001

Chief Scientific Adviser (2001), Energy Research Review: Full Report

Commission for the European Union (1997), The Atlas Project

Commission for the European Union (2001a), Communication on the implementation of the first phase of ECCP, COM (2001) 580

Commission for the European Union (2001b), Energy Efficiency: Action Plan

Commission for the European Union (2001c), Greenhouse Gas Emissions Trading within the European Community, COM (2001) 581

Commission for the European Union (2001d), Green Paper – Towards a European Strategy for the Security of Energy Supply, COM (2000) 769 Final

Commission for the European Union (2001e), Proposal for a Directive on the Energy Performance of Buildings, COM (2001) 226 Final

Darmstadt, J, Titlebaum, P, Polach J (1971), John Hopkins Press for Resources for the Future

Department of Energy (1989), Energy Use and Energy Efficiency in Transport

Department of the Environment (1993), Planning Policy Guidance Note 22: Renewable Energy

DEFRA (2000), Waste Strategy 2000 for England and Wales

DEFRA (2001a), Energy Efficiency Commitments 2002-2005 Consultation Paper

DEFRA (2001b), Digest of Environmental Statistics (derived from NETCEN, 2001, UK Greenhouse Gas Inventory, 1990-1999, AG Salway, TP Murrells, R Milne, S Ellis)

DEFRA (2001c), Managing Radioactive Waste Safely Consultation Paper

DETR (2000), UK Climate Change Programme

DTI (1997), Energy Paper 66 – Energy Consumption in the UK

DTI (1998), New and Renewable Energy: Prospects in the UK for the 21st Century, Supporting analysis

DTI (2000a), DUKES, 2000, Emission factors of fossil fuel in 1998, Table B.1.

DTI (2000b), Energy Paper 68 – Energy Projections for the UK

DTI (2000c), The Energy Report 2000

DTI (2000d), UK Energy Sector Indicators 2000

DTI (2001a), Digest of UK Energy Statistics

DTI (2001b), Draft Social and Environmental Guidance to GEMA

DTI (2001c), Energy Sector Indicators

DTI (2001d), Energy Trends, Provisional Estimates for CO2 emissions by sector, March

DTI (2001e), Government Response to Ofgem's reports 'The New Electricity Trading Arrangements – Review of the First Three Months' and 'Report to the DTI on the Review of the Initial Impact of NETA on Smaller Generators' of 31st August 2001

DTI (2001f), Quarterly Energy Trends

DTI (2001g), Renewables Obligation Statutory Consultation

DTI (2001h), Review of the case for Government support for cleaner coal technology demonstration plant, Final report

DTI (2002), Inter-Departmental Analysts' Group on Low Carbon Options report on Long Term Reductions in Greenhouse Gas Emissions in the UK

DTI, DEFRA (2001), The UK Fuel Poverty Strategy

DTI, DTLR, Ofgem (2001), Embedded Generation Working Group – Report into Network Access Issues, Vols 1 and 2

DTI, Scottish Office (1995), The Prospects for Nuclear Power: Conclusions of the Government's Nuclear Review, Cm 2860

DTLR (2000), Transport Statistics

DTLR (2001a), Building Regulations. Part L Approved Document, May

DTLR (2001b), New Parliamentary Procedures for Processing Major Infrastructure Projects

DTLR (2001c), Planning Green Paper- Planning: Delivering a Fundamental Change

DTLR, DTI, HM Treasury (2001), Powering Future Vehicles

ETSU (1998), The Value of Electricity Generated from PV Power Systems in Buildings (for Department of Trade and Industry)

Federal Energy Regulatory Commission (2001), Ensuring Sufficient Capacity Reserves in Today's Energy Markets: Should We? And How Do We? Study Team Discussion Paper

Ferguson, M (2001), see list of Working Papers

Goddard, S (1991), 'Future Programmes' in Where Are We Now on Nuclear Power, pp. 59-70, London, Institute of Energy

Green Alliance (2001), Signed, sealed and delivered? – The role of negotiated agreements in the UK

Hartnell, G (2001), 'Planning and renewables: implications for meeting the targets' Regional Planning Targets: rationale, progress and practical implementation, CREA Conference at ImechE, 1 Birdcage Walk, London, 22 March

HM Treasury, DETR (2000), Environmental Issues in Purchasing, guidance note

House of Commons Science and Technology Committee (2000-01), Seventh Report on Wave and Tidal Energy

ICCEPT (Imperial College Centre for Energy Policy and Technology) (2001), Scoping R&D Priorities for a Low Carbon Future, Imperial College report on priorities for the Carbon Trust commission by the Carbon Trust and Department of Environment, Food and Rural Affairs

IEA (2000a), Energy Policies of IEA Countries, OECD

IEA (2000b), Experience Curves for Energy Policy, OECD

IEA (2001a), Energy Balances of OECD Countries, 1998-1999, OECD

IEA (2001b), Natural Gas Information 2001 (2000 data), OECD

IEA (2001c), Nuclear Power in OECD, Paris, OECD

ILEX (2001), see list of Working Papers

Intergovernmental Panel on Climate Change (1999), Aviation and the Global Atmosphere

Intergovernmental Panel on Climate Change (2000), Third Assessment Report, Working Group III

Intergovernmental Panel on Climate Change (2001), Climate Change 2001: Mitigation. Contribution of Working Group III to the Third Assesment

International Atomic Energy Agency (1 November 2001), Press Release – Calculating the New Global Nuclear Terrorism Threat

Layfield, F (1987), The Sizewell B Public Planning Enquiry

MacKerron, G (1994), The Capital Costs of Sizewell C, submitted to Government's Nuclear Review, COLA 3

McDonald, A & Schrattenholzer, L (2001), 'Learning rates for energy technologies' Energy Policy 29, pp. 255-261

Milborrow, D (2001), see list of Working Papers

Ministry of Fuel and Power (1965), Fuel Policy, Cmnd 2798, HMSO

Moore, A (2001), e-mail from Alan Moore (MD of National Windpower), Wind under NETA, 3 December

Murry, R (2001), Creating Wealth from Waste, DEMOS

National Assembly for Wales (2001), Wales Spatial Planning: Pathways to Sustainable Development – consultation

OECD Nuclear Energy Agency and the International Atomic Energy Agency (2000), Uranium 1999: Resources, Production and Demand, Paris

OXERA (2001), see list of Working Papers

National Audit Office (1998), The Office of Electricity Regulation (1998): Improving Energy Efficiency Financed by a Charge on Customers. Report by the Comptroller and Auditor General, HC 1006 1997/98

Office of National Statistics (2001), UK National Accounts

Official Journal of the European Communities, 2001, Directive 2001/77/EC of the European Parliament and the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market, L283/33-40

Ofgem (2001a), Report to the DTI on the Review of the Initial Impact of NETA on Smaller Generators

Ofgem (2001b), Submission to PIU Energy Review

PCAST (Presidential Committee of Advisors on Science and Technology) (1995), Report of the Fusion Review Panel

PCAST (Presidential Committee of Advisors on Science and Technology) (1997), Report to the President on Federal Energy R&D Challenges for the 21st Century

PIU (2001a), Renewable Energy in the UK

PIU (2001b), Resource Productivity: Making more with Less

Royal Commission on Environmental Pollution (2000), Energy – The Changing Climate

Royal Society for the Protection of Birds (2001), RSPB Market Research Project 0136 – The GB public's views on energy issues, on

Scottish Embedded Generation Working Group (2001), Report into Network Access Issues – a Consultation Document from the Joint Government Industry Working Group on Embedded Generation

Scottish Executive (2000a), National Planning Policy 6: Renewable Energy Developments

Scottish Executive (2000b), Public Attitudes Towards Wind Farms in Scotland, August,

Shell (2001), Distant Gas – Will it arrive on time? European Autumn Gas Conference, 7 November

Social Exclusion Unit (2001), Transport and Social Exclusion Consultation

Strbac, G, Jenkins (2001), see list of Working Papers

Thorpe (1999), A brief Review of Wave Energy in the UK

UNDP, WEC (United Nations Development Programme & World Energy Council) (2000), The World Energy Assessment

US National Academy of Sciences (2001), Energy Research at DOE: Was it Worth it? Energy Efficiency and Fossil Energy Research 1978-2000, US Department of Energy

US National Energy Policy Development Group (2001), Reliable, Affordable and Environmentally Sound Energy for America's Future

Utterback (1997), Mastering the dynamic of innovation, Harvard University Press

Wind Power Monthly, January 2001

Working Papers

These can all be found on the PIU website: *www.piu.gov.uk*

Chief Scientific Adviser (2001), Energy Research Review: Full Report

Ferguson, M (2001), Working Paper on Transport

ILEX (2001), Working Paper on NETA and Small Generators

Milborrow, D (2001), Working Paper on Penalties for Intermittent Sources of Energy

OXERA (2001), Working Paper on Renewable Energy Cost Modelling

PIU (2001c), Working Paper on Energy Efficiency Strategy

PIU (2001d), Working Paper on Energy Productivity to 2010 – Potential and Key Issues

PIU (2001e), Working Paper on Energy Scenarios to 2020

PIU (2001f), Working Paper on Energy Systems in 2050

PIU (2001g), Working Paper on Environmental Costs and Risks

PIU (2001h), Working Paper on Generating Technologies: Potentials and cost reductions to 2020

PIU (2001i), Working Paper on The Economics of Nuclear Power

Strbac, G, Jenkins, N (2001), Working Paper on Network Security of the Future Electricity System

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