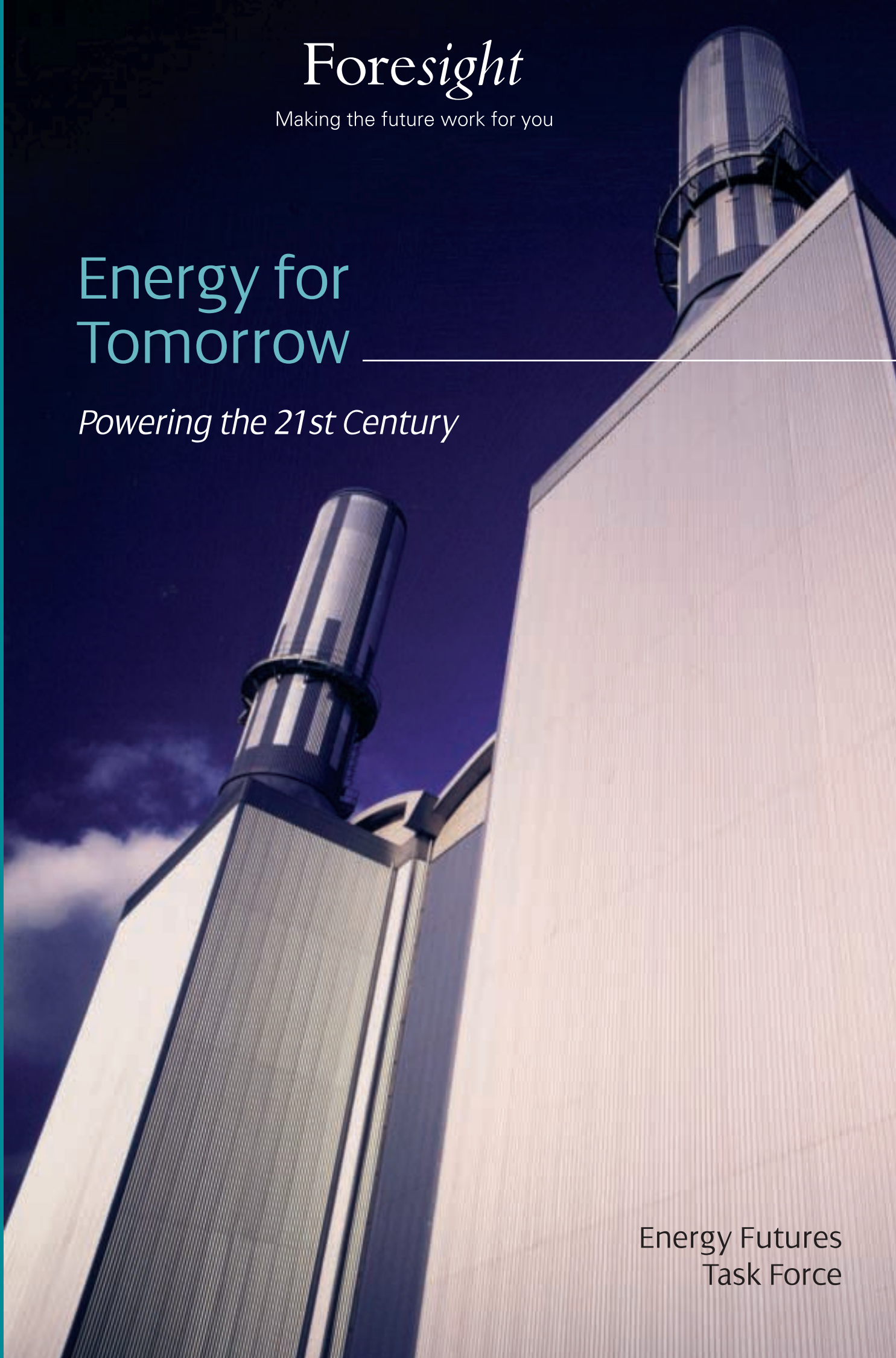
Foresight

Making the future work for you

Energy for Tomorrow

Powering the 21st Century



Energy Futures Task Force

“God provides the wind but man must raise the sails“

St Augustine

Front cover:
Seabank Power Station (a joint venture between Scottish and Southern Energy plc and BG Group plc) at Avonmouth near Bristol – at the forefront of today's gas-fired power generation technology.

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A message from the Chairman

Professor John McMullan, Director
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Within the activities of the Foresight Energy and Natural Environment Panel, the role of the Energy Futures Task Force was to develop a robust view of the research and development and associated activities that will provide the best prospect for achieving Foresight objectives over the next forty years. This is a long time to look ahead in an uncertain world, but it is one that is appropriate to the energy industries because of plant lifetimes and the scale of investment involved.

The Task Force approached the problem by considering the implications of the four environmental scenarios already developed within the Foresight programme. It analysed the energy implications of these scenarios and then undertook a wide consultation in order to develop a consensus on the consequent challenges and opportunities.

I would like to thank all those who took part, my colleagues on the Task Force, the Secretariat, the Foresight Regional Co-ordinators, and others, who organised the regional consultation meetings and contributed to their smooth operation, and finally, everyone who responded to the consultation itself. The constructive way in which each and everyone contributed has made this a rewarding experience.

Executive Summary

Looking ahead to 2040, this study by the Foresight Energy Futures Task Force focuses on what needs to be done to develop a mix of energy sources and infrastructure that will ensure a competitive future for the UK.

In this time span, North Sea oil and gas will be in decline and most estimates are that global production of these fuels will have peaked. Failing determined action to reduce the need for energy, global demand will have continued to increase and may have doubled. Against this background there is the concern over carbon dioxide (CO_2) released into the atmosphere by burning fossil fuels. This 'greenhouse' gas has been implicated in global warming and international agreements exist to cut emissions. Either for this reason, or because oil and gas become scarce and expensive resources, the next forty years will see a shift in the mix of energy sources away from these fuels. This report does not try to pick technology 'winners', but highlights research that should be begun now to ensure that we are able to make the right choices in the future.

Analysing four scenarios with widely-ranging starting assumptions, the Task Force has produced a short-list of key actions that should be addressed no matter what direction the future takes. These centre on the infrastructure, implementation, decommissioning, regulatory and education issues that will enable new technologies to be adopted and to achieve their potential as they are needed.

Among the key non-R&D issues, energy efficiency in end-use technologies and education were identified as being particularly significant. Energy efficiency measures can play a major role in moving towards sustainability by reducing energy demand. Implementation requires collective action, however, and so can only be achieved through widespread public co-operation.

The requirements in education include the continuing need to attract engineers and scientists to work in the energy sector, the encouragement of an energy conservation mentality, and the provision of accurate and unbiased energy information for decision makers. If the anticipated changes in the energy system are to take place, then public awareness of real energy issues must be increased. It is only in this way that planning decisions can be based on balanced arguments rather than first perceptions.

Three major R&D themes and recommendations emerge from the short-list:

Electricity Infrastructure Migration

Whatever the mix of energy sources it seems certain that more, smaller generation stations will be used in the future. These will be sited either at the point of supply, as for wind, wave and biomass power, or at the point of demand, as for combined heat and power (CHP) stations and embedded generation.

Long-term R&D must begin now to determine how best the UK can move from an infrastructure based on relatively few, large plants to one with many, smaller generators that are geographically dispersed.

If we neglect this we may fail to realise the full benefits of renewable energy, for instance by high project costs, by producing instabilities in the system, or by not being able to use the best sites (which are often remote from the point of demand).

Transport Fuel Migration

It is not yet clear what energy sources will replace oil-derived fuels for transport, although vehicle (including water- and air-borne) manufacturers and energy companies are actively researching this. However it is certain that changes to the supply infrastructure will be required, ultimately greater than those needed when the UK changed from town gas to natural gas in the 1970s.

R&D needs to be started and co-ordinated to ensure that the UK is able to manage the change from oil-based transport fuels. This includes ensuring an appropriate regulatory environment and enabling the UK to take a full part in international decision-making.

If insufficient attention is paid to this, UK business may be seriously disadvantaged by prolonged uncertainty and unpredictable costs.

Nuclear Power

In the UK, the last of our existing nuclear power stations is scheduled to close in 2035, although elsewhere in the world construction continues and the United States is considering re-starting its nuclear power programme. It is not yet clear how gas-powered generating capacity should be replaced as supplies of gas become more restricted. If the requirement is added that CO_2-emitting plant must be replaced by zero or close to zero emission generators, the problem becomes much greater – unless nuclear power is kept as part of the energy mix.

A full re-examination must be undertaken of the nuclear power issue. If a nuclear power component is required over the long term, then the UK must maintain and develop its expertise, to keep the option of designing, building, running, and eventually decommissioning, new plant. Much of this activity will take place through international co-operation and will focus on cheaper, more efficient and easier to decommission power stations. The issues of waste disposal and public confidence in safety must be addressed with further research.

The Task Force believes that this is essential if the UK is, at a minimum, in a position to be an intelligent customer should it prove necessary to buy nuclear plant in the future.

Offering zero CO_2 emissions and small amounts of relatively short-lived waste, fusion power is an attractive option. Fusion research is an area where the UK is world class and participates in the major international programme. However, on present projections for the construction of commercial fusion power plant, it is outside the forty-year horizon of this report.

1 Introduction

Energy makes a vital contribution to the lives of everyone. Without access to sufficient energy to meet its needs, the whole fabric of current society would be undermined. Life as we know it would become impossible: transport, heated homes, communications, food, retailing, manufacturing and our national security all depend on a diverse, sustained and adaptable supply of energy. As a consequence, the energy production and supply system is well developed and by and large unobtrusive. Indeed, it is only when a sudden disturbance occurs in its price or availability that energy concerns become prominent in public discussions.

The various predictions made of future energy supply and demand differ from each other in assumptions and detail, but are remarkably consistent in their general conclusions. The IEA[1] and the World Energy Council[2] predict an increase in global energy demand of 2-3% per annum for the next 25 years, while supplies of oil and gas are expected to peak over approximately the same timescale. Therefore, there is an increasing global requirement to identify alternative fuel resources, and to exploit them.

For the UK, this has to be viewed in the context of the limited remaining life of North Sea oil and gas reserves, the closure of much of the coal industry, and the finite life of existing nuclear power plant.

Energy is also a key driver for the environment. The combustion of fossil fuels releases large quantities of carbon dioxide, particulates, and oxides of sulphur and nitrogen. The Inter-governmental Panel on Climate Change (IPCC)[3] and the United Nations (Kyoto Protocol)[4] have reported extensively on the possible consequences for climate change of carbon dioxide emissions resulting from the use of fossil fuels. Other bodies have stressed the importance of sustainable development, and more general aspects of environmental protection. Responses to all of these concerns will have profound implications for energy production and use.

The energy sector may appear stable and mature. Yet there have been considerable changes in its technology, direction and experience over the last hundred years, and there is no reason to believe that this will not continue in order to meet the needs of the future. What is much more difficult is to see what the course of these developments may be. This sector more than most has always felt the need to look well ahead to try to meet predicted needs and the requirements for its products and services. However experience has shown that simply taking action based on long-term extrapolation from a particular prevalent position at any given time is likely to become inappropriate very quickly. Attempts to formulate long-term policy on that basis have had limited success, particularly in trying to pick long-lasting technology 'winners'.

The Foresight Energy & Natural Environment Panel believes the present almost total emphasis within the energy sector on addressing short-term, albeit business-critical, issues needs to change. To fulfil the demands of society and secure a strong international position

1 World Energy Outlook (International Energy Agency, 1998)

2 Joint Study by the World Energy Council and the International Institute for Applied Systems Analysis (World Energy Council, 1998)

3 IPCC Working Group 1. Climate Change 2001: The Scientific Basis. IPCC c/o World Meteorological Organisation, Geneva, Switzerland.

4 United Nations Framework Convention on Climate Change. Kyoto, 1997.

over the next forty years requires a long-term strategic framework that includes consideration of sustainable development and the environment. Focusing energy-related Research & Development[5] efforts on those areas of most significance to the UK is a first step to achieving success in the future.

The Foresight Energy Futures Task Force aimed to identify energy-related technologies, systems and practices that over the next forty years could present both opportunities and obstacles to UK business and society in general. This is a longer time frame than has been followed generally in the current round of the Foresight Programme and twice as far ahead as considered by the previous Foresight Energy Panel in 1994-5[6]. However, it reflects the need for a longer-term vision and matches approximately a time period over which most of the current energy-related infrastructure will have reached the end of its life and will have been replaced or superseded.

Climate change is an issue that is currently of very intense interest. It is not considered directly within this report because actions to address it are already being taken, with specific emissions reduction targets to be achieved by 2010. Thus it has an urgent and short-term priority demanding immediate action. Nonetheless, it remains as an important sub-text throughout the discussion, because all long-term environmental protection and sustainability issues have a parallel thrust and require similar lines of development, based on technologies with a long lead time. It is worth noting, however, that, as existing nuclear plants are closed, environmental targets will be more difficult to achieve if fossil fuel plant is used to replace the lost capacity. Fusion power is an attractive option for a low-carbon economy in the long term. However, on present projections, it is unlikely to be commercially viable until after the end of the forty year period being considered

The Foresight Energy Futures Task Force has tried to develop a consensus on the major energy issues facing the UK and the consequential R&D demands this will place on the sector. By facilitating widespread and forward-thinking discussion within the sector on the factors that will influence its future some common actions have been identified that can now be taken forward.

The work of the national Foresight Programme is supported by Associate Programmes undertaken by other organisations on their own initiative. These include professional institutions, research and technology organisations and trade associations. Associate Programmes investigate the future of a topic of interest to the specific organisation within the framework of the national programme.

Relating to the interests of the Energy Futures Task Force three Associate Programmes are already underway, or have been completed, examining requirements for particular generation technologies and their findings will be considered within the Task Force's action plan. These are:

- Advanced Power Generation Task Force - generation from fossil and associated fuels (waste & biomass);
- Solar Photovoltaics in the UK;
- Nuclear Technology Requirements out to 2020.

5 Throughout this document, the term R&D will be used as shorthand to include not just the basic research, but also the necessary technical development, pilot and demonstration plant, and associated dissemination activities needed to realise a usable product or service.

6 Progress Through Partnership: Energy (HMSO, April 1995)

2 Methodology

There have been several recent studies relating to technological needs in this area and focusing in particular on concerns about climate change or on specific issues. The most notable recent examples are the report by the Royal Commission on Environmental Pollution (RCEP)[7], and the Commons Select Committee on Science and Technology Report on Wave and Tidal Power[8]. The Task Force wished to look to the future from a different viewpoint, and hence has adopted a complementary approach with the objective of widening the debate. This was achieved by using a prospective scenario-based process developed for the Foresight Programme. The aim of this approach is to identify common strands that are important across a wide range of potential futures and generate a set of underpinning actions that will be robust against differing outcomes, whatever they may prove to be.

The scenario approach provides a powerful aid to decision making. Instead of trying to predict the future, a number of contrasting futures are postulated and their implications analysed. The strength of the method lies not in the accuracy or otherwise of any one scenario, but in the insight that is to be gained from understanding the implications of a particular scenario and how these differ from (or are similar to) those of other scenarios. It is important to remember that a scenario is neither a wish to be attained, nor a prophesy, but a presentation of a possible future.

An important aspect of this technique is that it allows possible futures to be considered in which the major concerns are very different from those regarded as critical today. This should not be seen as wishing to ignore or downplay present day concerns, but to see beyond them. For example, it is conceivable that, by 2040, conditions might have arisen under which the provision of an energy supply of any type might be seen as being vitally important, whatever the environmental consequences may be. Also, the scenarios might take very different views about how adaptation to climate change may proceed.

The Foresight Environmental Futures scenario set[9] is an attempt to consider the main aspects of our society as it might be in forty years time. It proposes four possible futures:

- **World Markets:** a world defined by an emphasis on private consumption and highly developed and integrated world trading systems;
- **Provincial Enterprise:** a world of consumerist and short-termist values coupled with policy-making systems that assert national and regional concerns and priorities;
- **Global Sustainability:** a world in which social and ecological values are considered in economic decisions, and in which strong collective action through global institutions tackles environmental problems;
- **Local Stewardship:** a world where stronger national and regional governance allows social and ecological values to play a strong role in the development of markets and behaviour.

7 Energy – The Changing Climate (Royal Commission on Environmental Pollution 22nd Report, June 2000)

8 Wave and Tidal Energy. Commons Select Committee on Science and Technology Report No. 7, 30 April, 2001

9 Environmental Futures (Office of Science and Technology, March 1999)

These are global scenarios, set in a UK context. Each has been expanded to determine its consequences for key factors affecting different sectors of the energy market within the United Kingdom. None of these scenarios are expected to happen as stated and none form a vision of the future that the Task Force or the Foresight Programme wants to promote.

In formulating this analysis, the Task Force first met an invited group selected to represent the highest levels of expertise and experience in energy matters, and the widest range of views from within the energy community. The viability, stability and desirability of each scenario were evaluated and some of the challenges that each presented were identified. Subsequent discussion focussed on the R&D requirements facing the energy sector within these possible futures. Areas of common cause were highlighted, as were knowledge gaps. Discussion was not restricted to technological matters, but included social and educational needs.

Following the work of the experts' group, a Consultation Document[10] was published and the views of industry, commerce, public authorities, NGOs, charities, professional bodies, academia and the general public were solicited. The responses helped to shape the 'challenges' chapter (Section 4), and the recommendations presented in Section 6. An analysis of the responses is given in Section 7.

10 Fuelling the Future – A consultation document. Foresight 2000.

3 The Analyses

3.1 World Markets Scenario

DESCRIPTION

This is a world defined by an emphasis on private consumption and a highly developed and integrated world trading system. Social values are materialist, with resulting high levels of consumption and mobility. Working towards long-term sustainable development is marginalised as an international political goal.

There is a declining role for national governments in economic management and in the provision of public services. Pressure grows to reduce taxes. Regulation of utility and other markets is very light. There is minimal concern over inequality or social exclusion, and social tensions rise.

Large firms dominate global markets. Concentration into a few global players occurs in key industries (including integrated utilities) whilst there is a high degree of specialisation for smaller niche producers in other industries. Growth in services dominates and traditional manufacturing migrates towards the developing world. International best practice in technology and management is adopted quickly and global standards emerge for many products and services.

Energy markets are dominated by fossil fuels, particularly natural gas. By 2020, exploitation of alternatives to conventional oil, including tar sands, begins. Demand for electricity and transport fuels continues to grow. Electricity supply investments are generally in modular, more distributed power systems. Because of competition, energy prices remain low, and there is little concern for energy efficiency except in purely economic terms, although by 2010 most of the easy energy efficiency opportunities have been realised. High discount rates and the low priority attached to global environmental problems preclude the widespread adoption of renewable energy but promote investment in modular, more distributed power systems. Neither is there a revival of nuclear power because of the high discount rates and prevailing fossil fuel prices.

Individual consumerist values lead to smaller households as more people live alone.
A mobile labour force accelerates migration towards South-East England.
Segregation between the wealthy and the disadvantaged becomes marked and gated communities develop. High incomes mean more households can afford to occupy larger dwellings with an extensive range of domestic appliances, such as air conditioning units, with consequently high energy consumption.

DISCUSSION

The Task Force considered this to be a realistic scenario for evolution from the present, with broad agreement with both the overall theme and the elements within it. They agreed that neither nuclear power nor renewable generation would receive attention in an international society driven purely by economic factors. However, with time and noticeable environmental consequences, methods of carbon dioxide sequestration and emissions trading would be

demanded. In fact, there were questions as to whether this scenario could be sustained long-term. At some stage there would be pressures arising from either the price or the long-term availability of fossil fuels, even taking into account use of unconventional sources. It was thought that environmental or regulatory pressures would eventually restrain this society.

The domination by natural gas in itself would promote modular, distributed generation. Use of inexpensive micro-turbines, and eventually other discrete technologies such as fuel cells using gas as fuel, was considered likely to develop increasing momentum within this scenario as investment in large scale capacity becomes rare in a very competitive environment. The Task Force believes that there are significant shortfalls in current knowledge and technology with regard to building secure and stable networks incorporating distributed energy systems. Opportunities to develop CHP were thought particularly good within the growing service sector.

Clean coal technologies such as gasification and liquefaction could be favoured in some areas, and combustion re-emerges through the use of supercritical coal fired plants. As prices rise over time, the efficient generation and supply of power as well as its efficient end-use also become significant. There would be significant overseas opportunities for the UK coal-power sector to provide not only the technology but also the expertise to build and operate the generating capacity of developing countries.

Transition to hydrogen was considered to be possible but only in the very long-term. One way it might enter the market within this scenario was though fuel transition in the transport sector. Fuel cell powered vehicles are presently operating, but are at an early stage of development. Urban travel using hybrid and electric vehicles is part of this scenario, although their presence would become obvious only in the latter half of the time frame.

The Task Force felt it important to communicate to the public the effects of such a future on the natural environment. Social science research is needed into issues such as how the public perceives risk and how to influence attitudes regarding sustainability. It is believed that education would also play an important role in society accepting and adapting to a culture of more sustainable development.

KEY R&D ISSUES

- Improved fossil fuel extraction (conventional and unconventional)
- Increased efficiency of generating technology
- Increased efficiency of end-use, both stationary and transport
- Clean coal technology
- Carbon dioxide sequestration
- Mechanisms to facilitate emissions trading
- Alternative fuels in support of sustainable transport, e.g., fuel cells and their associated infrastructure
- Network issues for distributed energy systems
- Provision of energy as a service rather than a commodity
- Social science investigation of societal behaviour and attitudes. How to engender ownership of sustainable development
- Education to ensure an adequate skills base

"World Markets" Scenario

Factor	Industry	Commercial, Public & Service	Transport
Economic Growth	High growth in UK & world trade. Shift from heavy to light industry but increased trade internationally industrial skill and technology as required overseas. Clean coal technology, chemicals, metals, consultancy.	Substantial growth in service sector. Growth of financial and other personal services.	High economic growth increases demand within all transportation sectors. Globalisation increases freight transport distances travelled.
Industrial Structure	High value added industry thrives. Regional specialisation. Pharmaceuticals, commodities, biotechnology, ICT. Large transnationals and SME's serving niche markets.	Multinational companies catering to global mass markets. Smaller companies specialising in niche markets.	Car use continues to increase, as does rail and air travel and shipping. Large investment in infrastructure with some restrictions to future access.
Fiscal and Regulatory Policies	Liberalised open markets with light regulation. Competition promotes efficiency in use of resources. High rates of return are sought, reducing high capital cost investments.	Liberalised global markets increase opportunities but also competition. Limited role for public policies and institutions.	Market forces apply leading to cheaper travel. Some service integration. Use of road tolls.
Environmental Awareness	Minimal unless impinging on the life style of the affluent influential.	Environment viewed as a recreational resource to be purchased from leisure and tourism sector.	Low priority given to increased noise and pollution.
Local Environmental Policies	Industrial run-offs affecting water supply may provide opportunity for environmental technology and biotechnology. Waste is a commodity & incineration plants are located in poorer or industrial areas.	Few policies with negligible impact, especially upon global companies.	Any local concerns hindered by a weak planning system.
Global Environmental Policies	Weak. International emissions credit trading and technology transfer.	Ineffective.	Little impetus to control environmental impact.
Energy Consumption	Increases despite the decline of the more energy intensive industries. Natural gas is major fuel.	Increases.	Continues to grow.
Energy Security	Increased resource extraction – opportunities for exploration and extraction industry.	Impact on sector limited to opportunities for energy and particularly dispersed electricity and gas distributors.	A concern, especially as oil and gas supply influenced by world market demand.
Energy Costs	Low. Competitiveness more important than efficiency – no imposed costs (taxes).	Low.	Low.
Embedded/Distributed Power	New build of natural gas-fired, distributed power. More opportunity for smaller UK companies to become involved, e.g. in GTCC. Later possibilities as nuclear decommissioning peaks. Power from waste expands.	Opportunities for medium capital investment CHP systems for the growing service sector. Gas-fired microturbines or small scale GTCC.	Congestion increases demand for road and air infrastructure.
Technological Change	Rapid and innovative but based on short-term goals and market driven.	Transition to service and knowledge based economy coincides with rapid innovations in ICT that will revolutionise the sector.	New lighter materials of construction. Use of hybrid and electric technology in cities.

Domestic	Agriculture	Power Generation	Facilitation
High growth world of materialistic demand with high levels of consumption. Expansion of the construction industry.	Globalisation of industrialised agriculture.	Increased electricity demand despite loss of heavy industry. Decline of nuclear power generation.	Sustainable development marginalised as a political goal. Market values dominate to maximise economic growth.
The scale of the built environment increases Existing buildings are scrapped. New modular buildings are assembled from units pre-fabricated off-site.	Farm size increases but considerable conversion of agricultural land to housing and recreational purposes. Market dominated by large retailers.	Mixture of some large multi-utilities and many small scale generators.	Large transnational interests create global standards and adoption of international best practice.
Light regulation. High rates of return are sought, reducing capital investments.	Liberalised agriculture removes subsidisation from farming.	Light regulation of utility markets. High rates of return reduce investment for large-scale plants. Decommissioned nuclear capacity replaced by cheaper options.	Internationalist policies. Pressure to reduce taxes. Light regulation of utilities. No incentives or subsidies, which would interfere with, market forces.
Pleasant environment a commodity for the rich.	Pleasant environment a commodity for the rich.	Has no impact on generation.	Minimal, not to influence market.
Relaxed planning controls enable widespread building. Loss of green field sites. Increase in household waste.	Agricultural run off causes problems that are only addressed if affecting the rich, or public health.	Not significant to power sector. Waste incineration plants are developed.	Little policy at local level beyond assertion of lifestyle requirements by those who can influence the market. Local environment becomes another commodity.
Little effect upon sector.	Little effect upon sector.	Used to increase trade by selling generation technology and knowledge to developing countries in lieu of meeting any emissions targets.	International climate regime ineffective. Large-scale emissions trading and exploitation of the system occurs in response to market demands.
Increases with demand, despite new housing being more energy saving and having integrated services.	Greater use of technology & greater transport distances will lead to a gradual increase in energy use.	Increases, initially through use of natural gas, then clean coal technology becomes competitive.	Increases without control.
No impact upon sector.	No impact upon sector.	Exploitation of fossil fuel based generation. No uptake of uneconomic renewable based generation.	Increased resource extraction as and when needed.
Low.	Low.	Low. Competitiveness is the driving factor.	Competitiveness key issue - no imposed costs or taxes.
Distributed communities.	Fewer, large scale farms.	Growth of modular distributed power systems. New builds dominated by natural gas-fired generation, e.g. GTCC. Eventual re-emergence of larger scale efficient ultra-supercritical coal-fired plants.	Price dictates use of natural gas as main energy source, which in turn leads to distributed generation.
New technologies, materials and construction processes are adopted.	New technologies are adopted as agriculture becomes industrialised.	Rapid, innovative, modular; based on economics and resource availability.	Rapid and innovative but based on short -term goals and market driven.

3.2 Provincial Enterprise Scenario

DESCRIPTION

The Provincial Enterprise scenario envisages a world of private consumption values, coupled with lower level policy-making systems to assert local, regional and national concerns and priorities. Market values are dominant, but the scope of markets is limited by national and provincial boundaries. Sustainability more or less disappears as a political objective.

The pursuit of narrow national interests means that, whilst the world economy grows at 4 per cent per year, UK GDP grows sluggishly at 1.5 per cent per year. Economic growth is constrained due to capital and periodic resource shortages. Economic policy is concerned with protecting and supporting 'national champions' against foreign competition through various non-tariff and tariff barriers. There is little commitment to social or environmental goals, and an 'enterprise' ideology informs most policy decisions.

Supplies of fossil fuels last for longer in this scenario because of economic and other restraints on demand. There is a strong tendency to preserve existing sources of energy including indigenous coal and nuclear power by extending the lives of existing stations. Prices for final consumers of energy are higher than in the World Markets scenario because some higher cost forms of generation are maintained. However the pursuit of energy efficiency is limited in this scenario despite higher prices, due to a lack of available capital and the low priority attached to environmental investments in the light of low levels of public concern. Renewables do not develop under this scenario, though there is some further development of combined heat and power plant.

The trend towards people living in smaller households is constrained by the high cost of housing and limited social provision. There is continued growth in the number of household appliances but, compared with the 'world markets' scenario, this is limited by higher prices and non-tariff barriers to international trade.

The energy efficiency of lighting, appliances and domestic heating systems improves but national standards are not tightened, reflecting fears that this will put producers at a competitive disadvantage in export markets. Energy use per household is stable, with growth in household appliances and heating demand offset by modest gains in energy efficiency. With the number of households steady, overall domestic energy consumption is flat.

DISCUSSION

This scenario as a whole was thought to be incapable of persisting for long and would take significant changes to establish. However, there were elements present that were considered plausible and worth discussion. It was suggested that this was the most "negative" of the four scenarios. The potential for unrest within society, as well as the inevitable disintegration of strong trade barriers, were highlighted as causes of instability for this scenario.

Developing methods of large-scale energy storage was considered more important than new technology for power generation. However, development of any nature was expected to be minimal. Priority would be given to maintenance and preservation of existing capacity, including nuclear generation. It was thought that research would be required into the social acceptability of maintaining the UK's nuclear capacity. Planning issues were thought to pose difficulties for any new power generation site in this scenario, such that extensive links would be essential with consumer groups and local interested parties.

There would be some development of CHP as a consequence of the stabilisation of national industries and their auto-production of heat and power. Again, it was felt important to investigate network issues and system dynamics to prepare for this and for the possibility of individual cities seeking to generate their own capacity.

Although generation is expected to be largely utility-based, where the need arises, potentially from areas with poor energy resources, biomass and waste could be used to generate power. Attention would need to be paid to the development of biomass markets and waste-to-energy schemes.

KEY R&D ISSUES

- Large-scale energy storage
- Extension of plant life
- Network issues for distributed energy systems
- Social science investigation into the resolution of planning difficulties, e.g. siting of wind farms or transmission lines
- Biomass and waste utilisation
- Education to engender ownership of sustainable development

"Provincial Enterprise" Scenario

Factor	Industry	Commercial, Public & Service	Transport
Economic Growth	Slow economic growth nationally and limited international growth in an isolated sovereignty. Manufacturing stabilises with local substitution (where possible) for previously imported goods or materials.	International services and products decline, e.g., finance, but national monopolies created and growth in personal services for the wealthy.	Growth in transportation sector falls with decreased economic growth.
Industrial Structure	Existing industrial capacity is protected, creating "national champions" such as producers of steel, paper, chemicals, pesticides and fertilisers. Global specialised industry declines.	SMEs producing goods and services for the national market.	Slower growth of car use and ownership. Increase in air travel lessens. UK freight transport mainly by road.
Fiscal and Regulatory Policies	Protectionist policies defending UK monopolies: pharmaceuticals, defence, electronics and media. Mixed energy intensity. Economic independence preserved, which hinders access to global capital investment.	Investment is low and focuses on small-scale opportunities. Few public finance initiatives. Protectionist policies for national security.	Protection of existing industry but low investment leads to a stagnant vehicle market of older and polluting vehicles.
Environmental Awareness	People want clean air and better built environment but inconsistent practices between regions. Little consideration of wider environmental issues.	Low environmental awareness.	Little value attached to the environment.
Local Environmental Policies	Any action is a reaction to a perceived local problem and is enterprise led to address poor industrial performance. Opportunities for remediation and clean-up technologies. Landfill usual with some waste incineration. Illegal dumping is a significant problem.	Industry is not eco-efficient. Some environmental services offer remediation for local environmental concerns.	Not in my backyard (NIMBY) protests ineffective.
Global Environmental Policies	Climate regime falters through lack of commitment and ineffective co-ordination. Sustainability not considered.	No commitment to sustainable practise.	No impact upon transportation sector.
Energy Consumption	Increases, all indigenous sources used.	Increases.	Increases slowly.
Energy Security	Fossil fuel plentiful but of increasing low quality. Sensitivity to local scarcity leads to interest in alternative, biofuels.	Fossil fuels plentiful.	Stronger reliance on indigenous fuel sources.
Energy Costs	High generation costs from older plants. No priority given to efficiency improvements or cheaper long-term production from new-builds.	High energy costs.	High.
Embedded/Distributed Power	Utility dominance. Extension of existing plant lives of fossil fuel and nuclear power plants. Some CHP, some energy from waste.	Some CHP developed.	No growth in infrastructure. High congestion.
Technological Change	Slow innovation, low R&D investment. Small scale technology uptake in commodities sector. Growth of biotechnology industry ensured primarily through scientific knowledge rather than investment.	Biotechnology biggest driver, IT to a lesser extent.	Lack of investment precludes most developments in technology or efficiency.

Domestic	Agriculture	Power Generation	Facilitation
Slow growth in housing.	Intensification of agriculture without significant international input.	Slow economic growth due to capital shortages. No significant new plant builds. Some growth in CHP, partly supplied by large industrial auto-producers.	Slow economic growth with no co-ordination beyond national level.
Construction and upgrading of existing urban areas.	Intense exploitation of agriculture with greater diversification to meet local demands.	Large utility based generation.	Economic protection measures created to support existing national structure.
Lack of investment in housing and infrastructure.	Protection of agricultural market against outside forces.	Low levels of investment. Policy protects existing utilities.	Market values coexist with a supported local economy. Use of tariffs and tariff barriers. Restrictions on availability of global capital. Widespread lack of investment.
Low value placed on environment.	Low value placed on environment.	Has no impact on generation.	Environmental appreciation minimal due to lack of access and experience.
Little conformance to building or other regulations. Illegal disposal of waste.	Farming influenced mostly by retailers and at cost to wildlife.	Environmental problems caused by ageing plants are not addressed due to lack of political will.	Planning and regulation come second to local requirements for employment and economic growth.
Little effect upon sector.	Little effect upon sector.	Slow economic growth is much more significant than any international agreement.	National interests weaken already ineffective climate regime. No international co-operation and no response to climate change.
Increases. Lack of energy saving materials or operation.	Increases.	Increases. Energy efficiency is not considered. Biofuels may be considered for areas with poor energy resources.	Increases, using strategy of extending plant lifetimes.
No impact upon sector.	No impact upon sector.	Plentiful supply of fossil fuel. Rather, priority given to preservation of power stations.	Met by indigenous local sources without consideration to emissions.
High.	High.	High as high cost generation maintained. Coal-fired and nuclear power generation dominate.	High energy costs. Lack of exploitation of lower energy costs, arising from new technology, due to absence of high capital investment.
Small scale new build on brown field sites.	Medium to large scale farms. Some increase in use of greenhouses to substitute for produce currently obtained from international markets.	Preservation of existing structure.	Economic and political power consolidated in strong interest groups such as the defence and manufacturing industries.
Emphasis on refurbishment, reuse and low cost approaches.	Little technological change in this sector.	Limited to increasing the lifetime of existing generation capacity.	Slow technological change without capital or demand.

3.3 GLOBAL SUSTAINABILITY SCENARIO

DESCRIPTION

This is a world in which social and ecological values are pronounced and in which the greater effectiveness of global institutions is manifested through strong collective action in dealing with environmental problems. Stress is placed on balancing economic, social and ecological values, resulting in the adoption of sustainable technologies and patterns of behaviour. Governance structures become more global but also more distributed.

There is greater co-operation and management within the international system and the role of national governments is primarily in the negotiation and enforcement of global economic, social and environmental agreements. Global trade grows, but international trade and environment policies are co-ordinated, reducing the scope for national discretion, to support international equity and sustainable development.

Access to education is widespread and helps to underpin support for sustainable development strategies, including their social and equity dimensions. High mobility labour, global markets for training and education, and global tourism are all engines of convergence between cultural and political systems.

The 'greening' of business is pervasive, with adoption of 'best available' technologies. Some of the greatest commercial opportunities arise in fast-growing developing countries experiencing 'catch-up'. Interest rates are low, producing high levels of investment, especially in projects with longer-term benefits to the economy and society.

Household formation falls due to more collectivist social values and controls on new housing development. These controls also restrain the extent to which increased incomes lead to demand for increased living space. New dwellings, concentrated in existing urban centres and on brownfield sites, are built to high environmental standards. There is strong growth in the number and range of domestic appliances in the home but these too are built to high standards. Consumers are attitudinally green and want to make eco-effective purchases.

Reductions in domestic energy use are limited, however, by an increase in home working. Energy use per person declines by 0.50% per annum but increasing household size means that, overall, household consumption is hardly changed.

Natural gas is the dominant energy source up to 2010 in this scenario, but renewable energy sources gain a large market share thereafter. Emission-free fossil fuel options, including large-scale carbon sequestration, begin to play a major role in the UK energy mix in 2010-2020. A large global market for renewables builds up by 2020-2025. Encouraged by regulatory incentives, energy suppliers move towards the provision of integrated services, greatly enhancing the take-up of energy efficiency measures. Investment in higher-cost energy forms and environmental controls mean that the price of energy for the final consumer is high. The need to reduce carbon emissions coupled with a willingness to invest in technologies with low rates of return on capital, allows a partial revival of nuclear power from 2015. With the growing importance of non-fossil energy, hydrogen becomes a significant energy carrier by 2030 and there is major infrastructure investment associated with its production, storage and distribution.

Use of natural gas will encourage modularity and domestic generation using new technologies, probably including micro-turbines through to fuel cells, which will allow for a gradual shift to hydrogen in the long-term. In the interim renewable energy sources dominate, creating yet again the need for a new approach to management of the electricity network. Opportunities exist for the development of innovative techniques for control, transmission and storage of electrical energy. Clean coal, biomass and nuclear power could all re-emerge as competitive options in comparison to renewable conversion. It was recognised that R&D used to reduce the cost of either renewable energy or carbon sequestration would in the long run favour the introduction of hydrogen.

DISCUSSION

The development of a strong partnership between government and the energy industry was considered essential to this scenario to permit the co-operation necessary to produce such a consensus throughout the sector. There would need to be a full understanding of market dynamics to stimulate development and of mechanisms to facilitate long-term investment in efficiency and R&D.

To reach a point at which society has fully internalised the costs of energy conversion would require many years of communication, education and a full understanding of the public's needs and behaviour. In such an informed and environmentally aware society, the re-emergence of nuclear power could only be subsequent to safety and waste concerns being addressed. This would initially involve technological solutions, but also the development and acceptance of comparative risk by the public. As with previous scenarios, education has a pivotal role to play.

KEY R&D ISSUES

- Development of technological capacity and storage capability
- Solar, wind, wave and tidal energy conversion
- Increased efficiency of technology and end-use
- Transportation technology, e.g., fuel cells, and fuel and their associated infrastructure
- Clean coal technology and subsequent sequestration
- Network issues for distributed energy systems
- Nuclear safety, management and disposal
- Mechanisms to facilitate emissions trading
- Provision of an integrated service for the consumer rather than a commodity
- Regulatory facilitation of investment in energy efficiency and reduction measures
- Familiarisation with future export opportunities
- Investigation into social acceptability of renewable, nuclear power and large-scale generation
- Research to study the effect of policy upon public behaviour
- Education to promote an understanding of sustainable development
- Development of hydrogen infrastructure

"Global Sustainability" Scenario

Factor	Industry	Commercial, Public & Service	Transport
Economic Growth	High growth but sustainable & co-ordinated at international level. Increase in eco-efficient goods & services. Opportunity to provide "catch-up" for fast-growing developing countries.	High level of sustainable growth at national and global level. Highest growth in sectors providing eco-efficient goods and services.	Sustainable and equitable growth has a major impact on transportation. Integrated travel at both national and global level.
Industrial Structure	Strong partnership between government and industry. Large global market for solar energy by 2010. Increased emphasis on provision of services as opposed to goods.	Increased provision of services over goods. Rapid penetration of new eco-efficient services of high quality.	Heavy investment in public and mass transport. Freight transport shifts to rail and water.
Fiscal and Regulatory Policies	Low interest rates, high investment levels. Long-term socio-economic benefits valued. Regulatory incentives to integrate energy services.	High levels of investment in long-term projects. Waste minimisation regulations. Domestic fiscal instruments used to meet global agreements.	Regulations & incentives used to change behaviour. International agreements with manufacturers prove effective. Major investment in new technology.
Environmental Awareness	Environmental concerns are ideological as well as practical and immediate.	Environmental conservation through resource efficiency and waste minimisation.	"Best" environmental solutions adopted.
Local Environmental Policies	Negotiation and enforcement of global agreements. Packaging minimisation and substantial waste recycling and recovery.	Major recycling and recovery programmes at local level.	Controlled by global agreements.
Global Environmental Policies	Taxes and regulations used to meet Protocol targets. Tight controls on trade and emission sinks.	Strong global agreements met through local government enforcement of eco-efficient practises.	Global emissions targets increase innovation
Energy Consumption	Increased consumption. Natural gas dominant until 2010, when renewable energy systems matures. Nuclear power revival from 2015.	Increases.	Increases.
Energy Security	Global markets exist with a supply infrastructure to ensure equity.	Sharing of resources, use of renewables and implementation of hydrogen based services.	Greater sharing of resources within trading regimes.
Energy Costs	Final cost to user high. Environmental control, efficiency and sustainable energy usage take priority.	High energy costs to protect the environment leading to higher cost goods and services.	High.
Embedded/Distributed Power	Economies of scale realised from large solar energy production. Hydrogen based economy begins and infrastructure created.	Energy suppliers provide integrated services. Large scale solar power.	Significant investment in infrastructure but after consideration to the environment.
Technological change	Rapid adoption of environmental Best Available Technology (BAT) throughout industry, e.g. low temperature, low pressure (lowT, lowP) chemical processes.	Strong technological growth. Best Available Technology adopted.	Rapid uptake of low emission technology and green technology such as hybrid and fuel cell vehicles.

Domestic	Agriculture	Power Generation	Facilitation
Sustainable development of housing. Fall in formation of new households. More use of underground sites.	Sustainable development of agriculture. Decrease in land use for agriculture. Livestock farming declines.	Emphasis on sustainable growth causes substantial developments in the generation sector. Fastest growing sectors include renewable and hydrogen based power systems.	Consideration given to factors other then GDP such as social and ecological values and indicators.
Rapid turnover of housing stock and reclamation of brown field sites. New energy efficient buildings with short lives. District heating developed alongside gas supply networks.	Agriculture supplies major brands and retail chains.	Growth of small scale power plants. Initially natural gas based, e.g. GTCC. Subsequent introduction of fuel cells.	World Environmental Organisation formed and strong trading regimes are created that operate within its rules. Global carbon trading.
High levels of investment for restructuring and energy efficiency measures. Controls on new housing development.	Common Agricultural Policy supports sustainable management of rural landscape	Low interest rates favour long-term investments. Economic policy is used to support the introduction of renewable energy based power production.	International co-ordination to support sustainability and equity. Considerable investment to establish eco-efficiency. Renewable energy conversion technology supported.
Environmental concerns dictate housing policy.	Environmental concerns dictate agricultural policy.	Driving force for change.	Preservation and restoration of environment a key priority.
Strong planning controls protect green belt via eco-sensitive development. Installation of energy saving materials and equipment due to subsidies and tax incentives.	Subsidy payments to farmers to ensure sustainable management of rural landscapes.	Individual responsibility for carbon emissions fostered by linking reduction with access to countryside and environmental goods.	Strict environmental controls in place.
International environmental policies promote clean, energy efficient priorities within sector.	International environmental policies promote clean, energy efficient priorities within sector.	Requirement to reduce carbon emissions contributing to change in generation technology choice.	Strong agreement to reduce carbon emissions. Investment and direct production subsidies, tax credits and market based policies such as market constraints and third party financing.
Increases.	Increases.	Consumption increases but from efficient clean sources or technologies.	Regulatory incentives provide motivation towards meeting increased demand through energy efficiency.
No concerns over energy security.	No concerns over energy security.	Possible limitation to growth of renewables eventually reached due to availability.	Energy shared on an equitable basis through investment in infrastructure and technology transfer to developing countries.
High, due to higher cost energy forms and environmental controls. Creates a market for small-scale (household) energy conversion.	High.	High prices as a result of prioritising environmental issues over economic competitiveness.	High energy costs from eco-efficient production using cleaner or alternative sources, or due to carbon taxation on production from older plants.
Avoidance of building beyond existing developed sites.	Support for farmers to preserve land for nature conservation.	Initially natural gas favours smaller scale distributed power production. Renewable generation moves to large-scale supply as solar energy matures. Clean coal and biomass re-emerge in the combustion sector. Also nuclear power.	International institutions and federal political systems push towards emission-free generation, from all energy sources.
Best available environmental technologies and practices adopted.	Rapid change in farming practices. Significant reforestation.	Strong technological growth of clean, low input production and consumption, both in renewable and fossil fuel based systems.	Low interest rates encourage investment in all cleaner production techniques and efficiency improvements.

3.4 LOCAL STEWARDSHIP SCENARIO

DESCRIPTION

Local stewardship implies a world in which stronger local and regional governments allow social and ecological values to be demonstrated to a greater degree through the preservation of environments at the local level.

Political systems are transparent, participatory, inclusive and democratic at a more local level. There is a high level of public provision for health, education and social services. Regional and local cultural identities are revived, and the family is strengthened as the primary social unit in the context of the local community. The flow of culture, people, capital, goods and services across economic and political boundaries is constrained. International economic and political institutions are seen as ineffective in a culturally and politically diverse world, and exist primarily to mediate relations between countries.

The trend towards smaller households is reversed as a result of lower rates of family breakdown and an increasing number of extended family units. There is general migration away from the larger cities and a corresponding growth of small and medium-sized towns. Tight planning control over the countryside and the need to preserve land for agricultural production lead to dense urban development with small dwellings.

Consumers become aware of the "greenness" of their purchasing decisions and the marketing of energy emphasises sustainability and service-based provision. This not only supports local employment but is also socially inclusive, with poorer households benefiting as much as wealthier ones.

Despite many more people working at home, energy use per household declines by 0.75% per year and, with a decline in the number of households, total domestic energy consumption reduces by 1.5% per annum.

The exploitation of local energy resources, both non-fossil and fossil fuel, is a particular feature of this scenario. A wide range of renewable energy technologies, including wind, biomass, photovoltaics and small-scale hydro is exploited, facilitated by a willingness to invest in technologies with low rates of return. However, economies and efficiencies of scale are more limited than in the Global Sustainability scenario because a diverse set of options is pursued without large-scale co-ordination. Some local coal resources are exploited in this scenario, but with high standards of environmental control. Local combined heat and power schemes flourish. Green tariffs find favour with environmentally conscious consumers and reinforce regulatory controls. Small-scale nuclear power could develop in some contexts of very high energy prices, partly as a route to energy independence. High energy prices will also lead to the large-scale adoption of energy efficiency measures. This is the only scenario in which energy demand is considered likely to fall, as well as becoming less carbon intensive.

DISCUSSION

As with the Provincial Enterprise scenario, this localised situation was difficult to envisage, especially how it could persist over a long period of time. The utilisation of such a wide range of generation technologies on a small scale would require a greater investment overall to develop, and the scenario implies that existing transmission systems would be abandoned, potentially impairing the security and stability of supply.

With such a strong dependence on small-scale local energy resources, system optimisation and energy efficiency must be prioritised. Widespread adoption of reuse & recycling and a voluntary reduction in travel are major changes in public behaviour that could only have arisen through an effective, long-term campaign to alter society's attitudes.

KEY R&D ISSUES

- Development of a full range of small-scale conversion technology
- Development of energy storage capability
- Increased efficiency of generating technology
- Increased efficiency of end-use technologies
- Transportation technology, e.g., fuel cells and their associated infrastructure
- Increased efficiency of end-use, both stationary and transport
- Clean coal technology and environmental control
- Network stability concerns
- Research into social behaviour, market dynamics and life cycle costs.

"Local Stewardship" Scenario

Factor	Industry	Commercial, Public & Service	Transport
Economic Growth	Slow economic growth, determined by local conditions with little consideration given to international markets.	Fall in demand for retail services. Increased public provision of health education and social services.	Slow growth has major impact on transportation. Internationally, freight movements decline.
Industrial Structure	"National champions" in energy and communications. Growth in small scale sustainable production and local services. New processes tend to be modular and "process intensive" using IT and biotechnology.	Locally based financial and other, high quality, services increase market share. Staggered working hours to lessen peak energy demands.	Car-sharing, home deliveries and other measures used to reduce car ownership. Increased use of mass transit systems.
Fiscal and Regulatory Policies	International economic and political institutions are seen as ineffective.Publicly funded science and engineering to meet local needs. Low investment, overall, but a willingness to invest in low rate of return projects.	Participation and individual responsibility encouraged over, but as well as, regulation. Low investment favours SME's.	Regulation replaced by governance by stakeholders. Relatively low investment.
Environmental Awareness	Environmental goals seen to improve quality of life.	Environmental awareness influences all consumer decisions.	Keen interest in environmental information.
Local Environmental Policies	Formal regulatory controls backed up by voluntary take up of green tariffs by some. Environmental quality ultimately dependent upon regional resources and capacity.	Uptake of energy efficiency in buildings in terms of their mode of use and materials of construction. Solar panelling and CHP from microturbines within larger buildings such as hospitals and schools.	A local community agenda develops that is supported by regional government. Decreased travel benefits local environment.
Global Environmental Policies	Piecemeal response to environmental problems. International agreements falter when in conflict with local sustainability issues.	Not significant to an inward looking culture.	Transport and its effects seen as a local issue. International interference not welcomed.
Energy Consumption	Demand falls. Exploitation of all local resources, renewable as well as fossil fuel.	Consumption falls due to less demand and widespread energy efficient practices.	Falls.
Energy Security	Energy independence ensured by utilisation of all energy sources available. Small-scale expensive nuclear power plants when necessary.	Energy security a main driver for falling consumer demand and desire for environmental practices and services	Independence important so conservation of resources.
Energy Costs	High energy costs necessitate energy efficiency and discourage consumption.	High costs of energy have less impact on this lower intensity sector.	Very high as environmental costs are internalised.
Embedded/Distributed Power	Diverse options are pursued for power generation on small scale. Widespread CHP fulfils growing service sector needs from distributed power network.	Energy needs met by local or unit production. Electricity and heat dominant.	Publicly owned transport systems.
Technological Change	Key technologies are renewable energy – wind, biomass, and photovoltaics. Transportation based on alternative technologies: fuel cells, electricity, and hybrids.	Substantial potential and public funding for provision of local needs such as energy, food, environmental services.	Fuel cells, hybrids and electrification of mass transport systems are all essential

Domestic	Agriculture	Power Generation	Facilitation
Low growth scenario with small-scale local housing development.	Support for agricultural protection.	Slow economic growth but increased use of renewables: wind,biomass, and photovoltaics. Alternative utility infrastructure developed to meet needs of small-scale development.	Low economic growth. Long-term equity and social inclusion regarded as highly significant.
Survival of traditional housing with investment in infrastructure to promote efficient use of local resources.	Traditional farming practices used. Retailers use local suppliers and lose customers to local markets and shops.	Diverse energy conversion technologies utilised in distributed networks. Fossil fuel, renewables and nuclear power exploited. Substantial CHP development.	Diffuse structure of governance.
Regulatory controls and green tariffs influence energy use.	Agriculture is heavily subsidised.	Investment levels low, but public funding for long-term needs. High cost acceptable to preserve national independence.	Public funding of R&D. Green energy tariffs and regulatory renewable obligations such as purchase agreements. Small generators have access to grid via non-discriminatory tariffs.
The environmental impact of all housing developments is given full consideration.	Agriculture takes account of environmental, long-term view.	Conservation of the environment is a key issue.	Sustainability of environment for the community considered essential.
Regulation used to preserve local environment. Local authorities manage recycling programmes and withdraw approval for energy recovery systems.	Tight planning preserves land for agriculture. Preservation of the countryside.	High standards of local environmental control placed on generation technology.	Use of local resources supported by infrastructure investment and regulation. Demand side management highly effective due to eco-consumer ethic.
Some international targets met by default as local needs supersede any global considerations.	Food production for the nation takes priority over global agreements.	Global agreements are made but not enforced as local concerns take priority.	Lack of co-ordination results in non-achievement of global targets. Little concern, however as focus is on local measures.
Energy consumption falls with large-scale adoption of energy efficiency measures.	Low energy methods of farming but many more small farms exist to meet demand for local supply.	Consumption falls.	Energy use discouraged through high prices but more so by public opinion and national interests.
Diverse and small scale options for energy conversion exploited to meet needs at local level.	Food security maintained by subsidisation.	Independence maintained by exploitation of all available local energy resources.	Exploitation of local energy resources through investment in smaller scale technologies. Protection of indigenous fuels through subsidisation.
High energy costs due to alternative energy use and small-scale production.	High costs.	High prices considered acceptable to preserve self-sufficiency.	High energy costs from capital intensive systems and high emission abatement technologies.
Growth of small and medium sized multifunctional towns. Supported by distributed power generation.	Small farms flourish, even in urban environments.	Power production sited to best exploit each particular resource and meet the needs of the local community.	National economic and political institutions. Little attention paid to international bodies.
Slow improvements in housing. Some small scale technology investment.	Considerable investment in agricultural technology to meet local needs.	Technology developments influenced by regional resources and capabilities.	Technology developments influenced by regional resources and capabilities. Management and control of emissions where clean generation not practical.

4 Challenges Arising from Scenario Analyses

The scenarios have allowed a number of R&D and other issues to be identified by considering worlds in which a greater or lesser emphasis is placed on sustainable development and concerns over climate change. These issues can be prioritised into a broadly-ranked list according to how widely they appear across the scenarios. This list provides a framework against which recommendations can be structured. The Task Force considers the main merit of this approach to be that the recommendations are robust against very different views about how social and political values may evolve.

Sustainable Development

The Foresight Energy and Natural Environment Panel believes there is a long-term need to facilitate 'a radical shift to an economy that uses much less energy and towards energy sources not based on carbon, or to novel ways of capturing and using carbon'[11, 12]. Such a shift can neither be delivered by incremental change, nor by considering only one side of the supply and demand equation.

There is a significant history in the UK of attempting to formulate energy policy to achieve a balance of environmental, social, and economic aims in the context of the time. For example over fifty years ago[13] the basic energy policy aims were:

- good standard of heating in the home
- electricity for all
- low cost and increased convenience
- national fuel economy
- smoke abatement

While the economic and social aspirations in this policy statement may be thought valid today, environmental considerations were then in terms of local pollution. National or international impacts with long-term implications were not considered. Today these concerns are reflected in the definition of sustainable development[14] in terms of a better quality of life for everyone, now and for generations to come, by:

- social progress that recognises the needs of everyone;
- effective protection of the environment;
- prudent use of natural resources; and
- maintenance of high and stable levels of economic growth and employment.

11 A Way to Go, Foresight Energy and Natural Environment Panel Consultation Document, June 2000

12 Stepping Stones to Sustainability. Foresight Energy and Natural Environment Panel, December 2000

13 Simon Report, 1946

14 A better quality of life: A strategy for Sustainable Development for the United Kingdom, May 1999

Following these principles the overall aims of energy policy are now stated as:

- the security and diversity of UK energy sources within a competitive market framework
- contributing to the UK's environmental emissions targets via the development of sustainable energy technologies

Energy conservation, energy efficiency, and reduction in materials use in manufacturing are key activities for the achievement of these policy aims. To an extent, industrial energy conservation and materials reduction is seen as being market driven, with an expectation that it will take place as part of normal industrial development. The building sector is much more intractable, however, because of the large existing stock and its expected longevity. If significant economies are to be achieved in this area over a reasonable timescale, strenuous efforts will have to be made in the retro-fit market.

Research and Development

The scenario exercise identified a number of Research and Development issues with long-term implications. Following the consultation process, these were refined to produce the list shown below. The consultation reinforced the importance of embedded and distributed generation with its associated electricity transmission and network issues. Concern was expressed that the present system might not be appropriately structured for the demands of embedded generation. Energy storage was seen as a priority area to complement the projected increase in the use of renewable energy technologies. Alternative transport fuel was identified as a key area, and the problems surrounding the production, distribution, and vehicular storage of hydrogen were identified as limiting factors for the widespread introduction of fuel cells.

R&D CHALLENGES ARISING FROM SCENARIO ANALYSES

- New networks for distributed energy systems, whether electrical or fuel based
- Development of more sustainable electricity generating technologies based on fossil fuels, renewable energy resources or nuclear fuels
- Increased efficiency of generating technology including co-generation (CHP)
- Increased efficiency of end-use technologies
- Transportation technology, e.g. fuel cells and their associated infrastructure, including further research into hydrogen production
- Biomass and waste utilisation
- Large and small-scale energy storage, including better batteries for possible transport use
- Decommissioning of all types of energy conversion plant
- Redeployment of existing technology through change of use, upgrading, installation of latest technology, or re-use of infrastructure
- Social science investigation of social behaviour and attitudes to energy use
- Education to engender understanding and ownership of sustainable development
- Mechanisms to facilitate emissions trading
- Carbon dioxide sequestration
- Regulatory mechanisms and facilitation of investment in energy efficiency and reduction measures
- Improved carbon-based fuel extraction (conventional and unconventional)

Possible future deployment of nuclear power appeared as a recurrent theme throughout the consultation responses. Some were strongly opposed to any such development because of waste management issues, cost or perception of risk, but a larger group could see no alternative if future energy demand and emissions reduction targets are to be met. Concerns were expressed that the skills base of the nuclear industry will be lost.

Decommissioning and safety were identified as issues for all types of energy conversion plant - including renewables. All current plant will require to be decommissioned over the next forty years and the safety of ageing plant will need to be maintained. This will place an immense burden on society in both cost and environmental terms, and the associated issues must be addressed if it is to be achieved smoothly and safely at an acceptable cost. There is a tendency to assume that decommissioning applies only to nuclear plant, but all energy intensive equipment is affected to some degree.

Most of these needs are already well known and many are already being addressed to a greater or lesser extent. There is, however, a much stronger emphasis on infrastructure and systems issues than in previous Foresight Energy Panel studies. We believe that this has arisen in part because of the longer time frame under consideration, but also because some shifts in thinking have occurred in the intervening years.

A system built around large-scale electricity generating plants may not necessarily be more efficient or cost-effective than one based on a larger number of dispersed smaller-scale units using different technologies. However, this was not the prevailing view when the energy transmission and distribution system now in place was planned and developed and it was not designed with small-scale generation in mind.

Concerns arose over the infrastructure for transport fuels in the near and mid-term. To a greater or lesser extent all the scenarios anticipate a need over the next forty years to begin a process of fuel substitution away from conventional oil-based products, particularly in the transport sector and in small-scale integrated energy supply applications. However, there are a number of options for substitute fuels, and how they would be transported and made available at the point of sale. Would this be in the same manner that petrol and diesel are today? A possibility is a progressive migration from petrol and diesel to methanol or hydrogen. Each of these would require a different backing infrastructure, and it seems unlikely that more than one would be developed in addition to the current networks.

Non-technical obstacles to the full implementation of future energy technologies were widely discussed. These included costs, regulatory frameworks, the need for education and training at all levels, and the problem of encouraging a community-based response if objectives such as energy conservation are to be attained.

Education And Training

It is worrying that the understanding of energy and environment issues seems to be insufficiently addressed in education and training, irrespective of discipline. Thus, high-level decisions may be made without full balancing of matters such as sustainability, perception of risk, security of supply, or the local environmental implications. In particular, training at all levels leaves little scope for addressing the interactions between these issues.

There is a recognised difficulty in attracting specialist scientists and engineers into the energy sector because it is perceived as less interesting or financially rewarding than information technology or finance. There has also been a real reduction in the number of jobs in major companies, creating an image of insecurity in employment. Of particular concern is the shortfall that is occurring in the number of newly qualified entrants to disciplines of importance to the energy and environment sector.

There were pleas for the introduction of general energy courses, for vocational courses, and for interdisciplinary energy courses.

Improved public awareness of energy issues is another important area that needs to be addressed. It is essential that decision-makers have briefing material available that allows them to make balanced and informed decisions. If distributed generation systems do begin to proliferate, balanced information should be available to the public so that planning can be addressed in an informed way and needless difficulties averted.

5 Key Actions

In the previous section, a list was presented of energy-related challenges that have significant bearing on the future of the UK over the next forty years, derived by consideration of four different views of the future. Some of these issues have already emerged from the considerations of other Foresight Panels and Foresight Associate Programmes, so we will not duplicate those here. Instead this report will try to identify overarching themes with long-term implications and propose steps that should be taken now to allow them to be engaged with.

Ultimately, whether justified by climate change arguments or by consideration of the implications raised by sustainability and conservation of resources, there must be a move to a low-carbon or carbon-neutral system of energy production and use. This migration will be enabled by the development of appropriate technologies, but will only be achieved through their widespread adoption. This will not happen overnight but will entail a lengthy migration period as new technologies supersede current ones.

Thus, the key actions arising out of our analysis centre on those infrastructure, implementation, decommissioning, regulatory and education issues that will enable new technologies to be adopted and to achieve their potential as they are needed.

One additional issue is that of nuclear power. The closedown of current UK nuclear power plant will steadily progress during the next forty years, being almost certainly complete by the end of the period, whatever the prevailing circumstances. This means that non-CO_2 producing plant will be being removed from the system and it will become more difficult to achieve CO_2 emissions targets. It also means that an important skills base will be progressively eroded. This cannot be allowed to happen without a full examination of the consequences and assessment of the appropriate response to make.

Infrastructure

There are two significant issues for future infrastructures. The first is the vexed question of the changes that will be needed in the electricity distribution network if distributed generation and renewable energy plants become a significant part of the generation mix. We believe that the goal should be a system that, as far as is practical, is neutrally designed to be capable of accepting generation close to the points of demand as well as offering opportunities for remote generation from large plants that may have been sited to take advantage of local resources (e.g. source of renewable energy or geological feature for carbon dioxide sequestration), with equitable charging for both.

The second is the development or adaptation of infrastructure that would be needed to support the wide-scale adoption of alternative transport fuels or natural gas substitutes. Possibilities include methanol or hydrogen. Each of these has risks and opportunities that must be considered, as well as taking into account how the transition could be phased and managed.

In practice, these two issues are really different expressions of the same problem, the migration of complex and extensive networks to meet new and developing patterns of supply and demand, making as much use of the existing systems as possible but not ultimately being constrained by them.

Implementation

Implementation of infrastructure changes is a critical factor that depends on a number of other challenges. A clear understanding is required of the control issues associated with the dilution of the fuel mix or increasing numbers of small power stations. Significant strategic decisions must be made regarding the choice of alternative fuels and arrangements for their production and distribution, especially during the critical migration period.

A good example is provided by the often proposed introduction of a hydrogen-based energy system utilising either fuel cells or conventional combustion technologies. Hydrogen is not readily available itself. It is usually manufactured from hydrocarbon fuels or through the electrolysis of water. It is unlikely that today's demand for liquid fuels could be met practically and economically from renewable energy driven electrolysis alone, so questions remain as to the best sources. There are also issues to be resolved as to the best means of distribution and storage. There is as yet no clear path to solving these migration problems.

The questions will have to be addressed in a co-ordinated manner as market forces alone are extremely unlikely to provide an initiative that is coherent in its thrust or occurs early enough to be effective.

Regulation

Consideration must be given to ensure that the regulatory regime itself does not become an impediment to necessary evolution and change. A successful regulatory framework would become a saleable product, in which the UK could maintain its present world-leading position.

Education

The requirements in education may seem familiar and present few surprises. They include the continuing need to attract engineers and scientists to work in the energy sector, the encouragement of an energy conservation mentality, and the provision of accurate and unbiased energy information for decision makers.

One issue stands out, however. If the anticipated move to distributed electricity generation and increased use of renewables and waste is to be allowed to take place, then public awareness of real energy issues must be increased. It is only in this way that planning decisions can be based on a realistic balance of sustainability arguments rather than first perceptions. Many megawatts of renewable energy generating plant have not been built through failure to secure planning permission for the plant itself, or for consequential improvements needed to the electricity transmission system.

6 Recommendations

There are many active technology initiatives that will identify potential energy technologies and establish their technical and economic viability. There is a strategic vacuum, however, in the study of how the existing system is to migrate to this new environment.

The Task Force recommends, therefore:-

1. The issue of energy systems migration is treated as a priority and that programmes are established to evaluate the measures that will be needed, involving all who would be affected by potential changes whether economically, environmentally, or socially.

2. Technical R&D should continue across a wide range of options. Distributed electricity generation and associated network issues, alternative transport fuels, energy storage, and the production and transmission of hydrogen are seen as having central importance.

3. A full re-examination is undertaken of the nuclear power issue. Current predictions make it difficult to be certain whether future energy needs can be met without a continuing significant nuclear component. If this is the case, then the long lead-time involved with nuclear power plant construction demands that urgent attention is given to the subject now.
   The concerns should be with the maintenance of technological capability, or the ability to import technology, in order to maintain nuclear capability either for fuel diversity reasons or to reduce CO_2 emissions.

4. Consultations should be established quickly with DEFRA, DLTR, DTI, EPRSC and with other Foresight bodies, (in particular the Chemicals Panel, the Materials Panel, Task Forces and Associate Programmes) to formulate specific actions on migration, feed-stocks, need for nuclear power, and advanced power systems. Link programmes and the EPRSC Energy Programme would provide ideal practical means for forwarding these objectives.

7 Appendix: Consultation Responses

This appendix summarises the range of opinion received during the consultation process to the document 'Fuelling the Future'. Hence the views outlined here are not necessarily those of the Foresight Energy Futures Task Force or the Energy and Natural Environment Panel.

7.1 Aims and Methodology

The forty-year time scale chosen for this study was generally accepted. Indeed it was appreciated by many as recognition that the issues do require consideration over such a period, although this may be difficult to reconcile with the much shorter timeframe to which businesses or even government generally work.

A few respondents thought that the setting aside of climate change concerns in the analysis to be an unusual or strange decision. However, these were balanced by a similar number who welcomed this as giving a different perspective on the issues, to compare with the recommendations given by recent studies that have concentrated mainly or solely on climate change.

The concept of scenario analysis and the way that the Task Force used it to derive R&D priorities was generally accepted. Some commented on the static nature of the scenarios as presented, in that the effects and consequences of fluctuations, potentially large, in commodity availability and prices over the years are not addressed, and that a single scenario would be unlikely to persist over the whole period under consideration. There was a range of views put forward on the likelihood of the individual scenarios and differences of opinion concerning whether or not the set encompassed the needed range of possibilities. Two respondents suggested that an additional chaotic scenario should be formulated. However the Task Force believes that instabilities of differing degrees and types can been seen within the existing scenarios, so there is no need to create and analyse a specifically chaotic one.

Some chose to emphasise the point, made in the consultation document, that in reality the world may contain aspects from all of the scenarios. Others found difficulties in focussing on the UK, separately from the global context, or in the implausibility of the world maintaining a uniform outlook. The base scenarios do consider global situations in some detail but the presentation of the energy consequences in the consultation document did not repeat all of this. There were differing opinions about the effects of the responses to climate change that underlie each scenario.

A small number expressed a preference for the use of more quantitative scenarios instead of, or in addition to the qualitative story line ones that were used. There have been a number studies of this type made by other bodies such as the IEA and World Energy Council, and we quoted some conclusions from those in the introduction.

7.2 Arising R&D Themes

Nearly all of the respondents agreed with the range of R&D themes suggested, although many wanted to lay particular emphasis on a sub-set of these. Themes attracting particular support were:

TRANSMISSION AND NETWORK ISSUES (GAS AND ELECTRICITY)

Advanced by a number of respondents, particularly in the context of sparsely populated areas, such as large parts of Scotland. The current electricity network is seen as a UK strength, in terms of its engineering and robustness, but opinions were expressed that it may not be appropriately structured for the demands of embedded generation. One rather different view was that the infrastructure needed to be strengthened to allow transmission of renewable energy from remote sites to the areas of demand.

ENERGY STORAGE

Energy storage was advanced as something that ought to be developed as an essential concomitant to the increased deployment of renewable energy from intermittent sources, and for use in vehicles.

CHP - INDUSTRIAL TO DOMESTIC SIZE

This was seen as an area where the UK has been weak, but recent incentives have started to stimulate deployment. Although the majority of responses welcomed this and wanted investigations of how it could be further increased, others called for more fundamental R&D on improving the overall efficiency of CHP. In contrast to that view, a few questioned its overall environmental benefits compared with renewable forms of electricity or heat generation.

ENERGY EFFICIENCY

Responses relating to energy efficiency fell into three main categories. The first were looking for promotional support and substitution for generation capacity. The second considered that this topic needed to be brought forward with greater emphasis in architecture and product design. The third considered this as an important part of the consideration of social attitudes towards energy consumption and favoured wider behavioural research.

CARBON DIOXIDE SEQUESTRATION

UK research into this was thought by a number to be inadequate, although one believed the UK was ahead. Another response mentioned that the UK has natural geological features that could be used to achieve a high level of long-term sequestration, but saw little effort being put into assessing the feasibility and practicality of this approach and the necessary changes to the infrastructure.

ALTERNATIVE TRANSPORT FUELS

Many responses highlighted one aspect or another of the need for more effort to be placed in the development and deployment of alternatives to petroleum-derived fuels for transport use. The consultation document suggested the development of a common strategy for this migration. Although there was support for a number of individual technologies, with advocates for both biofuels and fuel cells, no clear ideas were received on how such a strategy might be taken forward.

CONSEQUENCES OF DECLINING OIL RESERVES

A few responses concentrated on the uncertainty of the timing of the peak in oil production, with a consequential effect on the psychology of a market where oil is known to be a decreasing commodity. The complementary problem of accurately assessing the size of recoverable long-term conventional oil reserves was also raised. Disruption to oil and gas supplies arising from conflict or political instability was considered likely (as has happened in the past). To mitigate the consequences of these may require R&D on the effective and responsible utilisation of UK coal reserves.

ENERGY GENERATION TECHNOLOGIES

A number of possibilities were suggested for generation technologies to receive encouragement. Particular support was shown for increased use of biomass, offshore wind power, energy from waste, and building-integrated photovoltaics.

The issue that proved to elicit the most diverse variety of views was the potential for future deployment of nuclear power. A number of respondents saw it as positive that the consultation document did not rule out this possibility. However most of these considered that a technical and socio-political resolution of waste management is a prerequisite, before further power stations could be constructed. More polarised views were also expressed, either wanting nuclear power to be dismissed altogether, as a technology that had passed its time, or conversely wanting strong positive encouragement for early station builds.

A few thought the technologies suggested in the consultation document were too conventional and put forward more novel possibilities.

We also received comments relating to the areas of interest of energy-related Foresight Associate Programmes, questioning whether these fit in with the R&D themes that have been identified by the Task Force, or whether they form a logical and balanced set. However, Associate Programmes are run by diverse membership organisations outside the Foresight Programme and reflect their particular interests. The Task Force would welcome the establishment of other Associate Programmes in energy-related areas in order to broaden the base of Foresight studies.

7.3 UK Strengths and Weaknesses

A few people thought that the UK cannot be represented as being strong in anything. Most however offered opinions on both strengths and weaknesses, although these views varied considerably, as illustrated in the following compilation table.

In some cases conflicting opinions may reflect a difference between consideration of a technological capability and its deployment. Other incompatible views may have arisen because of long-standing weaknesses, offset by recent growth from this small base.

A range of suggestions was received for building on strengths or eliminating weaknesses. Mainly these can be encapsulated as the need to create a better environment for long-term investment. There were many pleas for greater financial support from government, either directly through funded programmes, or indirectly through the introduction of tax incentives, especially for pilot plant. Cases were advanced for particular support targeted at small- and medium-sized enterprises as they form a sizeable fraction of the businesses within the renewable energy sector.

Others concentrated upon what they saw as the detrimental effects of the current regulatory environment, perceiving that investment in longer-term R&D is not valued within the system, or is even positively discriminated against by a ratchet effect of price control policies. Opinions on the effectiveness and desirability of emissions trading were mixed.

INCREASING NUMBER OF RESPONSES	UK STRONG OR AHEAD	UK WEAK OR BEHIND
MANY	Regulatory mechanisms Network design and management Nuclear decommissioning Energy storage technologies CHP	CHP Biomass deployment Photovoltaic manufacture Wind Power Fuel cell technology Alternative transport fuels & infrastructure
	Energy efficiency Wave energy technology Biotechnology Environmental impact Assessment Tidal energy Photovoltaics Alternative transport fuels Wind power Biomass technology Nuclear fuel processing Improved fossil fuel recovery Electricity generation from waste	Integrated planning Waste heat recovery Carbon dioxide sequestration Nuclear waste transmutation Energy storage Decommissioning Social science and education
FEW	Decommissioning (general)	

7.4 Meeting the Challenges

The questionnaire asked for views about the respective roles and responsibilities of government, business, academia, facilitating bodies and the general public in meeting future energy challenges. Many supported the development of active partnerships through a co-ordinating mechanism that would embrace all of these sectors. Very few responses commented upon the role of facilitating bodies.

GOVERNMENT

Government was seen largely as the setter of long-term priorities and provider of support for innovative technologies through the provision of money or tax incentives. The setting of the appropriate level of regulation and frameworks, such as planning, were considered equally important by many. A few saw as particularly valuable the development of international consensus and convergence and the provision and sponsorship of the education and training framework.

BUSINESS

Primarily the responsibility here must be to fulfil the needs of all stakeholders but, above all, to be safe and profitable. Business was seen as the prime mover for implementation, through managed risk-taking, the provision of capital investment and delivering products and services to fulfil society's needs. Some saw a positive role for business to develop and foster new markets both domestically and internationally. Others felt that business would have to accept a different taxation regime geared to driving down the use of energy or carbon.

ACADEMIA

Seen as the main trainer for able scientists and engineers, the mechanism for realising research targeted at the needs of business and the main conduit for far-thinking blue-skies research.

GENERAL PUBLIC

The role of the public was not clearly defined by the responses. Most considered its views to be paramount, although the expression and interpretation of these was thought to be difficult other than through the operation of normal democratic processes. A few thought that there was a need actively to influence and modify generally-held opinion, so that change is embraced, behaviour altered, and lifestyle modifications and increased energy taxation accepted.

7.5 The Context for Education and Training

Two different types of responses were received for the questions relating to education, skills and training. Most considered how to improve both the number and the quality of people who wanted to make a career in the energy sectors. Others deliberated over wider aspects of general energy education and awareness.

The energy sector has difficulty in attracting specialist scientists and engineers to work within it. It is viewed as less interesting, or not so financially rewarding, as other career options available – such as information technology, biotechnology, or finance. This has been heightened by a real reduction in jobs in major companies, such as the utilities, with a consequential drop in real or perceived job stability.

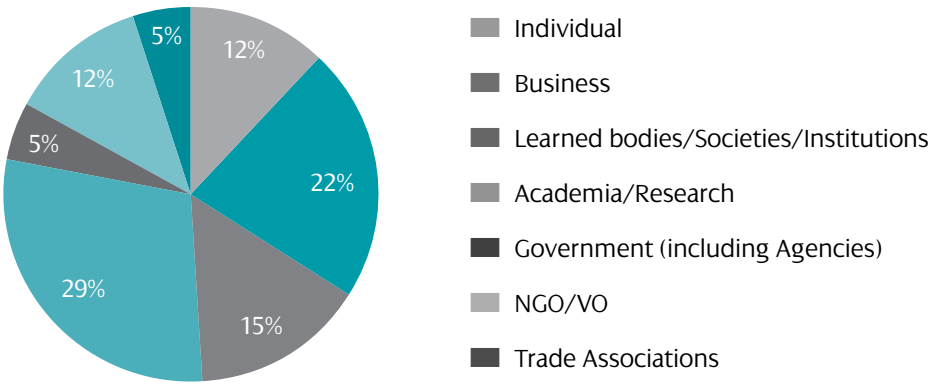
Although raising the prestige of the energy sector was frequently suggested, there were few ideas about how this could be achieved. Suggestions were made that industry should take a more active role in pre-recruitment by sponsoring students through their courses with some kind of guaranteed employment to follow. This may help to "capture" people who otherwise would not consider the energy sector.

A few highlighted the paucity of general energy courses, let alone more specialised ones such as nuclear engineering. The lack of apprenticeships and courses leading to vocational qualifications was also mentioned . These responses were balanced by the view that energy should be viewed as an interdisciplinary component for inclusion in other disciplines such as architecture, design, and agriculture.

Concerning more general education, suggestions favoured the production of clearer and more direct public awareness material to bring home a message about the effect that individual choices have on the overall environmental burden.

7.6 Breakdown of Results by Type of Respondent

Altogether forty-three responses were received and three regional consultative meetings were held during the consultation phase*. All responses were published on the Foresight web site and respondents are listed below. Some organisations could reasonably be allocated to more than one category and we have in these cases made a judgement in placing them.



* Middlesbrough (4 November 2000), Belfast (11 December 2000) & Stirling (15 February 2001)

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The Environment Agency

Glass NTO - Centre of Excellence for Glass

Industrial and Power Association

The Institute of Logistics and Transport

The Institute of Physics

Jaguar Cars Ltd

Merseytravel

Midlands Renewable Energy Technology Transfer (MRETT)

Mothewell Bridge Holdings

Northern Ireland Electricity

Northumbrian Water Ltd

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Renewable Energy Office for Cornwall

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Royal College of Physicians of Edinburgh

The Royal Society

The Royal Society of Edinburgh

The Scottish Institute of Sustainable Technology, Heriot-Watt University

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SEPA

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8 Glossary of Terms and Abbreviations

Autoproducer	Organisation generating electricity for its own use only.
Biomass	Organic material e.g. wood, animal wastes.
Biotechnology	The application of knowledge about living organisms and their components to create industrial products and processes.
Carbon Sequestration	The capture and storage of carbon emitted from the global energy system.
CHP	Combined heat and power.
Climate Change	Changes in the long-term manifestations of weather.
CO_2	Carbon dioxide.
DEFRA	Department for the Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions. The environmental responsibilities of DETR have now transfered to DEFRA and its transport responsibilities to DTLR.
DTLR	Department for Transport, Local Government and the Regions
Distributed Energy Systems	Electricity generation from many smaller units that are geographically dispersed (distributed) or close to point of demand (embedded), as opposed to large power stations.
DTI	Department of Trade and Industry.
Emissions Trading	A market-based approach to ensuring global emissions reductions where companies can trade all or part of their obligation without any loss of environmental benefits for the scheme as a whole.
EPSRC	Engineering and Physical Sciences Research Council
Foresight Associate Programme	A Foresight exercise managed and run by an organisation in agreement with (but outside) the Foresight Directorate, and which is entitled to use official Foresight branding.
Fossil fuels	Fuels whose origin is biological and formed in the geological past (e.g. coal, oil, etc).
Fuel Cells	Devices that convert the "free" energy of a chemical reaction, typically between hydrogen and oxygen (generally from air), directly into low voltage direct current (DC) electricity and into heat.

GDP	Gross Domestic Product.
GTCC	Gas turbine combined cycle.
IEA	International Energy Authority.
IPCC	Intergovernmental Panel on Climate Change.
Micro-turbines	Gas turbine generators with very small capacities.
NGO	Non-governmental organisation.
Photovoltaics	Devices that convert solar radiation directly to electricity.
R&D	Research and development.
RCEP	Royal Commission on Environmental Pollution.
Renewable Energy	The term used to describe those energy flows that occur naturally and repeatedly in the environment (e.g. from the sun, the wind and the oceans, and from plants and the fall of water). It also refers to the energy available from wastes.
World Energy Council	Global multi-energy organisation which exists to promote the sustainable supply and use of energy.

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16 Until April 2000
17 Until January 2000
18 Until September 2000
19 March 2001
20 Until December 2000

The Foresight Programme

Foresight is about being ready for the future. The UK's Foresight programme is the Government-led initiative that looks at what might happen in the future and what we need to do now to secure long-term competitive advantage and enhanced quality of life.

Foresight brings together the voices of business, Government, the science base and others to identify the challenges and opportunities that we are likely to face over the next ten to twenty years or more. In doing so, Foresight aims to bring about a culture change for the better in the way business and the science base relate to each other and to the future.

The programme was launched in 1993 following the white paper on science, engineering and technology, *Realising our Potential*. It has a panel-based structure and operates on a five-year cycle. The current round of Foresight began in April 1999 and included three thematic and ten sectoral panels looking to the future in their particular areas.

All panels consider the implications of their conclusions for education, skills and training and sustainable development.

This report - and those of the other panels - represent the culmination of over a year's intensive research, debate and discussion. It forms part of the basis that the Enery and Natural Environment Panel is taking forward and working towards turning into action.

Foresight panels:

- Ageing Population[21]
- Crime Prevention
- Manufacturing 2020[22]
- Built Environment & Transport
- Chemicals
- Defence, Aerospace & Systems
- Energy & Natural Environment
- Financial Services
- Food Chain & Crops for Industry
- Healthcare
- Information, Communications & Media
- Materials
- Retail & Consumer Services

A further industry-led panel looks at Marine issues.

In addition to this report the Energy and Natural Environment Panel has published 'Stepping Stones to Sustainability' (December 2000). Its Environmental Appraisal Task Force has published 'Towards more sustainable decisions' (January 2001).

Copies of these and the reports of all Panels and Task Forces are available from the Foresight web site at **http://www.foresight.gov.uk** or by faxing your requirements to Foresight, Office of Science and Technology, 020 7215 6715.

21, 22 These thematic panels stood down at the end of 2000

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