OFFICE OF SCIENCE AND INNOVATION
FORESIGHT – HORIZON SCANNING
REVIEW OF FUTURES STUDIES CONDUCTED ON ENERGY

This report was commissioned by the Foresight Programme of the Office of Science and Innovation to support this review. The views are not the official point of view of any organisation or individual, are independent of Government and do not constitute government policy.

EXECUTIVE SUMMARY

Between March and August 2006, the Foresight programme at the Office of Science and Innovation conducted a short project that asked how science and technology could help meet future energy challenges. There were several strands of work in the project. This report arises from the strand that reviewed existing futures studies.

The project was undertaken to inform any subsequent futures studies by Foresight in the broad area of energy. The principal aims of the review of futures studies were:

- to assess the range of futures already considered by other organisations
- to analyse the trends and drivers on which the studies were based
- to identify gaps in the futures coverage and the factors considered.

In total, 38 studies were reviewed. All of the studies had been conducted to promote strategic thinking around energy issues. Twelve studies focused on the UK and 26 were international and their foci ranged from energy issues in individual countries and energy issues for regions, for example, the European Union, through to a global energy perspective.

Most of the studies reviewed used scenario generation as the futures technique to explore their issues. Five of the studies used some form of technology roadmapping. Few studies could be reported as drawing conclusions, although many reported findings and some made observations. Often the findings mentioned the need to consider fundamental shifts in the ways energy is supplied and demand is managed.

UK studies tended to refer to the significance of demand management, the infrastructural challenges posed by increasing demand and the need for renewed infrastructure to permit rebalancing of centralised and decentralised generation of both heat and electrical power. In managing the demand for energy, modification of the building stock and addressing the issues of transport are both important. Behavioural change is important, and so is innovation and associated investment. There is scope for improved metrics to aid investment decision making.

The international studies drew various conclusions, some only of local relevance, e.g. Canada's findings in relation to its self-reliance on fossil fuels and new supplies, such as tar sands; and China's findings in relation to the options for enabling the rate of economic growth to outstrip the rate of

national consumption. Other conclusions resonated with the findings of UK studies, e.g. the criticality of pricing and investment (India); the importance of understanding what people will want/need in terms of energy demand (New Zealand); the importance of policy and investment decisions in injecting momentum for change and encouraging rapid adoption of new technology (Europe). The global studies emphasised the importance of gas as a bridging fuel and reflected UK studies in anticipating a move towards greater decentralised and distributed generation. The difficulty of identifying 'winning' technologies in a period of high innovation was noted. Some global studies referred to fuel inequalities, noting that 2 billion people do not have access to commercial energy supplies.

Meeting CO_2 emissions targets was the focus of a number of both UK and international studies. In many of the studies, there was a strong emphasis on supply-side issues, but some explored demand from a technological or social standpoint, or came at energy tangentially, for example, examining the implications of technological developments for developing a societal infrastructure (particularly for transport) that is more energy-efficient. Few studies explored energy transmission, distribution and storage.

The trends and drivers explored in each study were identified and analysed using the social, technological, environmental, economic and political (STEEP) framework. For some categories, e.g. the social and the economic, there was a fair degree of consensus in the drivers. For example, a number of studies looked at population/demographic and lifestyle issues in the social category and the link between economic development and energy consumption in the economic category. In the environmental category, environmental concerns and CO_2 emissions were the primary drivers. The technological category had the greatest range of drivers. Studies considered technologies addressing energy resources scarcity, renewables, nuclear generation, and emissions abatement.

Some of the gaps in analysis that emerged from the work include:

- how to get people to adopt a sustainable lifestyle
- better understanding of the link between carbon emissions from energy consumption and economic growth
- possible opportunity for greater use of information and communication technologies in energy management
- examination of distribution, transmission and storage issues (many of the studies focused on energy supply and demand).

These could be areas of focus for potential Foresight futures studies.

INTRODUCTION

This review of futures studies conducted in the energy area contributed to a project on energy carried out by the Foresight programme at the Office of Science and Innovation (OSI) between March and August 2006.

The project asked how science and technology could help meet future energy challenges. Leading scientists in energy demand management, energy generation and storage, infrastructure, fuels and the social sciences looked to a 50-year horizon and beyond. Discussions with senior stakeholders working in the energy field were held in order to explore issues, challenges and opportunities in energy. The review of existing futures studies formed the third strand of the project work.

AIMS

The purpose of this review was to inform any subsequent futures studies by Foresight in the broad area of energy. The principal aims of this review were:

- to assess the range of futures already considered and the conclusions being drawn
- to analyse the trends and drivers on which the studies were based
- to identify gaps in the futures coverage and the factors considered.

The selection of the studies included in the review was based on a number of factors, including their availability to the public, expert recommendation (both from a futures and an energy perspective) and that the studies were written in the English language. In total, the review looked at 38 studies, some of which focused on the UK while others took an international perspective.

BACKGROUND

What are futures studies?

As an input to strategic planning, some organisations carry out 'futures studies' to provide a context(s) in which real or potential policies could be explored. The frameworks that are generated by the work provide a common language in which discussions on a topic can be held among a range

of sometimes diverse but interested parties. 'Futures' comprise a number of different techniques or methodologies, such as scenarios or technology roadmapping. Futures studies can help us better understand the impact of trends and drivers or influences on a topic and the possible uncertainties that could arise in the future. The outputs or 'visions' derived from futures, however, are not predictions or forecasts. The intended outcome is to support the development of robust, well-informed and considered strategies.

SELECTION OF FUTURES STUDIES FOR THE REVIEW

The selection of futures studies was carried out through consultation with people working in the energy and futures fields and through searching internet sites.

In total, 38 different futures studies in the area of energy were reviewed. Of these, 12 focused on UK energy issues (Annex A) and the remaining 26 looked at energy in other national or international contexts (Annex B). Some studies took a global view, others a regional perspective, such as that of the European Union, and some had a country-specific focus, such as Canada and New Zealand.

Five studies included in the review were technology roadmaps (Annex C) and the remaining futures studies reviewed were based around scenarios. It was not the aim of this review to focus solely on scenarios but it appeared that scenarios was the preferred futures technique selected by the authors of the studies under review. The reason why scenarios were chosen over other futures methodologies is unclear from the material in the publications. A possible explanation may be the long-term focus of many of the reviews, e.g. looking at energy issues as far out as 2100. The difficulty for anyone working in the futures area is that the further away from the present day one takes a topic, the more vague and uncertain some of the influences on it become. One of the methodological strengths of scenarios is that they provide a descriptive, readily accessible context that allows engagement and discussion by participants who may have very different perspectives but share a common interest in a topic.

The publication dates of the studies ranged from 1998 to 2006. The foci of the studies ranged from:

- management of energy demand
- energy supply, energy storage
- transmission and distribution
- mitigation of the environmental impacts resulting from the generation, storage, distribution and use of energy.

In some cases, the foci covered more than one category. The outlook of the scenarios ranged from 2015 to 2100. In some of the publications, the scenarios also covered a year or so between the starting year and the endpoint, e.g. starting with 2002 as the baseline year, with 2050 as the final year but also considering a future scenario at the 2025 point.

DRIVERS AND TRENDS

What are drivers and trends?

In thinking about a possible future situation in any subject area, it is necessary to consider the likely key trends that may influence its future shape. Broadly speaking, trends can be defined as patterns in events (that can be seen now and are likely to be seen in the future) that are brought about by drivers of change. The relationship between drivers and trends depends on the context – one person's driver is another person's trend. For example, stress in people in the developed world could be described as a driver, as it produces observable trends, such as an increasing number of days taken off on sick leave. On the other hand, stress levels could also be considered as a trend, with the underlying drivers being the breakdown of the community and family and the increasing pace of life. The identification of key trends and drivers is one of the early stages in the development of futures work.

In this review, we identified, where possible, the drivers and trends on which the futures studies were based. These have been analysed using the social, technological, economic, environmental and political (STEEP) framework.

In some cases, the driver or trend could be placed arguably in more than one of the STEEP categories. To avoid duplication, a decision was taken as to the most appropriate category. The different studies are summarised in the Annexes. They have been divided into three categories, UK-based studies, international studies and technology roadmaps. UK-based studies are listed as numerical references and the international studies are listed alphabetically. Technology roadmap studies are prefixed ‘TR’ followed by a number.

Social drivers and trends

There was a fair degree of commonality over the social drivers and trends considered by the different studies. The two main drivers of energy consumption were population (e.g. 01, 13, 18) and lifestyles and values (e.g. 01, 02, 04).

On population, several of the studies touched on the projected population growth in the developing world and the likely population decline in the developed world. Urbanisation, demographics and land use, and the influence of these on energy consumption, were considered in several studies (e.g. 01, 12, 17, 18, 22).

Consumer choices over lifestyle have an impact on the demand for energy and some studies examined how society needs to understand the relationship between consumer choices, energy and environmental impact (e.g. 01, 02, 03, 04, 14, 17, 18, 21, D, J). In one study, regard for environmental issues was extended beyond the public to include business (16). Some studies expressed the desire to maintain social development as well as sustainable energy development and looked at drivers such as public commitment to solving energy-related challenges (e.g. 01, 14). The impact of purchasing decisions by individual and industrial consumers on new technologies was a driver for one study (18). Two studies explored the cost of energy to the consumer and one of these explored the energy contribution to the Consumer Price Index (e.g. 15, H).

Two studies were based on the desire to avoid and/or eliminate energy poverty (e.g. 08, A). Other trends and drivers identified in the social category included concerns for human health as a consequence of the possible environmental impact of global warming (e.g. 12). One driver was public fear of radioactive waste (12).

Gaps in the social trends and drivers
There are several gaps in the social trends and drivers considered in the studies under review. One gap is the challenge of looking at the likely impacts of limited access to energy on society. Limited access could be in the shape of limited energy supply and/or prohibitive pricing. Another under-explored area in these studies is factors that encourage people to adopt a sustainable lifestyle. This subject could be particularly interesting if the work looked across both developing and developed countries with differing historical energy patterns, different economies and different cultural perspectives. Other issues that could be explored further include individual versus social responsibility and privacy and choice. A global perspective would, again, provide potential insights into the way these issues could be understood.

Technological drivers and trends

Energy resource scarcity, for example, the oil peak, was identified as a driver of technological development in the studies reviewed, as was the associated motivation to access difficult-to-exploit resources, such as tar sands, which could potentially extend the use of fossil fuels (e.g. 03, 04, 08, 13). Technological trends in the energy supply area included developments in nuclear power (e.g. 14, E) and renewable energy sources, such as solar voltaic cells as well as wind and wave power (e.g. 04, 12, 14, A). One study explored the market penetration of a range of renewable

energy technologies and the build rate of some of these technologies (H). The successful commercialisation of many technologies that improve energy efficiency and reduce carbon emissions was a driver for one study (18).

Technologies that offer some form of emissions abatement, for example, flue gas desulphurisation, carbon sequestration, and advanced gas and chemical separation technologies were considered (e.g. 14). One study identified the continuing growth in bioscience research that could, in the long term, help with the development of the role of biofuels as a potential energy source (12).

Various studies covered issues around investment in energy technologies (e.g. 21), including investment in low- and zero-carbon technologies (I).

Energy distribution networks were a focus for two of the studies. One of the drivers was the issue of geographical location and how it would influence a country's ability to 'plug in' to energy networks in other countries (e.g. 02). The same study also looked at the concern over long power lines and the electricity lost through these (the study cited about 15%). One study looked at centralised and distributed power generation (21). Another study looked at the restructuring of electricity plants to accommodate a larger number of smaller generating plants within them (D).

Annex C summarises the technology roadmaps that were reviewed. The technology roadmaps covered both a UK focus (TR5) and an international focus (TR1, TR2, TR3 and TR4). Two covered a broad strategic perspective on energy, while the remaining three covered the petroleum industry, renewable energy, and electricity respectively.

Gaps in the technological drivers and trends
Some energy-related technology roadmaps are available and, although some of these linked the output from the roadmaps to other futures studies, such as scenarios, there is scope for more work in this area.

One gap in most studies was an exploration of the potential for cross-fertilisation between different areas of science and technology. Linking developments in the biosciences with a possible application in the biomass/biofuels area is just one possibility.

From the studies reviewed, there was a lack of consideration of drivers associated with the rate of deployment of technologies for supplying or using energy. None of the studies explored how new materials or processes or, for example, nanotechnologies, could contribute to any part of energy management.

The role of information and communication technologies to help better manage energy use and supply could be explored in more detail. Further work could also consider how potential changes to energy technologies, from supply to storage, distribution and demand, would impact on society.

Economic drivers and trends

The main economic driver identified in the studies is the strong link between economic growth and energy consumption/demand (e.g. 01, 13, 14, C, D). Several studies looked at this relationship. Some noted the impact of rapid urbanisation, such as in India and the corresponding increase in energy consumption (e.g. 01, 12).

Rising global energy prices were also a driver considered in several studies (e.g. 02, 05, 12). The competitiveness of different countries, for example, the UK and China, was the focus of several studies (17, I). Fair market value of renewable electricity was also a driver of patterns of consumption (H). The adoption of sustainable business practice was a driver for one study (20).

Gaps in the economic trends and drivers
There is scope to further explore what would happen if economic growth slowed down or stopped. Only one study explored the possibility of 'modest economic growth'. Another driver that would be interesting to include in any futures study would be the influence of the carbon market on the overall economy and to examine the effects of fluctuations in such a market and their potential impact on an economy. Work that would support a better understanding of the whole-lifecycle issues of the energy system could be a topic for future work.

Environmental drivers and trends

Environmental concerns such as global warming and CO_2 emissions were the primary environmental drivers on which a number of the studies were based (e.g. 01, 02, 03, 12, 13, 14, 21, I). Other drivers included the limitations of non-renewable sources (e.g. 13), mobility of people, power generation, and buildings (e.g. A) and the energy demand management needed to reduce the environmental impacts of all of these areas (e.g. 06).

There was some overlap with some of the social and economic drivers and trends in relation to consumer behaviour and the demand for information and communication technologies, the growth in demand for electrical appliances, and growing service sectors requiring commercial buildings (e.g. C).

Gaps in the environmental trends and drivers
There is scope for exploring the (inter)relationship between the environment, economics, and the energy system. The development of new areas of economics, such as behavioural neuroeconomics, and the impact that these have on our understanding of people's behaviours could contribute to how we manage energy in the future. Better understanding of relative energy costs, for example, the costs – environmentally and financially – of shipping food from overseas against producing fertiliser and growing the food in the UK could be an area to explore in a future(s) context.

Political drivers and trends

The desire to establish energy security, including both national security and trust in the marketplace, was one of the main drivers common to a number of the studies (e.g. 01, 02, 07, 14, 18, A, J).

The power of the state to intervene through actions such as regulation, environmental taxation, accountability and good governance was identified as a driver (e.g. 07, 13, 14, 15, 17, D, I). Also, the extent to which government provides subsidies and opportunities for investment in research and development of energy sources and technologies was considered by a number of studies (e.g. C, H). The degree of government's commitment to long-term planning was a driver in two studies (16, 18).

Gaps in the political trends and drivers
There was a fair degree of consensus among the studies as to the main political drivers. Two particular areas that could be identified as gaps, or at least could be considered as interesting issues to explore, are the influence of local/regional as well as national governance on energy management, and ways in which developed and developing countries could share best practice in the management of energy.

DISCUSSION

There was a broad range in the detail of how the scenarios were developed across the studies reviewed. Some studies (e.g. 11, C) presented very detailed information, whereas others provided little information on how their scenarios were generated. No doubt, that this is a reflection of many factors, including the original focus of the studies and the purpose for which they were developed.

The scope of the different studies varied greatly. Some studies had a broad brief (e.g. 07), while others had a more focused issue to consider (e.g. A). Such variation in the nature of the studies made comparison challenging because of the level of detail available. Therefore, in order to compare trends and drivers across studies, only general trends and drivers were identified.

UK-focused studies

A number of the UK studies were focused on ways of meeting CO_2 targets through changes to supply and demand and technological advances. A few looked at energy supply through the use of non-fossil fuels, such as nuclear and renewables.

For some of the studies, the focus was on specific energy-related issues, for example, power generation, renewables or transport. Supply and demand issues were the main themes in the majority of the studies, although a few did explore the transmission and distribution side too. Energy demand issues focused mainly around consumer energy choices and energy consumption and the subsequent environmental impact.

UK studies tended to refer to the significance of demand management, the infrastructural challenges posed by increasing demand and the need for renewed infrastructure to permit rebalancing of centralised and decentralised generation of both heat and electrical power. In managing the demand for energy, modification of the building stock and addressing the issues of transport are both important. Behavioural change is important, and so is innovation and associated investment. There is scope for improved metrics to aid investment decision making.

Internationally focused studies

In a similar way to the UK studies, several of the international studies were conducted to look at reducing CO_2 emissions.

A few of the country-specific studies explored unique issues. For example, the New Zealand study noted the country's geographical isolation and hence its inability to 'plug in' to the electricity networks of other countries.

Some focused on the future of fossil fuels, such as the role of gas and how non-conventional fossil-fuel sources, for example, tar sands, could be integrated. Other studies centred on the role of renewable sources. Market incentives and regulation were explored by some studies, as was innovation and the deployment of technology.

The international studies drew various conclusions, some only of local relevance, for example, Canada's findings in relation to its self-reliance on fossil fuels and new supplies such as tar sands; and China's findings in relation to the options for enabling the rate of economic growth to outstrip the rate of national consumption. Other conclusions resonated with the findings of UK studies, e.g. the criticality of pricing and investment (India); the importance of understanding what people will want/need in terms of energy demand (New Zealand); the importance of policy and investment

decisions in injecting momentum for change and encouraging rapid adoption of new technology (Europe). The global studies emphasised the importance of gas as a bridging fuel and reflected UK studies in anticipating a move towards greater decentralised and distributed generation. The difficulty of identifying 'winning' technologies in a period of high innovation was noted. Some global studies referred to fuel inequalities, noting that 2 billion people do not have access to commercial energy supplies.

Trends and drivers

Not every study included drivers and trends for each of the STEEP categories, which reflected the original focus and scope of each of the studies. What was interesting was the commonality across studies with regard to the drivers and trends that were identified.

The aim for many of the studies reviewed was to develop scenarios. There was little information on how the scenarios were used to inform subsequent decision making. However, for a couple of the organisations, e.g. Shell International and the Tyndall Centre, more than one futures study had been carried out, suggesting that using futures in the energy area has been found to be a useful contribution in the strategic decision-making process.

Gaps in futures studies

Looking across the studies, the main areas covered were energy supply and demand. Several considered mitigation of the environmental impacts resulting from the generation and use of energy. Few studies developed scenarios that focused on energy transmission and distribution issues and energy storage.

Some of the gaps in analysis that emerged from the work include:

- how to get people to adopt a sustainable lifestyle
- better understanding of the link between carbon emissions from energy consumption and economic growth
- possible opportunity for greater use of information and communication technologies in energy management
- examination of distribution, transmission and storage issues (many of the studies focused on energy supply and demand).

These could be areas of focus for potential Foresight futures studies.

Annex A: UK-focused futures studies

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
A	2006	UK	Deloitte Touche	Deloitte Touche	2020 Vision: the Next Generation	Scenario generation	Meeting UK power generation objectives in 2020 – a strategic insight	2020

Key findings and/or observations

- The need to address issues on the importation of gas, including source, cost and improved storage capacity.
- The need to consider how to manage demand, including price and policy incentives, and the role of Government in demand management.
- The need to take decisions now about future supplies, as significant generation capacity will come off-line by 2020.
- The need to have a diverse change of power-generating technologies.
- The need to address the balance between centralised and distributed power.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
B	2003	UK	Tyndall Centre for Climate Change	Tyndall Centre for Climate Change and – Science and Technology Policy Research	UK Electricity Scenarios for 2050	Builds on existing Royal Commission for Environmental Pollution scenarios (see D)	To explore options for 60% reduction in carbon emissions by 2050 using the scenarios produced by the Royal Commission on Environmental Pollution and applying these scenarios to the UK electricity system	2050

Key findings and/or observations

The paper builds on the scenarios developed by the Royal Commission for Environmental Pollution.

The paper has established electricity-generating plant capacities, load factors and annual outputs for each scenario. Key features include:

- There is a shift in the role of fossil fuel electricity generation – away from base load or mid-range duty and towards back up for intermittent renewable sources.
- In two scenarios, there is a significant expansion of nuclear power (or fossil fuel stations with carbon sequestration).
- There is significant action to halt or reverse growth in energy demand that implies large improvements in energy efficiency.

- In some scenarios, there are very large mismatches between electricity generation and electricity demand. This is explained by the use of electricity to provide substantial amounts of high- and low-grade heat.

- There is no link between the expanded use of renewable sources to generate electricity and the production of hydrogen. In the scenarios, all hydrogen is produced from fossil fuels.
- Scenarios include large variations in the capacities and types of generating technology that will be required to meet this demand. Analysis of the scenarios suggests that a radically different electricity system to the current one is required.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
C	2005	UK	Tyndall Centre for Climate Change	Tyndall Centre for Climate Change	Decarbonising the UK – Energy for a Climate-Conscious Future	Scenario generation and modelling	Exploring a range of options for bringing together UK society with a true 60% reduction in carbon emissions by 2050	2050

Key findings and/or observations

The UK scenarios produced by the Tyndall Centre are the first to integrate fully the energy system and include CO_2 emissions from air, sea and land transport. The scenarios illustrate that a 60% reduction in the UK CO_2 emissions is technically, socially and economically viable.

Key observations include:

- efficiency improvements can dramatically decarbonise many sectors
- demand reduction offers greater flexibility than low-carbon supply
- supplying low-carbon energy is technically and economically viable
- a society with high energy demand will face future infrastructure challenges
- low-carbon futures do not preclude increases in personal mobility
- emissions from international aviation and shipping must be included in carbon targets
- the role of Government is to implement and enforce minimum energy standards
- equity concerns will demand innovative policy mechanisms.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
D	2000	UK	Royal Commission for Environmental Pollution	Royal Commission for Environmental Pollution	22nd Report: Energy – the Changing Climate	Scenario generation	Possible UK energy balances in 2050 (part of a larger report)	2050

Key findings and/or observations

All scenarios in this paper involve fundamental shifts in the next half-century in the ways energy is obtained and used and in the associated infrastructures. Key features include:

- the development of renewable energy sources on a very large scale
- extensive modification to both the building stock and the transport system in order to reduce the need for energy, e.g. district heating systems supplied by CHP and heat pumps in urban areas.
- electricity networks would have to be restructured to accommodate the much larger numbers of smaller generating plants embedded within them, many supplying electricity only intermittently.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
E	2006	UK	Sustainable Development Commission	Sustainable Development Commission	Reducing CO_2 Emissions – Nuclear and the Alternatives	Scenario generation and modelling (one of eight reports underpinning the Sustainable Development Commission's position paper on the role of nuclear power in a low-carbon economy)	Explores the potential contribution of nuclear power to long-term targets for the reduction of CO_2	2025

Key findings and/or observations

- This part of the overall study looks at the potential contribution of nuclear power to electricity supply and carbon reduction targets through scenarios.

- The baseline scenario is not considered to have an impact on CO_2 emissions as the retirement of nuclear capacity is expected. CO_2 emissions reductions need to be achieved in other areas.
- In scenario 1 (replacement), the maximum emissions savings are reached in 2024 when all new capacity is operating. Therefore annual emissions savings where 10 GW of new capacity is built would be 6.7 million tonnes of carbon (MtC) by 2024.
- In scenario 2 (expansion to double current levels), the estimated completion of the programme is calculated to be 2034, with the impact on CO_2 emissions an effective doubling of the savings in scenario 1.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
F	2006	UK	UK Foresight: Intelligent Infrastructure Systems	UK Foresight: Intelligent Infrastructure Systems	Intelligent Infrastructure Systems Scenarios	Scenario generation	Describes how science and technology might be applied to infrastructure over the next 50 years	2055

Key findings and/or observations

The focus of this work was primarily on transport. Information is the key element in an intelligent infrastructure and four levels of intelligence were identified. These were:

- intelligent design of infrastructure – minimising the need to move through use of urban design, efficient integration and management of public transport and local provision of production and local services
- the design of infrastructure to deliver intelligence, with sensors and data mining providing information to support the decisions of individuals and service providers
- designing intelligence into infrastructure so that it can process the vast amounts of information collected and then adapt in real time to provide the most effective services
- the intelligent use of infrastructure, where people modify their behaviour to achieve a more sustainable outcome.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
G	2006	UK	Department for Transport	Bartlett School of Planning, University College London, and Halcrow Group	Looking Over the Horizon: Visioning and Backcasting for UK Transport Policy	Scenario generation, backcasting and modelling	Examines the possibility of reducing transport CO_2 emissions by 60% by 2030	2030

Key findings and/or observations

The focus of the work was primarily on UK transport and it examined the possibility of reducing transport emissions by 60% by 2030. The study developed two images of the future for the transport sector in the UK. The study's conclusion is that the 60% CO_2 reduction target can be achieved by a combination of strong behavioural change and strong technological innovation, but it is in travel behaviour that the real change must take place. The study suggests that it is not possible to achieve the 60% CO_2 reduction with the expected growth in travel as the increase in CO_2 emissions from this growth outweighs many of the possible savings from behavioural change and technological innovation.[1]

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
H	2001	UK	Performance and Innovation Unit	Performance and Innovation Unit	Renewable Energy in the UK – Building the Future of the Environment	Qualitative and quantitative analysis	▪ Development of a resource productivity framework ▪ Application of the framework to energy productivity ▪ Analysis of the state of renewable energy	2050

Key findings and/or observations

- Deploying renewables on the ground will help to kickstart the wider use of the technologies throughout the UK – particularly those approaching, but not yet at, commercial viability.

[1] Executive summary: *Looking Over the Horizon*. Bartlett School of Planning, University College London, and Halcrow Group for the Department of Transport. January 2006.

- Offshore wind and energy crops are the key technologies to be promoted.
- The economics of offshore wind are subject to many uncertainties. Accordingly, there is a strong case for additional capital grant support to fund offshore wind installations.
- In energy crops, commercial electricity schemes (particularly those classified as CHP), infrastructure to link growers and energy providers and industrial heat are important areas for funding.
- Overcoming barriers imposed by local attitudes, planning processes and network connections will be crucial to getting renewables on the ground.
- Developing new technologies and expanding the UK's knowledge base will be important for the long term.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
I	2004	UK	Engineering and Physical Sciences Research Council	Institute for Alternative Futures and Institute for Innovation Research	Scenario Exercise on Moving Towards a Sustainable Energy Economy	Scenarios	Economic and social research priorities to develop understanding of the economic and social challenges of moving to a sustainable energy economy	2050

Key findings and/or observations

The paper makes recommendations in 13 areas:

- psychology of consumer energy choices
- government foresight and long-term action
- accelerating energy-efficiency improvements
- positive images of the future to motivate change
- encouraging innovation; media and public opinion
- vulnerability
- liberalised energy markets
- distributed generation
- joined-up government
- improved metrics for decision making and investment
- aviation
- changing values.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
J	2005	UK	N/A	Science and Technology Policy Research	40% House Background Material B	Scenario planning	Sustainable energy	2050

Key findings and/or observations

- Effect of household numbers on carbon emissions.
- Effect of low- and zero-emissions carbon technology on building fabric.
- Effect of investment in improving the housing stock.
- Extent of concern about – and education in – environmental issues.
- Effectiveness of policies to reduce carbon emissions.
- Effect of international framework of environmental regulation.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
K	2006	UK	Friends of the Earth	Friends of the Earth	A Bright Future	Electricity sector modelling	Future development of the energy sector	2030

Key findings and/or observations

- There is a large potential to reduce emissions in the electricity sector without relying on nuclear power.
- There is a need to promote renewable energy sources – including biomass and microgeneration.
- Upgraded and new fossil fuels should be made ready for possible future use of carbon capture and storage.
- Promote increased use of sustainable biomass and biogas for electricity generation.
- The UK can easily move away from nuclear power as long as efforts are made to promote other technologies.
- The UK needs more effective policies for CHP.
- The UK needs more effective policies for energy efficiency.
- The UK needs to set strong caps on the second phase of the emissions trading scheme.

Annex B: Internationally focused futures studies

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
01	1998	India	World Energy Council	World Energy Council	India's Energy Scenario in 2020 (based on a study titled Environmentally Constrained Alternative Energy Scenarios)	Scenario generation and projections of energy demand	The paper provides an overview of the energy sector development in India during the last 50 years and the likely energy scenario in the year 2020.	2020

Key findings and/or observations

Projections under each scenario take into account the overall availability of resources and the likely growth in the demand for energy in the economy. The three different scenarios produced different visions. The conclusion of the work was that from the point of view of new long-term sustainability, the country could ill afford an energy development scenario that places considerable strain on its resources. Any shift in pattern of supply and demand for energy from the business-as-usual scenario to an efficiency-oriented scenario and environmentally constrained scenario could take place only if an effort is made to consciously initiate appropriate pricing and investment policies.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
02	2005	New Zealand	Parliamentary Commissioner for the Environment	Parliamentary Commissioner for the Environment	Future Currents: Electricity Scenarios for New Zealand	Scenario generation and quantitative analysis	To promote long-term thinking and dialogue about the future of electricity.	2015, 2030, 2050

Key findings and/or observations

- The report describes two scenarios of New Zealand in 2015, 2030 and 2050 depending on energy choices made in 2005. The first scenario is focused along the lines of building big power projects, as they are seen as the key to a secure electricity supply. The second scenario is focused on 'getting more for less' by rethinking how electricity and other forms of energy are used.
- The study report that there was a need to focus on what people want and need, the connections between energy and need and how needs can be met – this might be through smart design, energy efficiency and/or switching to different energy sources where this is beneficial.
- The study also noted the need to inform people and involve many people and perspectives in the debate.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
03	2003	Canada	Canadian National Energy Board, with contributions from industry, environmental groups and government agencies	Canadian National Energy Board, with contributions from industry, environmental groups and government agencies	Canada's Energy Future – Scenarios for Supply and Demand to 2025	Scenario generation	To explore forces, uncertainties and key issues affecting energy supply and demand in Canada	2025

Key findings and/or observations

Two energy futures were explored through the development of scenarios.

- There are significant obstacles to changing the fuel mix or achieving large gains in energy efficiency due to the structure of the Canadian economy; energy-use patterns will change slowly and Canada will continue to satisfy the majority of its energy needs from fossil fuels until 2025.
- Natural gas will be in high demand as a premium clean-burning fossil fuel; however, a major uncertainty is the availability of supplies of natural gas.
- Oil sands production will increase significantly and will offset the decline in conventional crude oil production and become Canada's major source of oil supply; exports will increase considerably through 2025.[2]

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
04	2001	Global	Global Business Environment Shell International	Global Business Environment Shell International	Exploring the Future: Energy Needs, Choices and Possibilities	Scenario generation	The focus is on some key questions about how energy systems may develop	2050

Key findings and/or observations

[2] *Canada's Energy Future: Scenarios for Supply and Demand to 2025*. National Energy Board: http://www.neb.gc.ca/energy/SupplyDemand/2003/index_e.htm. Accessed October 2006.

Two scenarios were developed to explore how energy systems might develop taking into account uncertainties around long-term use of gas and its role as a bridging fuel. The scenarios have five common features:

- The important role of natural gas as a bridge fuel over at least the next decades and the importance of reducing supply security fears.
- The disruptions oil markets will face as new vehicle technologies diffuse.
- The shift towards distributed or decentralised heat and power supply for economic and social reasons.
- The potential for renewable energy sources to be the eventual primary source of energy and the importance of robust energy storage solutions.
- The difficulty of identifying winning services or technologies in a period of high innovation and experimentation.

The key differences between the two scenarios and their dominant energy products reflect different energy resource potentials, the timing and nature of technology possibilities and social and personal priorities. The two scenarios explore different paths to a sustainable energy system. At some point, beyond 2050, the elements that underlie the two paths could converge, possibly with hydrogen as the preferred energy carrier and storage medium.[3]

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
05	2004	Europe	European Renewable Energy Council	European Renewable Energy Council	Renewable Energy Scenario to 2040: Half of the Global Energy Supply from Renewables in 2040	Scenario generation with projections	Explores how renewable energy sources will be able to play a significant role in future energy supply worldwide	2040

Key findings and/or observations

Two scenarios were considered. The report outlines suggestions for policy measures to encourage the global support of renewable technologies.

[3] *Energy Needs, Choices and Possibilities: Scenarios to 2050*. Global Business Environment, Shell International. 2001.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
06	2005	Global	World Business Council for Sustainable Development	World Business Council for Sustainable Development	Pathways to Energy and Climate Change 2050	'Megatrends' – short snapshots of possible futures with projections and some regional trends	The study looks at the changes needed to begin to stabilise CO_2 concentrations in the atmosphere at no more than 550 parts per million (ppm) by 2050	2025, 2050

Key findings and/or observations

The scope of the work covers 'megatrends'. These are described as power generation, industry and manufacturing, mobility, buildings and consumer choices. It aims to enhance understanding of what changes would be needed in order to achieve a reduction in CO_2 emissions.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
07	2005	Global	Global Business Environment Shell International	Global Business Environment Shell International	Global Scenarios to 2025	Scenarios	Explores the three forces of market incentives, communities, and coercion or regulation	2025

Key findings and/or observations

The report identified three key drivers of world development:

- market incentives (efficiency)
- the force of community (social cohesion and justice)
- coercion and regulation by the state (security).

From the interplay and trade-offs of these three possible future worlds were developed:

- 'low trust globalisation' – more globalisation and market liberalisation but also more coercive states and regulators
- 'open doors' – heightened globalisation and more cohesive civil societies crisis of trust and security has been resolved
- 'flags' – states rally around the flag, trust is fragmented, national societies are split into diverse groups; efficiency and the market take a backseat to security and solidarity.

These three scenarios were also used to calculate possible average growth rates for each.

The report looked at the implications of the three scenarios for the US, China and the European Union.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
08	2005	Europe	Energy research centre of the Netherlands and the Ministry of Economic Affairs	Energy research centre of the Netherlands	The Next 50 Years: Four European Energy Futures	Scenario analysis	Explores the future of European energy innovation	2055

Key findings and/or observations

This study developed four scenarios.

From the perspective of the Netherlands, the key points emerging from the work were:

- the move from hydrocarbons to renewables
- geographical position and international links put the country in a strong position for future developments in new energies
- natural gas to play an important role for the next two decades.

These scenarios differ from previous studies in that in the past they were viewed from the perspective of Dutch priorities and ambitions. It was recognised that in the next 50 years energy innovation should be looked at from the point of view of Europe.

The study identifies three dimensions of the energy value chain: upstream and downstream; services and equipment; and agriculture and chemicals. It also suggests that central power and residential heat may shift, for example, to mobile and microgeneration. There may be hybridisation through the introduction of multiple gas sources; co-evolution of technological and institutional systems and transition to European energy regimes.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
09	2006	EU member states	Directorate-General for Energy and Transport, with contributions from member states' energy experts and European Commission officials	Directorate-General for Energy and Transport, with contributions from member states' energy experts and European Commission officials	European Energy and Transport – Trends to 2030	Modelling analysis of the European energy system	Explores possible energy and transport developments over the next three decades	2030

Key findings and/or observations

The report reviews the key issues arising from an assessment of likely economic, energy, transport and CO_2 trends over the period to 2030 for current EU member states and EU candidate and neighbouring countries.[4] The baseline used for this study can contribute towards identifying challenges and opportunities implicit if present trends continue. The indicators in this study can also help policy makers to evaluate existing trends in relation to policy objectives. The study can also be used as a starting point for further scenario analysis policy-relevant cases.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
10	2000	Global	Intergovernmental Panel on Climate Change	Intergovernmental Panel on Climate Change	Summary for Policymakers: Emissions Scenarios	Scenarios	Covers a wide range of the main driving forces of future emissions	2100

Key findings and/or observations

A set of scenarios was developed to represent the range of driving forces and emissions.

Future work on emissions scenarios that was considered to be useful included:

- establishment of a programme for ongoing evaluations and comparisons of long-term emissions scenarios
- capacity building, particularly in developing countries, in the area of modelling tools and emissions scenarios
- multiple storyline, multi-model approaches in future scenario analyses

[4] Executive summary: *European Energy and Transport – Trends to 2030.*

- new research activities to assess future developments in key greenhouse gas driving forces
- improved specification and data for, and integration of, the non-CO_2 greenhouse gas and non-energy sectors, such as land use, land-use change and forestry, in models, as well as model inter-comparison to improve scenarios and analyses
- integration into models emissions of particulate, hydrogen, or nitrate aerosol precursors, and processes, such as feedback of climate change on emissions, that may significantly influence scenario results and analyses
- assessment of strategies that would address multiple national, regional, or global priorities
- development of methods for scientifically sound aggregation of emissions data.[5]

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
11	2004	Global	World Energy Agency	World Energy Agency	World Outlook Scenarios 2004	Scenario modelling	Explores probable developments of global energy markets until 2030	2030

Key findings and/or observations

- The Reference Scenario takes account of government policies and measures that were enacted or adopted by mid-2004.
- The World Alternative Policy Scenario depicts a more efficient and more environment-friendly energy future than the Reference Scenario does. It demonstrates that policies to address environmental and energy-security concerns that countries are already considering, together with faster deployment of technology, would substantially reduce energy demand and CO_2 emissions.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
12	2006	Global	Office of Science and Innovation Horizon Scanning Centre	Office of Science and Innovation Horizon Scanning Centre	Entries on the Sigma (Trends and Drivers) and Delta (Science and Technology) Databases http://www.foresight.gov.uk/horizon scanning	Scan of scans of trends	Scan of scans of trends underpinning energy	Various

[5] *Special Report Emissions Scenarios: Summary for Policymakers*. A Special Report of IPCC Working Group III. Intergovernmental Panel on Climate Change. 2000.

Key findings and/or observations

The entries explore various factors that could impact on energy in the future.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
13	1998/2000	Global	World Energy Council	World Energy Council	Global Economic Scenarios to 2050 and Beyond	Applied Systems Analysis	Broad scenario approach to consider future energy options	2050

Key findings and/or observations

- There is huge scope to raise the efficiency with which energy is provided and, more particularly, used. Over 60% of primary energy is, in effect, wasted – and over 60% of that in end uses.
- Nearly 2 billion people do not have access to commercial energy services.
- Just over 75% of the world's current primary energy supplies come from fossil fuels and only 2% from new renewables other than large hydro. Geological resources for these fuels and uranium are huge and technological advances are allowing more and more of them to be exploited. The decarbonisation of the fuel mix is likely to be a very protracted process.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
14	2000	USA	US Department of Energy (DOE)	Interlaboratory Working Group	Scenarios for a Clean Energy Future[6]	Scenario modelling	The potential for public policies and programmes to foster efficient and clean technology solutions to future energy challenges	2020

Key findings and/or observations

The study does not make policy recommendations. Rather, the purpose of the study is to better understand the costs and benefits of alternative sets of policies to accelerate clean-energy technology solutions. The tested policies do not address the complete range of policy options. For example, the scenarios do not include international emissions trading which could be important to meeting possible carbon emissions targets. The structure development of energy scenarios allows a way to examine a range of public policies and to consider alternative possibilities.

The study's key conclusions are:

[6] Executive summary only.

- Smart public policies can significantly reduce not only CO_2 emissions but also air pollution, petroleum dependence and inefficiencies in energy production and use.
- The overall economic benefits of these policies appear to be comparable to their overall costs.
- Uncertainties in this study's assessment are unlikely to alter the overall conclusions.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
15	2001	USA	US Department of Energy (DOE)	RAND	E-Vision 2000: Key Issues that Will Shape our Energy Future	Scenario planning	Broad energy trends to inform DOE planning	2020

Key findings and/or observations

RAND reviewed a number of historical documents and scenario models and aggregated them into a smaller set of 'meta-level' scenarios that could be distinguished from one another and identified a number of policy issues. These included:

- Disruptions and shocks to the *status quo* – explored unanticipated events and suggested the need to consider policy actions that would increase the proportion of cleaner, domestic energy in the fuel mix and increase energy efficiency are robust actions against unanticipated events.
- Availability and security of fossil-fuel sources – most scenarios show increased use of oil and natural gas and their supply, including imports, is a key policy issue. Increased oil imports are assumed to come primarily from the Persian Gulf and natural gas from additions to proven reserves. Alternative oil or liquid fuel supply options and pricing and policy incentives for gas production are critical issues.
- Feasibility of rapid technological change – many of the scenarios assume rapid adoption of improved technology, sometimes coupled with changes in patterns of energy consumption. These futures are unlikely to come about without policy actions, e.g. a greenhouse gas emissions 'cap and trade' programme. It's not clear that such a future is obtainable through pursuit of existing policies.
- Need for analysis of nuclear options. Most scenarios assumed that nuclear power plants would be decommissioned on schedule and that no nuclear power plants would be built. Although this reflects current trends in the USA and Europe, the Energy Information Administration Kyoto Protocol scenario variants suggests that extending the lifetime of existing plants can be an essential and cost-effective component of a carbon reduction strategy. In the light of the current level of international concern about greenhouse gases, nuclear power, as a carbon-free source of electricity, needs to be analysed and considered within an objective framework that compares the costs, risks and impacts of alternative energy sources.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
16	2002	USA/Canada	Canada-USA DOE	N/A	North American Transportation Energy Scenarios[7]	Scenario planning	Evolution of the transportation sector and impact on energy use and the transportation system	2050

Key findings and/or observations

The purpose of the study was to establish a range of plausible futures for the evolution of the transportation sector and to estimate their impacts on energy use and the transportation system.

The paper describes some correlation of the scenarios against gross domestic product (GDP) data drawn from the International Institute for Applied Systems Analysis (IIASA).

ID No.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
17	2003	China	Energy Research Institute of the National Development and Reform Commission, People's Republic of China[8]	Energy Research Institute of the National Development and Reform Commission, People's Republic of China	China's Sustainable Energy Future – Scenarios of Energy and Carbon Emissions	Long-range energy alternatives planning system software	Energy and carbon emissions	2020

Key findings and/or observations

- The primary purpose of the study was to give Chinese policy makers detailed information about whether the stated goal of achieving a four-fold increase in GDP with only a two-fold increase in energy consumption is possible.
- The results of the study have convinced the project team that such an achievement will not come easily to China, but it is feasible given aggressive implementation of policies across all sectors to increase energy efficiency, to switch rapidly to cleaner fuels and to restructure energy-intensive sectors and activities.

[7] Outline only.
[8] Supported by the Shell Foundation's Sustainable Energy Programme.

- Even the 'greenest' scenario (Green Growth) will require tremendous development of the energy supply infrastructure to support rising levels of activity and associated energy demand. Particularly important will be investment in natural gas pipelines and terminals, electricity transmission and distribution networks, nuclear and wind generating capacity, cleaner, more efficient coal-power technology, and public transportation.
- While industry must remain a focus of policy makers' attention, transportation and building energy consumption are already expanding rapidly, and will continue to increase very quickly in the coming years. Therefore it is vital that energy-efficiency policies are strongly promoted in these areas as soon as possible.
- A large uncertainty that could significantly affect China's pollutant emissions path (including carbon emissions) is the magnitude of the role that natural gas will play in the energy mix in the coming decades. It will be very important for China to promote rapid substitution of energy-dense fuels, like oil and gas, for the lower-energy-content solid fuels currently used in most applications.
- The project team states that one limitation of this study is the fact that costs are not included in the model. If cost data were included, comparisons of the costs of certain development paths over others could be compared. Although the final accounting results of total CO_2 emissions resulting from an energy development trajectory are indeed important to the Chinese Government, costs are important factors to assess at each stage where a decision is made to introduce a new technology or a new policy programme.
- Analysis of other benefits of alternative energy development paths also needs to be evaluated. Integrated assessment work could quantify the benefits of greater efficiency and better fuels in terms of reduced damages to the environment and human health. Integration with macroeconomic analysis could potentially gauge employment impacts as well. Benefit–cost calculations could assist in prioritising areas in which to promote investment. Sensitivity analysis would allow policy makers to understand the different effects of various policy options. Analysis could focus on the effects of introducing varying levels of efficiency standards for vehicles or household appliances at different times, and the impacts on different regions and demographic groups.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
18	2003	USA	Pew Centre on Global Climate Change	Pew Centre and Global Business Network	US Energy Scenarios for the 21st Century	Scenario planning	US electricity and energy market	2035

Key findings and/or observations

The primary purpose of this study was to explore economic, technological and socio-political developments that raise questions about electricity market restructuring and whether a more efficient and competitive US energy market will evolve in the near future.

Several technologies have the potential to radically transform future US energy supply and demand:

- geological sequestration
- fuel cells
- hydrogen
- advanced nuclear technologies
- energy-efficiency technologies
- distributed generation.

Climate-change policy was deliberately excluded from the 'base case' scenarios. In order to explore the possibilities of reducing US carbon emissions in each of the scenarios, a hypothetical suite of emissions control policies (the policy overlay) was identified. The portfolio of policies includes:

- performance-based CO_2 and efficiency standards applied to the transportation sector, implemented through tradable emissions credits
- incentives to accelerate the research and development of new low-carbon and energy-efficient technologies through innovative public–private partnership
- a downstream carbon emissions allowance 'cap and trade' programme applied to the electricity generation and industrial sectors of the economy
- investment and production tax credits for efficiency-improving and carbon-emissions-reducing technologies
- a set of 'barrier busting' programmes designed to reduce market imperfections and promote economically efficient decision making by individual consumers, investors and institutions.

This policy overlay was used as an analytical tool to explore the costs and feasibility of reducing carbon emissions from energy production and use. It was limited to measures that could reduce US domestic CO_2 emissions because the scope of this project was limited to US energy production and use.

Taken together, the three policy overlay cases show that a **portfolio of market-oriented policies and standards can lead to substantial reductions in US CO_2 emissions by 2035**, without major negative impacts on the overall level of US economic activity. However, implementation of such policies could have significant costs for the energy and energy-intensive sectors of the economy.

Without a mandatory carbon constraint, the absolute level of emissions rises in each base case scenario, despite the fact that the carbon intensity of the economy declines considerably. This result points to the **need to develop climate-change policy** in order to stem these increases.

Natural gas is one of the most important contributors to the decline of the carbon intensity of the energy sector in both the base and policy overlay cases. The market for natural gas expands in all scenarios, with and without the policy overlays. Substituting natural gas for coal results in approximately half the carbon emissions per unit of energy supplied. **Increased use of natural gas** also has energy security benefits for the US.

Energy-efficiency improvements also play a key role in reducing carbon emissions. In response to the carbon constraint, the fuel economy of cars and light trucks dramatically improves in the policy cases, significantly reducing oil imports. In each of the scenarios, CHP technology improves the efficiency of electric generation. When the carbon policy overlay is imposed, performance standards for electrical devices and for gas- and oil-fired equipment lead to improved energy efficiency in the residential, commercial and industrial sectors.

Renewable-energy and distributed-generation technologies contribute to the reduction of carbon emissions in each of the scenarios and their policy overlay cases. While both renewable-energy and distributed-generation technologies grow in the base case scenarios, they experience more substantial increases following the implementation of the policy overlay, which aids their commercialisation by promoting investment and by breaking barriers to entry in US energy markets.

Nuclear power plays a significant role in each of the scenarios and their associated policy cases. Nuclear power production remains close to the level in 2000 in each scenario, with and without the policy overlays. In the absence of nuclear power, carbon emissions would be significantly higher in 2035.

Geological sequestration emerges as a key technology in the policy overlay cases, allowing continued reliance on fossil fuels, even in the face of a carbon constraint. Sequestration is particularly important in Turbulent World with Policy, a scenario in which hydrogen is produced primarily from coal. Geological sequestration allows hydrogen to be produced from fossil fuels without releasing carbon emissions, facilitating the transition to a hydrogen economy.

Hybrid electric vehicles play an important role in the transportation sector and act as a bridge technology for fuel cells in mobile applications. Many of these critical technologies, however, are not commercially viable in 2003 and public policies at the state and federal level are necessary to lower barriers to commercialisation of these technologies and to stimulate sustained investment during the course of these scenarios. Included among the policies that promote commercialisation of these technologies are a carbon emissions allowance 'cap and trade' programme for some sectors and a set of equipment efficiency credit trading programmes, as well as renewable portfolio standards, fuel economy and air-quality requirements, and electric power grid interconnection standards.

One key insight that emerged is that policy is necessary to address climate change. A second is that there are technologies – with supporting policies and investments – that could address climate change, accelerate capital stock turnover, and enhance the nation's energy security, no matter which direction the future takes. Finally, the scenarios indicate that energy policy and investment decisions made today affect the difficulty of implementing a climate policy tomorrow. If US decision makers

can implement the necessary policies and encourage appropriate investments during the next 30 years, the US could be better positioned to achieve its complementary economic, energy security, and environmental goals.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
19	2004	Australia	Clean Energy Futures Group[9]		A Clean Energy Future for Australia	Backcasting/fore casting	Future of Australia's energy market	2040

Key findings and/or observations

The study used a model to forecast what the Australian economy will be like in 2040 (sectors, outputs, growth, etc.) and then used that to explore a number of energy-related factors in the future:

- energy demand
- energy intensity
- energy efficiency technologies and key sectors
- renewable energy
- future fossil-fuel technologies
- decarbonising energy supply
- energy costs.

The study created a number of different scenarios: a baseline scenario (an extrapolation of current patterns of demand and use), a clean-energy scenario and two low-emissions scenarios. The model explores various parameters and sets out the cost involved in creating the Clean Energy Scenario.

The study does not clearly set out key findings – but perhaps the most relevant findings are that:

- The cost of electricity generation in the clean energy scenario is as good as the most efficient fossil-fuel (baseline) scenario.
- The environmental and health costs of the fossil-fuel (baseline) scenarios are much dearer than the Clean Energy Scenario.

The study also (slightly confusingly) notes that 'any additional costs of the Clean Energy Scenario could be readily paid out of the existing financial subsidies to the production and use of fossil fuels', which include:

- electricity price subsidies to aluminium smelting
- tax benefits for salary packaging motor vehicles
- Greenhouse Gas Abatement Program (which goes mostly to fossil fuels)
- fuel excise reduction
- fuel sales grants scheme
- automotive industry support
- land for roads and car parking

[9] A mixture of industry associations and World Wildlife Fund.

- reduced import duty on 4-wheel drives
- inappropriate company tax concessions
- research and development support for fossil fuels
- non-recovery of government agency costs (e.g. Department of Industry, Tourism and Resources, various state departments).

The report concludes that 'a small fraction of these [subsidies] could be used on a temporary basis to speed up the transition to a 50% reduction in CO_2 emissions from stationary energy.' It also notes that 'the macroeconomic benefits of increasing energy efficiency are conceptually identical to the macroeconomic benefits of increasing labour market efficiency. In fact, minimising the amount of energy required to produce a given level of output is as economically beneficial as minimising the amount of labour or capital input. Reducing energy consumption per unit of output will free up resources, particularly resources that would otherwise be directed towards energy generation and distribution, that can be directed towards more productive purposes.'

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
20	2005	Ireland	Feasta	Feasta	Energy Scenarios Ireland	Scenario planning/evaluation of capital creation options (ECCO) modelling	Sustainable future for Ireland's economy	2015

Key findings and/or observations

There are no specific findings from the study. It is sponsored by Feasta, a sustainable economics non-governmental organisaton, which seeks to identify the economic characteristics that Irish society must have in order to be economically, environmentally and culturally sustainable and to share the analysis with the widest audience possible. The work is still – to some extent – in progress.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
21	2005	USA	Electric Power Research Institute	Global Business Network	Electric Power Industry Technology Scenarios[10]	Scenario planning	Factors and variables that will shape the role of electricity in the future	2025

Key findings and/or observations

Ten technology recommendations arise from the work:

- **Customer portal investment.** The portal provides the physical and logical links that allow communication of electronic messages from the external network to

[10] Interim report.

consumer networks and intelligent equipment.

- **Distribution automation.** Integrated energy and communications system architecture; fault-anticipation technology to forecast grid failures; adaptive islanding and storage technology.
- **Carbon capture and sequestration**. Breakthrough technologies that reduce the economic impact of removing CO_2 from fossil generation plants; pilot-scale and full-size demonstrations of these advances.
- **Advanced coal and nuclear generation.** Low-emission designs of integrated gasification combined cycle (IGCC) generation for coal; demonstration of a stable licensing process and cost-effective deployment of advanced light water reactors; technology basis for the helium reactor.
- **Environmental emissions.** Control of a wide range of gaseous, aqueous, and solid pollutants that are produced as by-products of electricity generation and use. Examples include SO_2, NO_X, fine particles, mercury compounds, and CO_2 for fossil generation.
- **Energy storage.** Large-scale, low-cost storage systems, focusing on advanced technologies such as flow batteries, flywheels, ultracapacitors, and compressed air energy storage.
- **Transmission portfolio.** Planning for expanding and enhancing the North American transmission grid; planning tools to assess the location, timing, and size of new power plants and transmission lines; integration of generation and transmission system upgrades.
- **Sustaining existing nuclear fleet.** Application of reliability-focused technologies to resolve issues and manage assets; managing the transition to advanced light water reactors.
- **Training and simplification.** Development and deployment of tools for managing a power industry staffed with individuals who are not as well-trained as their predecessors.
- **Sustaining existing gas and coal fleets.** Advanced technologies for operating and maintaining the current fleet of fossil power plants, including asset management tools; address the need to meet emissions targets for these plants.

ID no.	Date of publication	Region	Sponsors	Authors	Title	Methodology	Focus	Timescale
22	Work in progress	Italy	Multi-client study (private sector)	Cambridge Energy Research Associates Ltd	Dawn of a New Age: Global Energy Scenarios for Strategic Decision Making – The Energy Future to 2030	Scenarios	How geopolitics, technological change, and economic, demographic and environmental trends could evolve in next 25 years.	2030

Key findings and/or observations

This project was in progress at the time of writing; report available from summer 2006.

Annex C: Technology roadmaps: summary

ID no.	Date	Region	Sponsors	Title	Methodology	Timescale
TR1	2000	USA	American Petrolum Institute, National Petrolchemical and Refiners Association	Technology Roadmap for the Petroleum Industry	Roadmap	2020
TR2	2002	Australia	N/A	Renewable Energy Technology Development	Roadmap	2015
TR3	2003	USA	Electric Power Research Institute	Electricity Technology Roadmap	Roadmap	2050
TR4	2005	Japan	Ministry of Economy, Trade and Industry	Strategic Technology Roadmap (Energy Sector)	Roadmap/constraints backcasting	2100
TR5	2006	UK	Office of Science and Innovation	Intelligent Infrastructure Futures: Technology Forward Look – Towards a Cyber-Urban Ecology	Roadmap	2050

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