RSE COMMITTEE OF INQUIRY INTO ENERGY ISSUES FOR SCOTLAND

FINAL REPORT

June 2006

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PREFACE

The Royal Society of Edinburgh, as the National Academy for Scotland, has a Fellowship containing great expertise across all the sciences, technologies, humanities and the arts. The Fellowship is elected from the worlds of academe, public and private service, commerce and industry. As a membership organisation it has no political allegiance nor does it represent any sectoral interest. As such it is uniquely placed to offer informed, independent comment on matters of national interest.

In May 2005, the Council of the RSE established a Committee of Inquiry into Energy Issues for Scotland. The Committee was given a broad remit to consider all aspects of energy supply and demand but also to examine relevant economic, environmental and social matters. I believe that this represents the most comprehensive study of energy issues ever undertaken in Scotland.

Energy issues have become a matter of global concern and in Scotland there has been a rapid escalation of public and political interest. We are at a turning point in our history as we move from being a self-sufficient exporter of energy to a possible dependence on imported energy from an increasingly competitive World.

It is my hope that this Report will stimulate and inform public debate on the issues and provide an evidential base upon which policy can be based and decisions taken.

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President, The Royal Society of Edinburgh

EXECUTIVE SUMMARY

The report is on energy issues for Scotland until 2050. It provides the global and UK contexts, the current Scottish position and the challenges for Scotland.

The key conclusions on the energy context for Scotland are as follows. Global energy demand is predicted to double by 2050. Energy prices will rise in real terms. There will be greater international market competition for energy. Energy availability will change. Oil and gas will decline continuously, posing particular challenges for transport, heating and electricity generation. Coal reserves worldwide are large but new low emission technologies are needed. Civil nuclear power in the UK has an excellent safety record and its efficiency in power generation will continue to improve, but there are continuing public concerns on waste disposal. Renewables will be in various states of development, economic viability and environmental effect. Continuing use of all fossil fuels will require lower emissions technologies.

Scotland cannot operate in isolation on energy. It is part of the global energy market. It will have to work within the powers reserved to the UK government on energy and use its own delegated powers, for example on promotion of energy efficiency. The Scottish Executive will need to work in harmony with the UK Government and promote the Scottish position.

The best estimates of population and economic activity in Scotland predict an increase in both with the consequential expectation of a 50% increase in energy demand by 2050.

Scotland is making a contribution already to the reduction of greenhouse gas emissions. Although small in global terms, there is a practical contribution and an ethical imperative to continue but the targets must not disadvantage Scotland’s competitiveness.

There is no clear societal consensus on energy and no one solution can provide all of the answers. However, Scotland will lose around 30% of its electricity generating capacity from large plants in 10 years and around 75% in 20 years. Given the timescale for approvals and building, decisions are urgent.

Scotland has to think in a global context and act locally using the natural resources at its disposal in a manner which provides social, economic and environmental benefits.

Given the unpredictability of prices, stability of energy source countries, and technological development, along with the need to combat the energy contribution to global climate change we propose the following approach:

- **a strategic aim:** a secure, competitive, socially equitable, and low carbon emissions supply of energy for Scotland.
- **four specific objectives**:

(1) To encourage energy efficiency to the benefit of economic development,

(2) To ensure that energy availability contributes to improvements in social benefits to Scotland’s people,

(3) To minimise adverse environmental effects, both locally and globally, and

(4) To capitalise on the natural energy resources of Scotland in an economically viable and environmentally sensitive way.

- **four components of action**:

(1) energy efficiency,
(2) cleaner energy sources,
(3) research, development and demonstration of renewable and low carbon technologies, and
(4) more effective instruments.

By ‘secure’ we mean having sufficiency of supply from a diversity of fuel types and geographical sources using a variety of technologies, encouraging new technological development to marketability and having the appropriate government framework and instruments. By ‘competitive’ we mean that the cost of energy will not result in Scotland being uncompetitive in world markets and also competitive in the use of technology and innovation. By ‘socially equitable’ we mean that all sectors of society should have access to energy at a price which they can afford, implying that some economically and socially poorer sections of society will be aided to rise out of fuel poverty. By ‘low carbon emission’ we mean that throughout their life cycle technologies should produce the lowest possible levels of greenhouse gas emissions, bearing in mind that there is none that has no emissions. Our strategic aim also implies a safety component that brings at best positive environmental benefits and at worst no significant environmental degradation, and provides assurances on human health.

Energy should be supplied from a diversity of sources and technologies using Scottish prowess and natural resources. Low greenhouse gas emission approaches should be favoured according to environmental benefit, economic viability and technical feasibility.

We propose the following action on **strategy and policy** by the UK Government and by the Scottish Executive.

> **Recommendation 1**: It is essential that decisions are taken by the UK Government by the middle of 2007 to provide a more stable and longer-term policy framework to give greater assurance to the consumer on continuity of energy supply and to give confidence to the providers of energy to make investment decisions.
>
> **Recommendation 2**: The UK Government should maintain the energy policy objectives set out in the 2003 White Paper: to ensure an adequate, safe and secure supply of energy, to reduce the emission of greenhouse gases with the setting of unambiguous long-term targets, to promote economic development, and to protect vulnerable sections of the population from the adverse effect of market forces.
>
> **Recommendation 3:** The UK Government should periodically review the instruments and targets used for implementing the policy framework to assess their effectiveness in achieving their intended objectives, and to ensure that unintended consequences have not arisen.

> **Recommendation 4**: We strongly recommend that the Scottish Executive develops a comprehensive energy strategy, within the boundaries of its powers and responsibilities and in consultation with the UK Government, by the end of 2007. This should embrace specific strategies on energy efficiency, transport, heating, electricity generation and the use of renewables. This should also include the strategic aim of **a secure, competitive, socially equitable, and low carbon emissions supply of energy for Scotland**, and the four supporting objectives we propose.

We propose the following changes in **the institutional structures for energy**.

> **Recommendation 5:** The Scottish Executive should seek Parliament's approval for the establishment of an Energy Agency for Scotland as a Non-Departmental Public Body. Its responsibilities should include the ability to advise the government and all other relevant interests on all aspects of energy, promotion of energy efficiency, disbursal of all grants and incentives related to energy, independent assessments of technology options and whole lifetime costs, and gathering and disseminating best practice on energy use.

If this is not established, then we make the following recommendation.

> **Recommendation 10:** The Scottish Executive should seek Parliament's approval for the establishment of an Energy Efficiency Agency for Scotland as a Non-Departmental Public Body. It should have both advisory and executive powers with authority to scrutinise and make recommendations on energy efficiency action in the public sector, disburse incentives for reducing energy use, increasing efficiency and supporting novel initiatives, and for disseminating best practice.

Energy efficiency

More efficient use of energy is needed with more effective instruments and an improved response from providers and consumers. We make the following recommendations.

> **Recommendation 7:** Industry should be persuaded, through economic instruments and approval mechanisms in the statutory planning system, to utilise waste energy, especially heat, for beneficial purposes. In particular, we recommend that all future small thermal generating plants, near to population centres, should have specific arrangements for the use of waste heat.

> **Recommendation 8:** Local Councils should stimulate more energy efficient housing designs through the Building Regulations system and should substantially improve the enforcement of Building Regulations in relation to energy efficiency.

> **Recommendation 9:** A more comprehensive and integrated package on energy efficiency should be developed at both UK and Scottish levels to reduce the current confusion and increase effectiveness. This should be linked

to strengthening the targets and ensuring their achievement under a revised Energy Efficiency Commitment.

Recommendation 11: The Scottish Executive should require Local Councils to achieve specific and measurable improvements in the efficient use of energy through the town and country planning system and building regulations.

Recommendation 12: As part of encouraging the change of behaviour needed on energy efficiency, a comprehensive set of measures including education, information and incentives should be developed by the proposed Energy Agency for Scotland (or failing that by the Scottish Executive).

Recommendation 13: The UK Government should consider measures, such as the use of lane preference and variable charging systems, to encourage higher occupancy in private vehicles.

Recommendation 14: Bus transport operators should be given greater incentive through the Scottish Executive's current service support mechanism to operate a wider range of vehicle types to cope with variable passenger loads.

Cleaner energy

In order to reduce emissions of greenhouse gases and to achieve security of energy supply a multi-pronged approach is proposed comprising emissions controls and substitution of fuels. We make specific proposals for the main energy using sectors: transport, heating and electricity.

(1) Emission control

Recommendation 15: Scottish Enterprise should engage with Scottish Coal, Scottish Power, Mitsui Babcock, the Scottish Universities and other stakeholders, to determine a significant clean coal research and development programme in Scotland.

(2) Fuel substitution

Recommendation 18: The Scottish Executive should ensure that the definition of forest waste used by SEPA enables state and private forest owners to utilise forestry thinning and other wood materials in energy production.

Recommendation 19: The Scottish Executive, as part of the development of its energy strategy, should develop fuel substitution targets for all of the main energy consumption sectors: transport, heating and electricity.

We consider that the current system for stimulating renewables – the Renewables Obligation Certificates – is ineffective. Our preference is for a system of incentives and disincentives which would stimulate low greenhouse gas emission technologies. This could take many forms.

Recommendation 20: We recommend that the UK Government, supported by the Scottish Executive, replace ROCs as soon as possible with a carbon emission reducing measure, such as a carbon levy applied at the point of carbon production. This should build on the existing EU Emissions Trading Scheme. Existing commitments should be honoured.

Fuel Substitution for Transport

Recommendation 21: The UK Government should review and improve the incentives to encourage fuel substitution in transport and the production of biofuels and associated infrastructure.

Recommendation 22: In the next Spending Review, the Scottish Executive should change the priorities in its transport budget to more adequately reflect its climate change priorities.

Recommendation 23: The Scottish Executive should develop an energy policy and targets for the railway system as part of the Scottish Railway Strategy.

Fuel Substitution for Heating

Recommendation 24: Local Councils should undertake the following to improve fuel substitution for heating:

(1) amend Structure Plans and Local Plans to stimulate the development of combined heat and power and district heating schemes in urban areas;
(2) do not approve Planning Permission and Building Warrant to developments on brownfieild and Greenfield sites without these facilities;
(3) work with the building construction industry to put into effect systems for the delivery of combined heat and power and district heating systems; and
(4) increase the targets for the reuse of municipal waste for energy production coupled with a reduction on material sent to landfill sites in Local Waste Plans.

Recommendation 25: The UK and Scottish Governments should introduce a tax disincentive on waste disposal, especially to landfill, and a greater tax incentive for the reuse of waste for space and water heating as part of District Heating and Combined Heat and Power Schemes. They should also introduce a tax credit system to stimulate the use of biomass and waste for the production of heat for all buildings; and should consider an energy efficient dependent stamp duty and Council Tax as incentives for improvements in building design and construction.

Fuel Substitution for Electricity

Without decisions in the next 12 to 15 months there are likely to be shortages of electricity in a decade. We identify the key dates in the Table.

Timescales for key energy decisions

Decision	**When**	**By whom**
UK Energy strategy	Mid 2007	UK Government
UK energy targets	Mid 2007	UK Government
Scottish Energy strategy	End 2007	Scottish Executive
Emissions targets for Scotland	End 2007	Scottish Executive
New electricity generating plant	Mid 2007	Scottish Executive/generators/National Grid Company
National Grid up grade in Scotland	Mid 2007	National Grid Company/Ofgem
National grid up grade Scotland/England	Mid 2007	National Grid Company/Ofgem

Recommendation 26: The UK and Scottish Governments should ensure that the framework for energy at both UK and Scottish levels encourages investors to produce electricity from a diversity of supply sources.

Recommendation 27: The Scottish Executive should redefine the 2020 target for the proportion of electricity generated from renewable resources in terms of reduction in greenhouse gases to meet the UK's 2050 target on emissions reductions, and set out a detailed and comprehensive strategy for meeting it.

Recommendation 28: A locational strategy and accompanying planning guidance for onshore wind development should be drawn up immediately by the Scottish Executive to guide Local Councils, investors and third parties, and speed up the process of decision making.

Recommendation 29: Subject to agreement on implementing a satisfactory solution to the very long term treatment of radioactive waste, we encourage both the UK Government and the Scottish Executive to keep open the nuclear electricity generating option in the interests of diversity and security of supply and suppression of greenhouse gas emissions.

Recommendation 30: Government, industry and political parties should retain options for new build electricity generation from a variety of technologies, specifically renewables, clean coal, gas and nuclear, subject to public engagement to decide whether any technologies should be excluded from consideration.

Recommendation 31: The Scottish Executive should discuss with the major generating companies and National Grid Company the decisions required by UK and Scottish Governments and also by generators for the replacement of large-scale electricity generating stations in Scotland. They should take into account the public engagement in Recommendation 30.

Recommendation 32: Government authorities with approval powers, and generating companies should favour the construction of new large-scale electricity generating plant adjacent to existing plant, with easy access to the grid.

> **Recommendation 33:** The Scottish Executive should carry out a review of the electricity infrastructure implications of its renewables policy, especially in light of the National Grid Company's grid connection charging policy.

Opportunities for Scotland

There are many opportunities for Scotland in the utilisation of its natural energy resources, its scientific and technical prowess, and its innovative local approaches.

(1) Distributed generation

> **Recommendation 34:** The various energy use advisory bodies should compile examples of distributed systems and ensure their wide dissemination.
>
> **Recommendation 35:** Joint initiatives by local enterprise companies, applied research and development groups, private enterprise, and especially local community groups, should exploit locally available energy resources for local use.

(2) Technology development

We are concerned about the lack of a rigorous approach in the assessment of energy technologies and consider its development to be an urgent priority.

> **Recommendation 6:** A common methodology could and should be developed by the proposed Energy Agency for Scotland to assess the relative merits of energy technologies, using the nine factors identified. It should include full lifetime costs and a carbon audit. Assessments using the methodology should be undertaken independently of specific interests and be open to public scrutiny.

Ongoing scrutiny of the opportunities from emerging technologies should be undertaken.

> **Recommendation 16:** An energy technology scrutiny and advisory service should be established by the Scottish Executive. Ideally this should be part of the functions of the proposed Energy Agency for Scotland with ITI Energy.

There are many opportunities for technology development. We specifically identify: 'clean coal' and carbon sequestration, the electricity distribution network, low carbon generation of hydrogen, and onshore wave and tidal energy.

> **Recommendation 17:** The research community, government, ITI Energy and the private sector should work together to provide the financial, intellectual, policy and enterprise stimulus for the development and use of appropriate renewable technologies in Scotland and the development of cleaner fossil fuel based technologies in Scotland. A Centre of Scientific Excellence in Energy could be an important means of exploiting Scotland's skills and opportunities. The Scottish Scientific Advisory Committee is encouraged to produce a strong proposal for it, which the Scottish Executive is encouraged to support.
>
> **Recommendation 36:** The Scottish Executive should carry out a detailed appraisal of the potential for hydrogen to contribute to Scotland's energy mix.

Public engagement

There are many views on energy issues in Scotland and these are frequently polarised. A process of public engagement and dialogue is a vital ingredient in seeking to achieve consensus on energy policy and on the key decisions in Scotland.

> **Recommendation 37:** The Scottish Executive should invite independent bodies, such as the Royal Society of Edinburgh, jointly to design and conduct a process of public dialogue and deliberation. Based on the outcomes of this process, they should make recommendations to the Scottish Executive about the range of technologies that should be acceptable as part of an energy mix in Scotland to ensure security of supply and economic competitiveness and to support the transition to a low-carbon economy. The process should be launched as soon as possible after publication of the UK Government energy review, and completed in the summer of 2007 at the latest.

1. INTRODUCTION

The Royal Society of Edinburgh established a Committee of Inquiry into energy issues for Scotland. This was launched in May 2005. This section provides the rationale for the Inquiry, states the formal terms of reference, and introduces the components of the report. Throughout the report we focus on the issues and the opportunities for Scotland within its wider UK and global contexts.

Rationale

Energy is an essential commodity for civil society. It is necessary for food production, for all forms of transport and communication, for commerce and industry, and it is an indispensable domestic consumable.

The provision of a safe, sustainable, reliable and affordable supply of energy should be of supreme importance to every nation. It is easy to lose sight of this priority following 50 years of abundant and relatively inexpensive energy. The global demand for energy quadrupled between 1950 and 2000 and is likely to more than double by 2050. Present energy sources will diminish and alternatives will need to be developed. There is increasing competition globally for energy, and very unequal access to affordable energy within civil society. Current energy generation and use are having damaging effects on the environment. The UK, along with more than a hundred other nations, has accepted the dangers of global climate change aggravated by carbon emissions from burning fossil fuels. These fuels currently yield 80% of global energy supplies, and the UK has pledged to cut carbon emissions by 60% by 2050. To meet this target will require a major restructuring of energy supply sources, delivery infrastructure and patterns of use.

Scotland has been an energy rich country for some decades with hydro, coal-fired, gas and nuclear electricity generating stations providing in excess of domestic needs, and with supplies of offshore oil and gas piped onshore.

This situation will not continue as fossil offshore reserves decline, onshore ones become less economic to exploit, and large plants fail stringent international environmental tests and require very substantial investment to continue operation. There will be greater dependence on imported electricity and other energy sources. Scotland has the potential, with its technological base and skills, to exploit its natural energy sources of wind, tides and waves. Exploiting these are not without potential social and environmental costs and there are many technical and policy constraints to be overcome. A significant amount of Scotland's electricity is generated by nuclear power, and despite the UK Prime Minister's recent announcements, current policy in Scotland would see this phased out within fifteen years. There is no public or political agreement in Scotland on possible replacement with newer nuclear technologies or other fuel alternatives. There is always the possibility of some radical new technology, such as hydrogen power and fuel cells, but prudence suggests that these should not be relied on until they are fully proven. It is always possible to save energy and use it more efficiently, but the most ambitious programmes in this direction still leave a shortfall in supply. Whatever scenario is adopted, the restructuring of our energy supplies will require massive capital investment with economic consequences, and it will be essential to ensure that the social and environmental effects are beneficial.

Time is of the essence. Present policies and plans will see a significant shortfall in Scottish energy supplies within ten to fifteen years unless major decisions are made within a very short time in Scotland and for the UK as a whole on electricity generation, transmission and distribution, on alternative more environmentally sensitive energy sources, and on persuading civil society to adjust its behaviour on energy use. In a democracy, such changes should involve extensive informed public debate and consultation followed by policy decisions, site identification, and careful planning procedures before construction and commissioning of new infrastructure can take place. Given the timescales for decisions and their implementation, it is essential to start the process now and this report is hopefully a contribution to the decision-making process.

For Scotland, there has never been a better time for radical forward thinking on energy supply and use, helping to position the nation to benefit socially, economically and environmentally from the opportunities. This has to be done in a UK context as most of the energy decisions are reserved matters for the UK Government. A successful energy policy and strategy to resolve these matters will only emerge if the two executive and legislative bodies work together to meet the UK's needs, while satisfying the legitimate needs and aspirations of the Scottish people.

Remit

The remit of the Inquiry was as follows:

To review the issues for Scotland's energy supply and demand between the present and the year 2050, in the context of the likely UK, European and global energy environment.

To review the options for providing for Scotland's energy supply and demand, considering feasibility, availability, reliability, sustainability, efficiency and capacity of sources and infrastructure for delivery, taking into account:

(i) *Economic issues of capital investment and distribution infrastructure, together with the impact of energy availability on commerce and industry.*

(ii) *Environmental concerns about global climate change and the impact on ecological and other natural resources, including waste management and landscape.*

(iii) *Social values and consequences of energy generation and distribution on employment opportunities, health, affordability and risk implications.*

To provide an evidential base for energy policy in Scotland within the framework of strategies for transport, industrial, commercial, public sector and domestic needs, providing timeframes for action at both the UK and Scottish level, and raising public awareness and informing debate.

No workable committee could contain all the expertise necessary to do justice to the full width of the Remit Thus from the beginning it was agreed that the Committee would consult widely, visit various part of Scotland and receive oral evidence. The public and all interested parties were invited to express their views either electronically, through a web site, in writing or at open meetings across the country. We acknowledge the substantial amount and quality of the evidence submitted to us.

Layout of report

The report is in four sections:

1. Set the energy supply and demand context for Scotland at global and UK levels, drawing lessons from comparable countries, assessing the supply and demand position in Scotland and setting out the challenges for Scotland.
2. Assess the current UK and Scottish energy powers and policies, and proposals for energy strategy and policy objectives for Scotland.
3. Consider options for the future through the development of technology, reducing demand through efficiency measures, bringing into use cleaner fuels for transport, heating and electricity, and identifying research, development and demonstration opportunities.
4. Make recommendations on the decisions needed for Scotland, including the public engagement process.

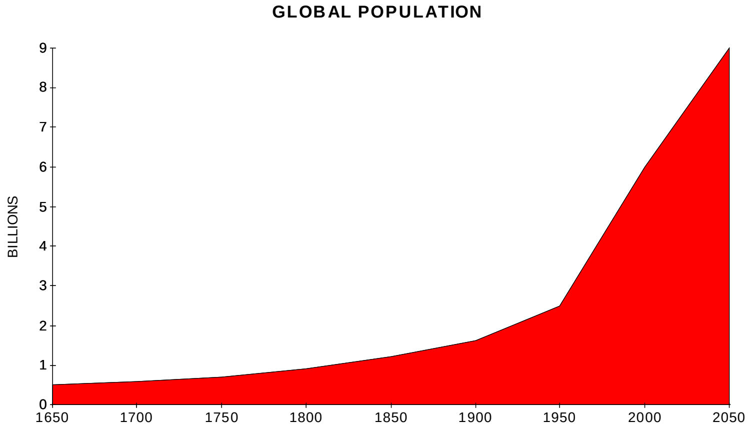
2. SETTING THE ENERGY CONTEXT FOR SCOTLAND

To set the scene on energy issues for Scotland, we consider global and UK energy supply and demand issues, and global energy contribution to climate change. We then consider briefly the position on energy in countries of comparable size and location and draw some lessons. And we set out the challenges for Scotland.

Global energy supply and demand

Energy demand has been growing over three centuries but between 1950 and 2000 it grew fourfold. The two principal drivers are population growth and economic activity: more people (56% increase) and higher levels of economic output (260% increase) both contribute to increased use of energy. On current trends (Figure 1), the world population is projected to increase by a further 50% in the first half of the 21st Century, reaching 9 billion by 2050 (UN Population Division 2001). . Global GNP is also expected to continue to grow, with a shift in manufacturing capacity from the industrialised nations to the developing world and with some countries enjoying high growth rates in recent years. If these are maintained, China looks set to replace the USA as the world's largest economy by 2050, and India to replace China as the most populous nation within the next 10 years. On conservative estimates, continued population growth and expansion of the world economy will lead to a further doubling of the world demand for energy between 2000 and 2050 (International Energy Agency (IEA); World Energy Outlook (WEO) 2004).

Figure 1: Global population growth 1650-2050. The projection from 2000 to 2050 is from the UN Statistics Service



According to the International Energy Agency (IEA) (Figure 2)[1], the world's final consumption of energy in 2002 was nearly 7100 million tonnes oil equivalent (Mtoe), divided between oil (43%), gas (16%), coal (7%), electricity (16%), combustible renewables and waste (14%) and other sources, including geothermal, solar, wind, and heat (3.5%). The main consumption sectors are industry (32%) and transport (26%).

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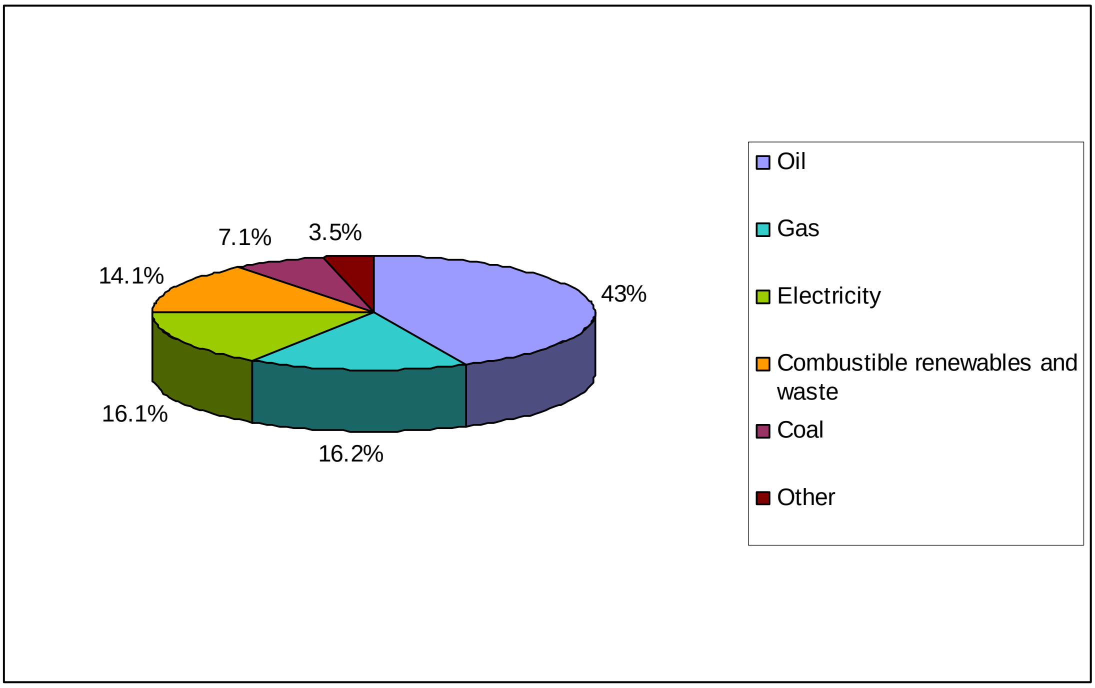
[1] Key World Energy Statistics 2004© OECD/IEA, 2004,[2002 Fuel Shares of Total Final Consumption p. 28]

Oil consumption comprises 27% of energy used by industry, 95% in the transport sector, and 18% in the remaining sectors.

Figure 2: Fuel Shares of Total Final Consumption



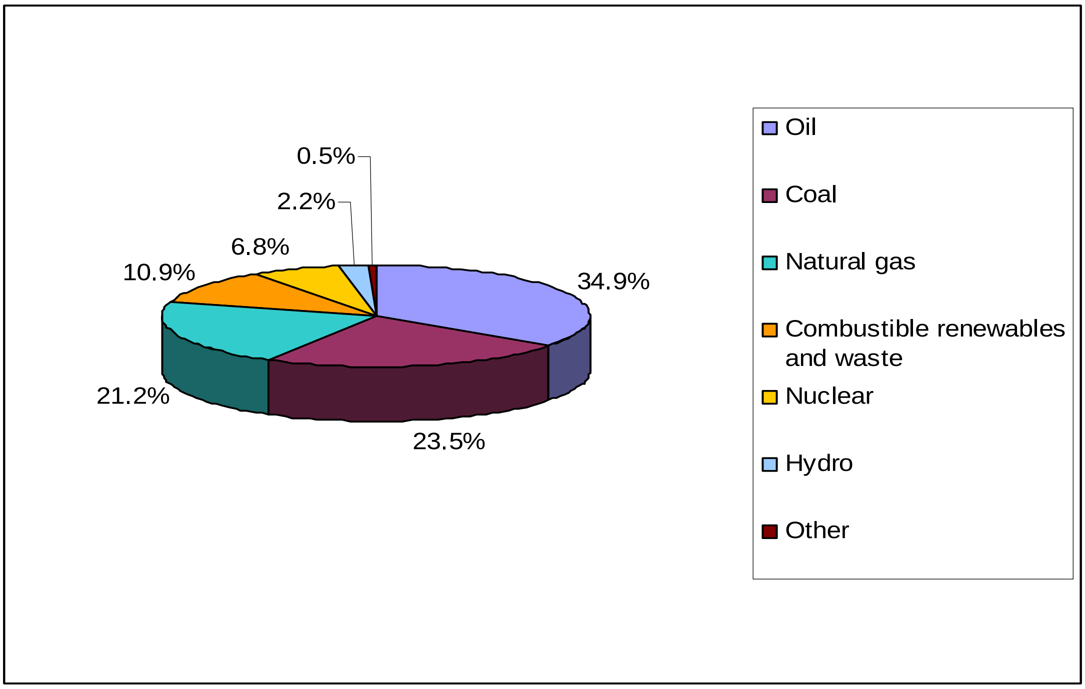
The pattern of demand varies according to a country's stage of development. In relatively advanced OECD countries, some 92% of final consumption is in the form of oil, gas, and electricity. There is relatively little demand for coal or combustible renewables; but these play a much more important part in developing countries. In 2002 North America accounted for 26% of total energy consumption, non-OECD Asia for 24% (of which China accounted for nearly half), Europe for 18%, the countries of the former Soviet Union and the OECD Pacific countries for about 8% each, with the balance divided between Africa, Latin America and the Middle East at around 5% each.

The current pattern of demand is influenced by existing technology and the relative prices of the alternative forms of energy. Transport relies on oil, heating largely on oil and gas, and power and light comes from electricity. In the absence of major technological changes, or of substantial changes in the relative prices of the different forms of energy, this broad pattern of demand can be expected to continue in the first half of the 21st century.

As energy has to be available to final consumers at the location and in the form in which they need it, energy consumption is only part of the picture of energy use. Transformation is a key factor. Electricity has to be generated from primary fuels, oil has to be refined, coal may be converted to coke, wood-chips have to be transformed into useable heat; and both primary fuels and end-products have to be transported from the point of production to the point of consumption. All this involves enormous inputs of energy, with the consequence that the total amount of energy used in 2002 (total primary energy supply) was 10400 Mtoe, nearly 50% more than total final consumption. Much of this difference is due to electricity production, which required some 3000 Mtoe of primary energy to produce only 1200 Mtoe of electricity. Around 5% was used by the electricity plants themselves, about 2% was lost in the course of transmission, and about 6% lost in the course of distribution to consumers. International marine bunkers, coal transformation, and own use by petroleum product and gas producers account for most of the remaining energy consumption.

According to the IEA, in 2002 (Figure 3)[2] the total world primary energy supply was 10230 Mtoe. Coal contributed 24% of the total primary energy supply, oil 35%, gas 21%, nuclear fuel 7%, hydro power 2%, combustible renewables and waste 11%, and other sources of energy (including geothermal, solar, wind power etc) less than 0.5%.

Figure 3: Fuel Shares of Total Primary Energy Supply



Fossil fuels – coal, oil and gas – contributed 80% of the world's primary energy supply. Nearly 60% of the coal, 20% of the gas, and 0.7% of the oil is used in electricity plants, with a further 7% of the coal and 12 % of the gas used in CHP plants (IEA; Key World Energy Statistics 2004).

The geographical distribution of the sources of fossil fuels, particularly oil and gas, differs markedly from the geographical distribution of consumption. Countries in the Middle East control some 60% of the proven oil and some 40% of the natural gas reserves. A further 30% of global natural gas reserves are in the former Soviet Union. A very high proportion of the production from these countries is exported, with many OECD countries wholly dependent on imports. Trade in coal is also significant, though the three largest producers, China, the USA and India, which together account for some two thirds of world production, consume most or all of their production domestically. However, other important producers, Australia, South Africa, Russia and Indonesia, account for some 20% of world production and are significant exporters (IEA; WEO 2004).

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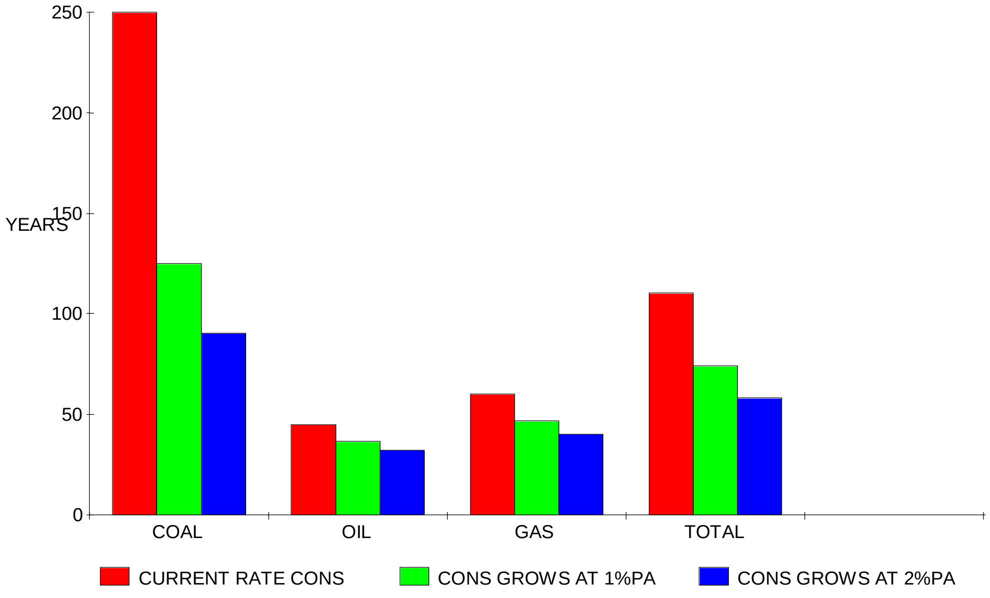
[2] Key World Energy Statistics 2004© OECD/IEA, 2004,[2002 Fuel Shares of Total Primary Energy Supply p. 6]

Global fossil fuel reserves

The dependence on fossil fuels as the world's principal source of energy has raised concerns about sustainability. Resources of fossil fuels are finite, and this places a theoretical upper limit on the world's cumulative consumption of them: if society in future wanted to consume fossil fuels at the current or increasing levels, in the end it would be unable to do so. In that sense, consumption of fossil fuels is unsustainable. The practical question, however, is whether there are sufficient resources of fossil fuels for society to be able to continue to use them for as long as it wants to do so. Figure 4 shows clearly that, while coal reserves on present assumptions about consumption and price will last well beyond the limits of our timescales, gas and oil will run out by the middle of the century.

Figure 4: Lifetimes of proven reserves of fossil fuel



According to the IEA (WEO 2004), the world's proven **coal** reserves are "enormous", over 200 years of consumption at current rates. Since countries which rely heavily on coal for domestic purposes or exports generally have large reserves, persistent shortages are unlikely to arise in the foreseeable future. In addition to the proven reserves, there are significant further resources of coal which might be mined if prices rose sufficiently. The UK, for example, has large reserves of coal, although many of these reserves were uneconomic to exploit in the past with the deep mining technology, the prices then available, and labour relations.

Natural gas resources "can easily meet the projected increase in global demand" over the next 25 years (IEA, WEO 2004). "Proven reserves have outpaced production by a wide margin since the 1970s and are now equal to about 66 years production at current rates." Moreover, potential gas resources are much greater. According to the US Geological Survey (USGS, 2000), only slightly over 10% of the world's ultimately recoverable gas resources had been exploited by 2000; reserves at that time amounted to 166 years-worth of consumption at 2002 rates.

There is no single authoritative estimate of the world's proven **oil** reserves. The estimates quoted by the IEA (WEO 2004) range from 36 to 44 years at current rates of production. Ultimately recoverable resources are considerably greater, with the most recent USGS survey putting the total of oil and natural gas liquids reserves at 3.35 trillion barrels, of which some 21% has already been extracted. The remaining 2.63 trillion barrels covered the IEA's projected average annual global production estimates up to 2030 some 70 times over. In addition, "non-conventional" oil resources (oil shale, extra heavy oil, tar sands and bitumen) could amount to some 7 trillion barrels. It is uncertain what proportion of this will ultimately be recoverable, but with existing technology and at current oil prices, some of this non-conventional oil is being exploited.

We are aware of other views on global fossil fuel reserves (Economist 2006). These predict more pessimistic reserve scenarios than the ones we have used above and consider that the peak of oil and gas production has already passed. There are a number of factors which persuade us to support the UN, IEA and other sources on fossil fuel reserves. The predicted real terms increases in fossil fuel prices (see next section) will encourage the extraction of fossil fuels from more difficult oil and gas reservoirs and coal seams. In turn, this will stimulate the development of new technologies capable of recovering proportionately more of the reserves. Already, we have seen, for example, in the North Sea oil and gas province increases in the reservoir extraction rates due to a combination of price increases and technological advancement.

Our conclusion is that the levels of currently proven oil and gas reserves could act as constraints on supplies of fossil fuels within the next 50 years, without future discoveries of new reserves. We also note that maintaining global supplies (and the future level of proven reserves) will involve a very considerable commitment of capital investment. For the period up to 2030, the IEA have estimated the cost of investment in natural gas (including gas transportation) as US$2.7 trillion (2000 prices), and the UK Offshore Operators Association (UKOOA) estimated the costs of oil and gas investment together as US$16 trillion. World GDP is estimated by the International Monetary Fund (IMF 2002) to have amounted to some US$31 trillion in 2000, so the UKOOA figure is equivalent to some 50% of one year's GDP. With world GDP expected to increase substantially between now and 2030, this is an average annual commitment of less than 2% of world GDP, a substantial amount but not one that is likely to pose any major financing problem.

Nuclear Fuel Reserves

Like fossil fuels, the planet contains finite reserves of nuclear fuel. There are only two elements in Nature that have the potential to be the bases of primary supplies of nuclear fuel: thorium and uranium. Uranium is a much more efficient fuel and is the current basis of all reactor fuels. There are larger resources of thorium and India, which has particularly large reserves, is experimenting with the development of thorium powered nuclear stations. It is, however, unlikely that thorium will replace uranium as the fuel of choice during the timespan of this report.

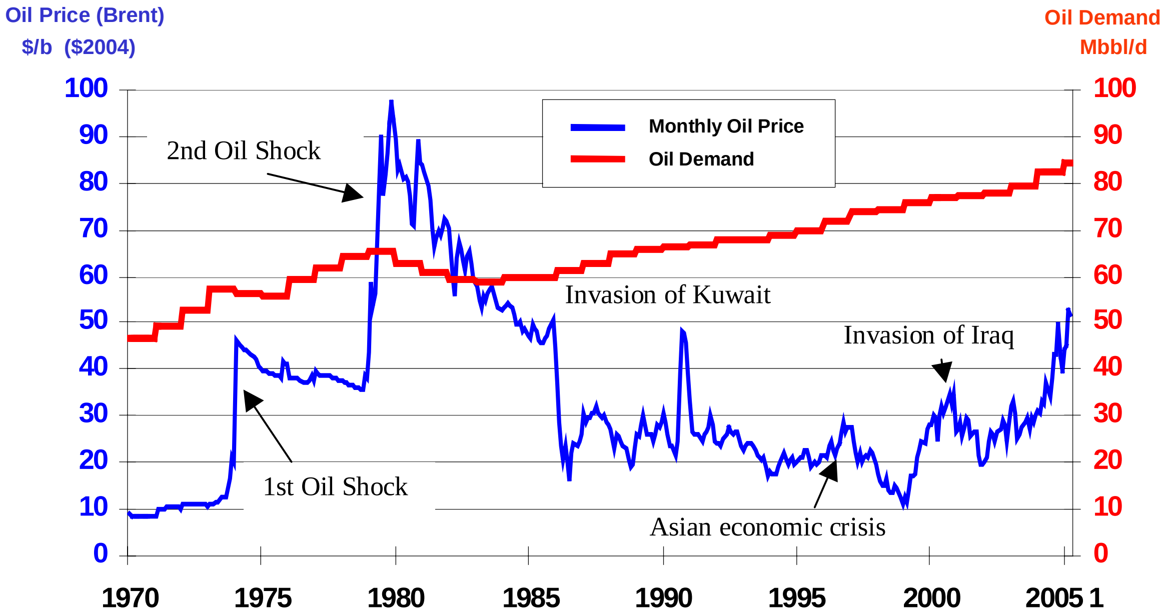
Naturally occurring uranium is unsuitable as a fuel due to the relatively low abundance (0.7%) of the fissile isotope ^{235}U. The uranium refining process involves enriching the ^{235}U abundance to around 3%. Unlike the fossil fuels, there are secondary supplies of potential fuel arising from the reprocessing of the tailings from the enrichment process and the waste of spent fuel. During the operation of a nuclear reactor a third element is created, plutonium, which is even more efficient than uranium. Stock piles of plutonium accumulated for weapon use during the cold war are now available as fuel for power reactors. In considering the reserves of nuclear fuel, it is necessary to take into account these secondary sources. Currently, secondary sources supply about 40% of nuclear fuel. This resource could increase considerably with the successful operation of fast breeder reactors. Thus the contribution of secondary sources of nuclear fuel depend on waste management programmes and the mix of reactor types. The availability of fuel depends, not only on the primary supply of uranium, but also on the reprocessing capacity.

The world's measured low cost, primary reserves of uranium are sufficient for 50 years at the current consumption rate They have increased by 70% in the past ten years despite low prices and steady consumption (British Energy). The World Nuclear Association estimates that a doubling of nuclear fuel price could result in a 10- fold increase in reserves. The IAEA-NEA estimates that all conventional resources would last approximately 200 years at current consumption rates.

Energy prices

With the demand for fossil fuels in OECD countries expected to increase, and with domestic supplies likely to fall as resources are depleted, the dependence of OECD countries on the Middle East, other OPEC countries, and the former Soviet Union for supplies of oil and gas seems set to rise. Surprisingly, long-term growth in demand for energy has not, in itself, led to persistently increasing prices. In fact, in the latter part of the 20th Century the prices in real terms (i.e. relative to other goods and services) of fossil fuels tended to fall. Oil prices increased dramatically as a result of the politically-induced oil shocks in the mid-1970s and early 1980s, but by the second half of the 1980s oil prices had fallen to around $20 per barrel (in year 2000 prices). From then until the end of the 20th Century prices followed a downward trend, interrupted only by significant increases when Kuwait was invaded and at the time of the Asian economic crisis (Figure 5).

Figure 5: Brent Crude Oil Price[3]



Gas prices in the past have varied significantly between regions (because of high transport costs). Between 1980 and 2000 real natural gas prices in the Pacific and in Europe fell by more than 50%, but have now started to rise (Figure 6).

Figure 6: Historical gas and electricity prices in the UK (Index of real prices, 100=1985, 2005 is an estimate)[*]

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[3] From TOTAL E&P UK Presentation to RSE Energy Inquiry July 2005

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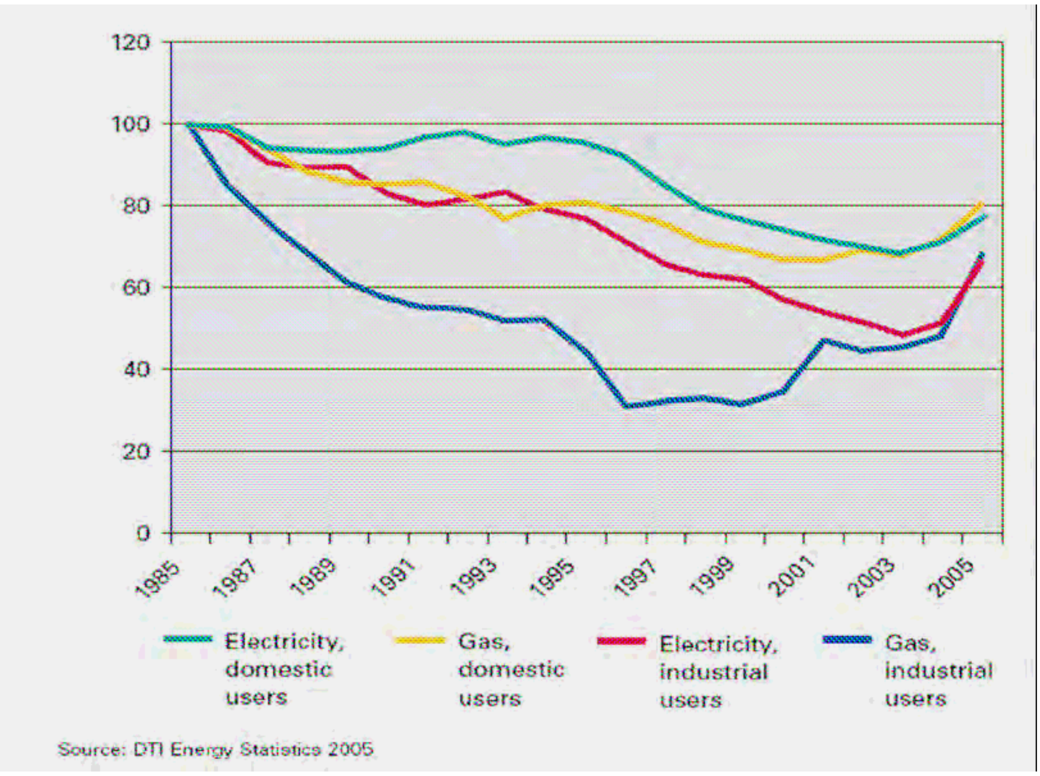
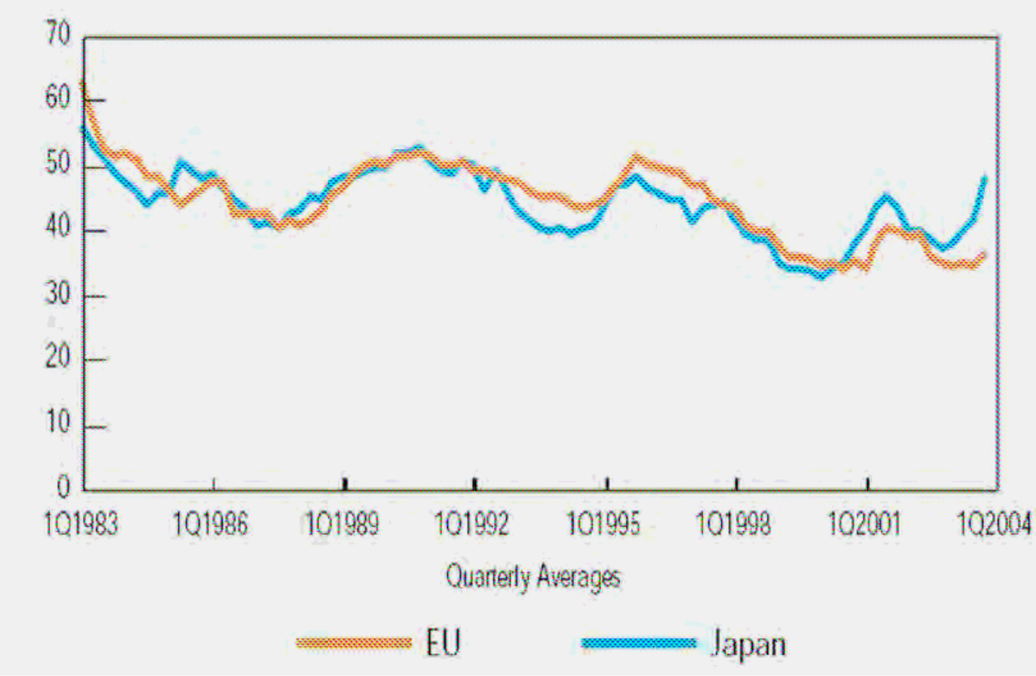


Source: DTI Energy Statistics 2005

During the 1990s steam coal prices also fell in real terms. Since 2001 (Figure 7), however, prices have risen sharply, reflecting continued increases in demand, short-term capacity constraints, the war in Iraq and supply disruptions.

Figure 7: Steam Coal Import Costs in US Dollars/tonne[4]



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[4] Key World Energy Statistics 2004© OECD/IEA, 2004,[Coal: Steam Coal Import Costs in US Dollars/tonne p. 41]

In practice, fossil fuels are traded in global markets, and conditions in these markets determine the prices that exporters can achieve and that importers have to pay. The use of Liquified Natural Gas as a means of transporting gas from areas remote to the principal markets in Europe and North America has accelerated this trend.

Our conclusion is that, while in the short-term prices may be determined by demand, in the long-run they are likely to be determined by costs of production and transport to market. While short-term volatility of prices can be expected, it is the costs of production that are likely to determine the long-run trends. For their reference scenario, the IEA have projected that fossil fuel prices (in real terms) will fall back to trend levels by 2010 and that between then and 2030 oil prices will rise by about a third, gas prices by about a quarter and coal prices by about 10%.

If prices do rise, we expect this to lead to economies in the consumption of energy, to substitution of fossil fuels by energy from other sources (e.g. nuclear, renewables), and, above all, to advances in alternative energy technologies.

We draw the following conclusions from our analysis of supply and demand and prices:

- First, as a best estimate, we cannot do better than adopt the IEA's reference scenario of gradually rising (real) prices, with the oil price rising by more than gas, and both rising by more than coal.
- Secondly, experience tells us that similar projections of rising commodity prices have proved ill-founded in the past - there is great uncertainty about the future trend of prices. The consequence is that the UK energy strategy needs to recognise that energy price trends cannot be confidently predicted over extended periods, and that our best estimate is nothing more than that – an informed guess.
- Thirdly, in view of the geographical concentration of supply, there are geopolitical and other risks associated with import-dependence. Supplies could be disrupted for short or longer periods for political or for technical reasons. The history of the oil market shows that, even if supplies continue to be available, there can be very severe price shocks lasting for several years.
- Fourthly, in view of the dominance of oil in energy supply and demand, its availability and price will be critical global factors in future energy policy.

Global environmental issues and energy

Global energy and the environment are inextricably linked. Increasing population levels, increasing consumption levels, and consequential industrialisation, increased personal mobility and greater long-distance transportation are likely to be the key drivers.

The *rising demand for energy* could stimulate the drive for energy efficiency and for new environmentally clean technology. This could be offset by the relative ease of access to fossil fuels which will remain in an abundant supply for at least the next half century according to IEA estimates. Rising population levels and associated increases in consumption, the continuing use of fossil fuels for bulk energy supply and the continuing use of wood for fuel and for cooking in many countries are factors. Traditional knowledge and traditional approaches to food production have now been overtaken by energy intensive mechanisms. Progressive industrialisation of developing countries and raising of living standards will increase the need for energy, particularly in India and China because of their population size, with global effects on atmospheric emissions. Development of large-scale, hydroelectricity schemes and the ability to increase the speed and scale of civil nuclear power programmes should reduce the level of increase of emissions to the atmosphere compared with most other technologies, but both have accompanying risks. Hydroelectricity systems with large dams could at least have a regional effect on the climatic regime and will have an effect on hydrology of the river catchments both upstream and downstream; this is likely to be the case with the Three Dams Project in China. Nuclear power poses the risk of the proliferation of radioactive material able to be used for weapons, as well as increasing the amount of long-term, highly radio-active waste for safe disposal.

The global agenda on *poverty alleviation*, agreed at the World Summit on Sustainable Development in Johannesburg in 2002 and encapsulated in the Millennium Development Goals, provides a new approach. It brings with it recognition that the sustainable use of natural resources, including energy, alongside the use of traditional knowledge in the use of natural resources, can improve livelihoods.

Another potentially damaging environmental trend is *food production for industrialised countries* from the developing countries. On the positive side, previously unproductive soil is being brought into use. This is counterbalanced by a number of factors. There is the potential release of carbon previously stored in the soil through cultivation and forest exploitation; the market-driven approach is likely to place low value on environmental sustainability; and food is transported from production source to market over much greater distances, especially by air, giving rise to greater greenhouse gas emissions into the atmosphere. The market strength of the multi-national food purchasers and competition in the market place has so far ignored the effects of environmental degradation and restoration.

The overriding environmental issue is about the impacts of *burning fossil fuel on the global climate*, and the consequent potential for rapid and extreme climate change to wreak damage not only to the economies of many countries but also to the ability of some countries to sustain their population. As a result of the above trends, it is likely that *fossil fuel emissions into the atmosphere* from electricity generation, heating and cooling, cooking, and transport will increase globally in the foreseeable future. Ever since the Industrial Revolution there have been concerns about carbon particulate (smoke) emissions from burning coal. In the 1960s, many countries brought in smoke control legislation. Then in the 1980s, concerns grew over the emission of sulphur containing molecules that led to acid rain; again emission standards were raised. The installation of flue-gas desulphurisation equipment, as an alternative to closure, is a continuing issue for coal-fired power stations in the light of current and likely future emission standards. Similarly, pollution from motor vehicles is mitigated by the use of catalytic converters, but concern is also growing over nanometre-scale, carcinogenic particulate emissions from burning oil.

The gas composition of the atmosphere is an important part of the Earth's thermostat and those of other planets in the solar system, as a consequence of a so-called and well-established "greenhouse effect" in which atmospheric gases trap solar radiation in a way that warms the atmosphere. Calculations of planetary surface temperatures, based on the intensity of solar radiation, give the wrong answer unless the greenhouse effect of planetary atmospheric gases is taken into account. This obviously also applies to the Earth. Over the last half million years at least, changes in the Earth's surface temperature have gone hand in hand with changes in the concentration of greenhouse gases like methane and carbon dioxide. There has been no significant variation in temperature that has not been accompanied by variation in carbon dioxide concentration. In the major cold-warm cycles that have characterised the most recent period of geological time, cold, glacial periods have been accompanied by atmospheric carbon dioxide concentrations of about 170 parts per million (ppm) and warm periods of about 280 ppm. In the present warm period, which began about 10,000 years ago, concentrations have been steady at the latter value. Since major industrialisation began around 150 years ago, burning carbon rich fossil fuels has progressively increased concentrations to 390 ppm, higher than at any time in the last million years, and probably the last 30 million years. It has been associated with an increase in northern hemisphere mean temperatures of 0.6^{o}C, a faster rate of climate change than any during the last 10,000 years. This may seem a small change, but the change in mean temperature from the coldest part of the last glacial period to the warm present is 5.0^{o}C. A major problem lies in the long residence time of carbon dioxide in the atmosphere of over 100 years, such that immediate cessation of fossil fuel burning would have limited immediate impact. As a consequence, delaying reduction in emissions by 20 years, for example, would require a rate of emission reduction 3 to 7 times greater than if started now.

Continuing to increase emissions beyond the next 20 years will create an atmospheric composition not experienced since the age of the dinosaurs, with increasing potential for severe and unpredictable climatic and environmental change. All computational models of future climate (Intergovernmental Panel on Climate Change (IPCC) 2001) agree that there is now a built-in trajectory of climate change with a global temperature increase of $1\text{-}1.5^{o}$C over the next 50 years. Such small changes in average temperature will have profound effects on atmosphere/ocean circulation with repercussions for global climates, which in turn will result in major social and economic costs, and dislocation of habitats and species. Beyond that, there is greater uncertainty about the future, but great concern about the potential for catastrophic change.

There is a lot of evidence that the concentration of carbon dioxide in the Earth's atmosphere has increased by about 30% over the last century. Carbon dioxide is well known to act as a greenhouse gas, retaining heat energy in the atmosphere and causing the temperature of the earth's surface to rise (by some 0.6 degrees Celsius over the last century). The current scientific view is that it is a virtual certainty that global warming is taking place. In addition, the scientific model used to calculate global temperatures between 1860 and 2000 can only fit the observed rise in global temperatures if both natural (variation in solar radiation output and emissions from volcanic activities) and human activities (enhanced greenhouse gas effect and deforestation) are included in the model calculations (IPCC 2001, Houghton, J. 2004, Maslin, M. 2004).

More than a hundred nations have now signed the Kyoto protocols, pledging staged reductions in emissions, based on a shift away from burning fossil fuels, between now and 2050, with the main burden of reduction falling on the most developed countries. The UK is on track to meet its Kyoto target of a 12.5% reduction in greenhouse gas emissions on 1990 levels by 2012. However, even if the Kyoto targets were achieved, they would now have a miniscule impact on climate change. The Royal Commission on Environmental Pollution (2000) suggested that countries such as the UK will need to reduce emissions by 60% by 2050 compared with the year 2000 if dangerous levels of atmospheric carbon dioxide are to be avoided. This has been accepted by the UK Government, but as yet, little progress has been made towards this objective, and the UK Government has now accepted (March 2006) that the interim targets for 2010 will not be met. Other major emitters of carbon dioxide, particularly the USA, which is responsible for about 25% of global emissions, have declined to accept the limited Kyoto targets, and are adopting a different policy of promoting the development of new technology to tackle the problem.

There remain a number of risks and uncertainties on greenhouse gas emissions: the speed and scale of industrialisation in developing countries, the rate of adoption of clean energy technologies, the progress on meeting the Kyoto targets and progress on new low-carbon technologies. Most significant of all, and partly related to the alternative approach, is the uncertainty about the levels of demand in the USA as the world's largest consumer of energy both in total and on a per capita basis. Both of these approaches are necessary to address this critical global issue, rather than selecting one only.

Lessons from other Countries

We review the energy position of other countries, as this may shed light on our assessment of the Scottish situation. There are no exact parallels to Scotland in terms of institutional structure and geography, so we have chosen four of the nearest equivalents: Denmark, Finland, Norway and Sweden. More detailed tables of the supply and consumption of energy and sources of electricity production are given in Appendix D. Figures for the Nordic countries are from the International Energy Agency for the year 2003. Figures for Scotland are from the Scottish Energy Study for the year 2002.

On energy supply, there are marked distinctions between the Nordic countries related to the availability of natural resources and the response of governments to the need for security of supply and the use of renewables. However, all have a relatively high levels of supply from renewables resources, including combustibles and waste, compared with global and European averages: Norway 45% (predominantly hydro), Sweden 25%, Finland 22%, and Denmark 13%. Fossil fuel supplies vary from Denmark (84%), Finland (61%), Norway (51%) and Sweden (37%). Sweden (34%) and Finland (16%) each have a significant proportion of energy supply from nuclear. By comparison, Scotland has 81% supplied from fossil fuels and only just over 2% from renewables sources.

The energy consumption for each country shows marked variations. Denmark has only 19% consumed by industry, compared with between 38% and 45% in the other three countries. Consumption in the transport sector is higher in Denmark (33%), compared with the other countries: Norway (23%), Sweden (23%) and Finland (18%). And, in all four countries the domestic sector consumes between 18% and 28%. The pattern of consumption in Scotland is similar with domestic 34%, transport 29% and industry 21%.

The greatest variation between the four countries is in electricity production. This is largely due to the supply of indigenous resources coupled with policy decisions on how to provide the balance. Two countries, Sweden (50%) and Finland (27%), have a large nuclear component reflecting scarcity of other resources and a desire to avoid over reliance on imports of fuels. Norway is almost entirely dependent on hydro (99%), Denmark on fossil fuels (81%) compared with Finland, the next highest fossil fuel dependency, with 50%. The percentage of Danish electricity generated from wind turbines (12%) is one of the highest anywhere. For Scotland, the pattern is most similar to Finland with 52% from fossil fuels, 37% from nuclear, 11% from renewables and 2% from other sources. The Nordic countries are members of the Nordic Power Market for Electricity, not dissimilar to the British Electricity Trading and Transmission Arrangements (BETTA) in the UK.

All four countries have policies to encourage energy, including electricity, from renewable resources; the resource depending on availability, for example Norway hydro, Denmark wind and Finland forest biomass. Sweden has generally high taxation on energy, a carbon tax on fuel requires electricity suppliers to acquire electricity certificates from renewable plants equal to a certain percentage of the electricity they supply with a target to double this by 2010, and has one of the highest levels of government support for energy research and development. Norway has been a pioneer in introducing a CO_2 tax system and introduced a quota-based emissions trading system which it is aiming to link to the European Union’s Emissions Trading Scheme. Denmark has decided not to build more wind turbines.

District heating and combined heat and power schemes have been extensively developed in Denmark, Finland and Sweden assisted by government policy nationally and locally. Denmark has a national heat plan which gives the national and local governments the power to prescribe for certain parts of the country the form of heating that citizens should use. Denmark has the highest share in the world of electricity generated in CHP plants and one of the largest existing district-heating systems.

Energy efficiency is an important element of energy action in all four countries. Norway has set up Enova SF as a state-owned company tasked with achieving energy saving.

Norway’s energy research and development is also closely aligned with its energy policy and presents good examples in terms of strong private-public co-operation, its monitoring and assessment efforts and collaboration among relevant institutions.

Norway has large offshore oil and gas deposits, but because of sea-bed topography the majority of these are landed by pipelines in other countries, including Scotland. It has had a long term policy of slow depletion of these resources because of its relatively low demand and the availability of hydro power for electricity for many decades. It has developed carbon capture and storage in the Sleipner offshore field.

The position on nuclear is varied. Finland has decided to develop more plants and agreed on a deep repository for radio-active waste rather than rely on imports of natural gas from Russia. Whereas Sweden had decided to phase out nuclear, it is beginning to have second thoughts as a result of the escalation in fossil fuel energy prices and the low carbon emissions from this source. Neither Denmark nor Norway has any nuclear capacity.

There are clearly common approaches and similarities between the four Nordic countries. The differences relate to the availability of natural resources for energy, and specifically for electricity production, to the economic basis for commerce and industry, and to the view taken on the geopolitics of energy.

The clear lesson is that no nation can divorce itself from the global energy scene but should take into account its own energy resources and geopolitical factors in determining the sources and fuel mix. As the demand for energy increases, it is essential that each nation develops policies that meet its own national needs while remaining responsible members of the World community. Each must exploit its own resources in an environmentally and socially sustainable manner, while ensuring that its energy costs allow it to remain competitive in the market places of the World.

UK energy supply and demand

Among Western OECD nations the UK is a relatively frugal user of energy (see Table 1 below). On average, the World's population consumes 1.65toe[5] per capita. The OECD figure is nearly three times this at 4.67toe, inflated by the USA figure of 7.97toe. In Europe, the UK figure of 3.83toe compares with France at 4.34toe and Germany at 4.2toe. For electricity consumption, the discrepancy between the global figure of 2.3MWh and the OECD figure of 8.0MWh is even more marked. The USA dominates the figures with 13.2MWh per capita compared with the UK's 6.2MWh, Germany's 6.8MWh and France's 7.4MWh per head (IEA; *Key World Energy Statistics* 2004).

Table 1: Global energy and electricity consumption

World/Region/Nation	Energy consumption toe/capita	Electricity consumption MWh/capita
World	1.65	2.3
OECD	4.67	8.0
USA	7.97	13.2
UK	3.83	6.2
France	4.34	7.4
Germany	4.2	6.8

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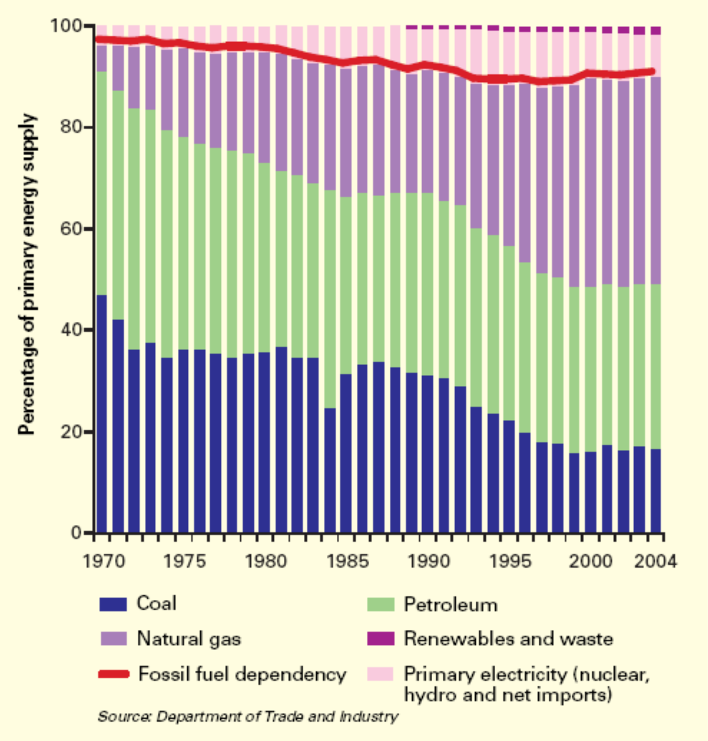
[5] Oil is traditionally measured in barrels, coal in metric tonnes, gas in cubic metres and electricity in Megawatt-hours (MWh). 'toe' tonnes of oil equivalent. The conversion factors are given in Appendix C.

Current UK energy supply (see Figure 8) is dominated by gas and oil (40% and 33% respectively) with coal providing 17%, nuclear 8% and renewables 2%. Electricity plays a key role in this system, not as a fuel but as a conduit of energy, generated from a mixture of coal 33%, gas 40%, nuclear 19% and renewables 4%. In the UK 16.8% of its energy is consumed as electricity, compared with the global average of 16% and the OECD average of 20%.

Figure 8: Shares of fuels contributing to UK primary energy supply; fossil fuel dependency[*]



Source: Department of Trade and Industry

The UK has experienced significant changes in consumption of energy in the last three decades (Figure 9). Total industrial energy consumption has fallen by 45% since 1970, largely as a result of the decline and closure of major energy using industries, especially the iron and steel industries. Consumption by transport has continued to rise as a result of increasing numbers of vehicles (and despite more fuel efficient

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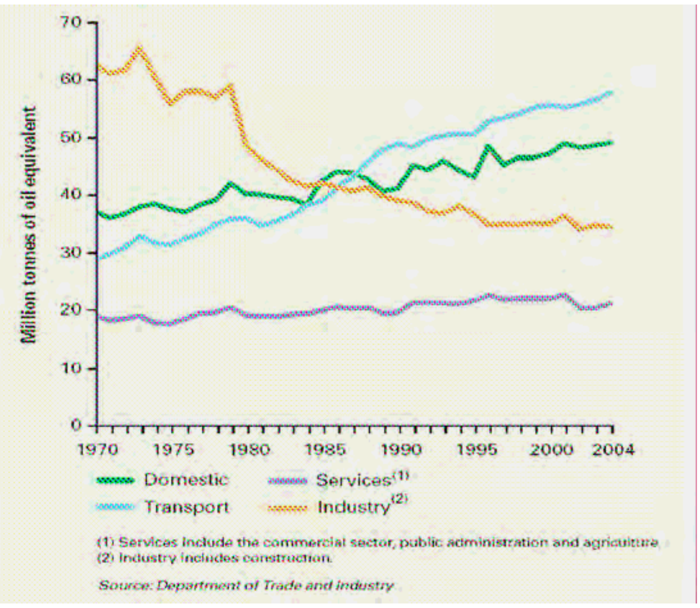
[*] UK Energy Sector Indicators 2005 Reproduced under the terms of the Click-Use Licence.

engines in recent years). Consumption in the domestic sector has risen due to the greater use of space heating and of white consumer goods.

Figure 9: UK Final Energy Consumption by Sector*



(1) Services include the commercial sector, public administration and agriculture
(2) Industry includes construction.

Source: Department of Trade and Industry

Putting energy supply and energy use together provides an intriguing picture (Figure 10). Within the complexity, a number of patterns emerge: the considerable proportion of petroleum exported and most of the remainder used as a transport fuel; the almost equal split in the use of coal between use in power stations for electricity generation and into other uses; and the preponderance of natural gas used by the domestic sector. It also worth noting the high levels of energy used to produce energy in other forms, especially the use of coal and other forms of energy for electricity generation, result in the conversion losses of more than half of the output of the power stations.

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[*] UK Energy Sector Indicators 2005 Reproduced under the terms of the Click-Use Licence.

Figure 10: UK Energy Flows 2004[*]

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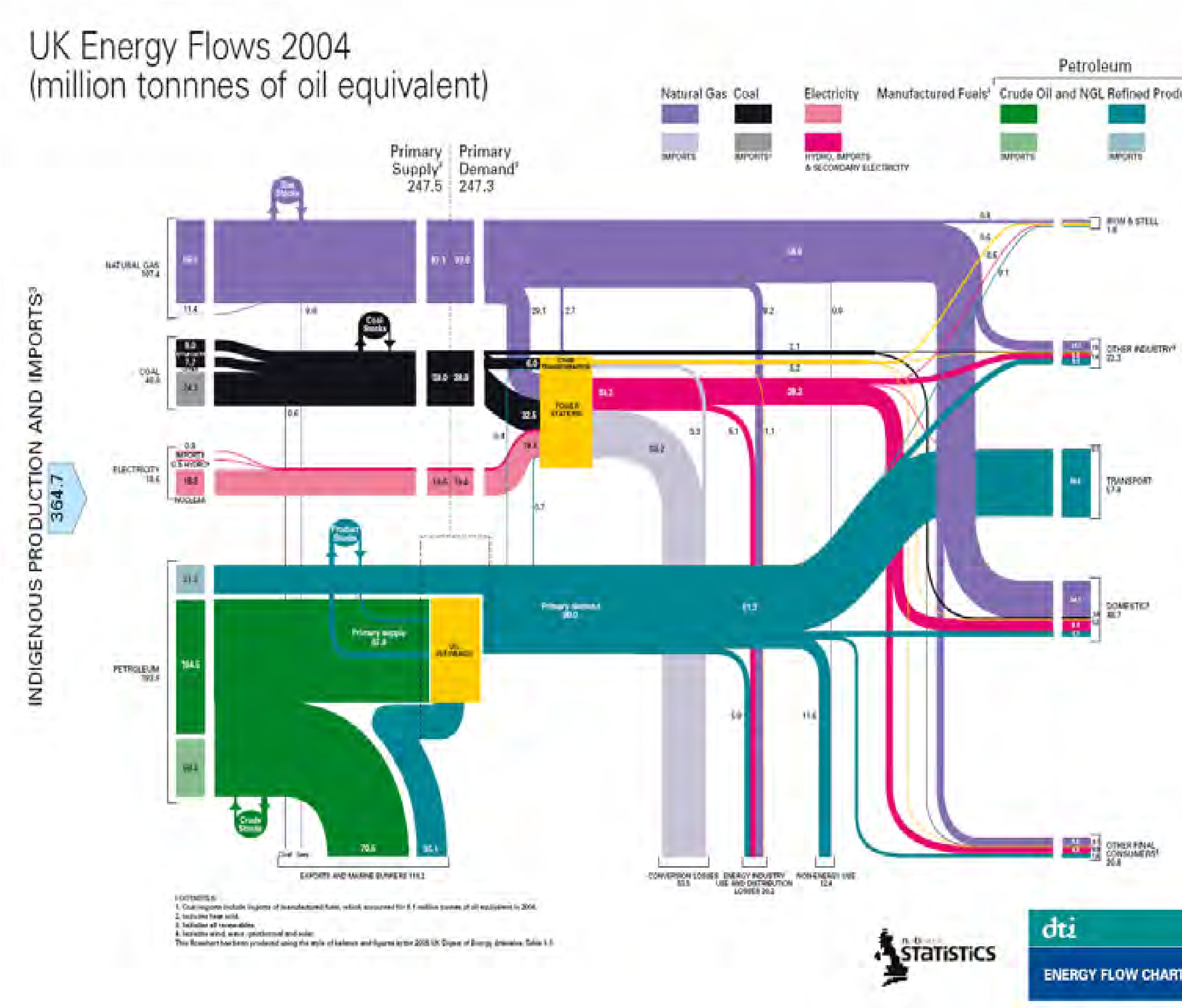
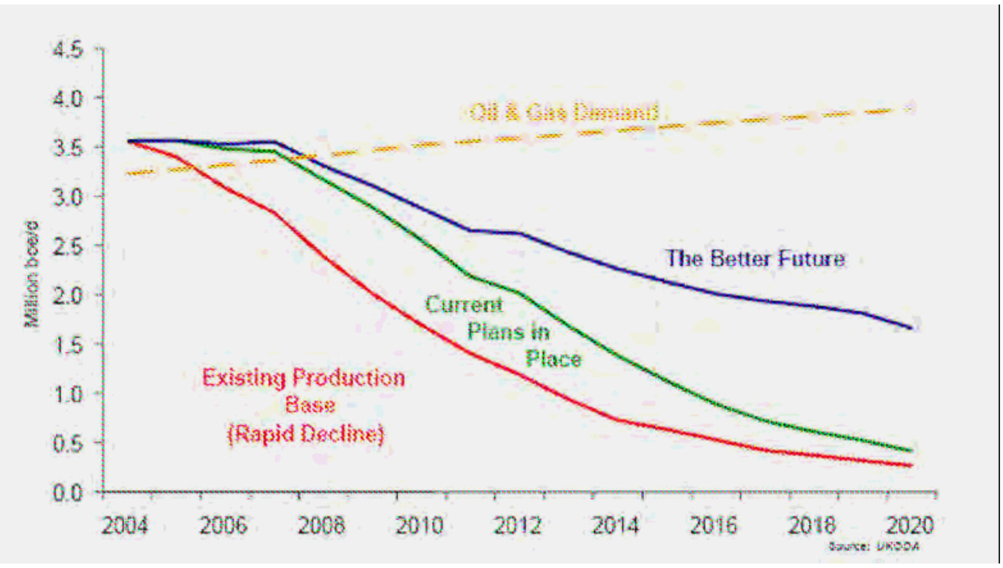
[*] DTI Energy Flow Chart 2004 Reproduced under the terms of the Click-Use Licence.



The UK is at a turning point in its energy trade balance. In recent years, it has been a net exporter of oil, self sufficient in gas, imported only 3.5% of its electricity. Although, in 2004, the UK imported 59% of its coal. Assuming that the UK North Sea follows the pattern of the USA Gulf of Mexico, technical advances and innovation to improve the efficiency of extraction from existing fields and to allow economic development of smaller accumulations will extend overall North Sea production, but will not arrest an inevitable decline. As North Sea oil and gas supplies decline, it will become much more dependent on imported oil, gas and coal (Figure 11).

Figure 11: Projected oil and gas demand and UK production



The UK became a net importer of gas in 2005, and is expected to become a net importer of oil by around 2010. The decline is predicted to continue in the longer term irrespective of success in the search for new finds and increases in the level of extraction from reservoirs. As much of the Norwegian North Sea oil and gas comes ashore in the UK, there is a need for continuing cooperation between Norway and the UK. Joint UK and Norwegian Governments approval has recently been given for a new 25-year contract for the supply of Norwegian gas.

The UK has significant reserves of coal. Most deep mines have closed. They may become more economic as the price of oil and gas continues to rise. It is more likely that only open cast mining will remain competitive with imported coal within the next 10 to 15 years.

There are a number of issues that affect electricity supply in the UK, especially the scale and timing of investment. Fossil fuel stations will need to be replaced or expensively restructured to meet new European emission standards. The nuclear generating capacity, which is due to be decommissioned in the near future, will have to be replaced by new plant of whatever fuel. If the current wind turbine generation programme is pursued as aggressively as the 2003 UK Government Energy White Paper suggests, the National Grid will require massive investment so that it can handle the installed generating capacity and deal with intermittent and remote generation. The National Grid Company have estimated a cost of £1.5B if all of the proposed wind generation capacity in Scotland is to be enabled. A major first stage in the grid development would be the upgrade of the Beauly to Denny transmission line, but we note that it is proving very contentious and no decisions will be taken until after a public inquiry scheduled to begin later in 2006 has reported. Similar issues will be raised if significant wave power generation comes on line. The only significant hydroelectricity plant project is the recently agreed Glendoe 100MW plant near to Fort Augustus, the first for several decades. It will be equivalent to about 1% of Scotland's current generating capacity. While solar power will continue to have important niche contributions, especially at smaller scales, it is unlikely to make a significant contribution to the nation's overall energy requirements in the foreseeable future.

The oil price increases resulting from the politically-induced oil shocks in the mid-1970s and early 1980s were sufficient to reduce UK energy use in that period. But by the second half of the 1980s, energy saving lost much of its urgency because oil prices had fallen back. After a period when demand fell, it began to rise again.

The recent 2005 and 2006 oil and gas price increases have not yet been in place for long enough to cause an increase in energy efficiency or a lowering of demand. There are three reasons for wanting to improve energy efficiency in general and the efficient use of oil and gas in particular: global climate change, reducing the level of toxic emissions into the atmosphere, and reducing UK dependency on oil and gas imports. On past evidence, oil and gas prices will have to stay at their current levels for some time before behaviour towards energy use changes.

A country's level of CO_2 emissions is governed largely by its choice of energy sources. The contrast between France and the UK is particularly marked. France is committed heavily to a nuclear electricity generation strategy, and today France consumes 13% more total energy per capita (20% more electricity) than the UK and yet emits 31% less CO_2 per head (IEA; WEO 2004). This is illustrated by Figure 12.

Figure 12: CO_2 emissions from different countries[6] t CO_2 /capita

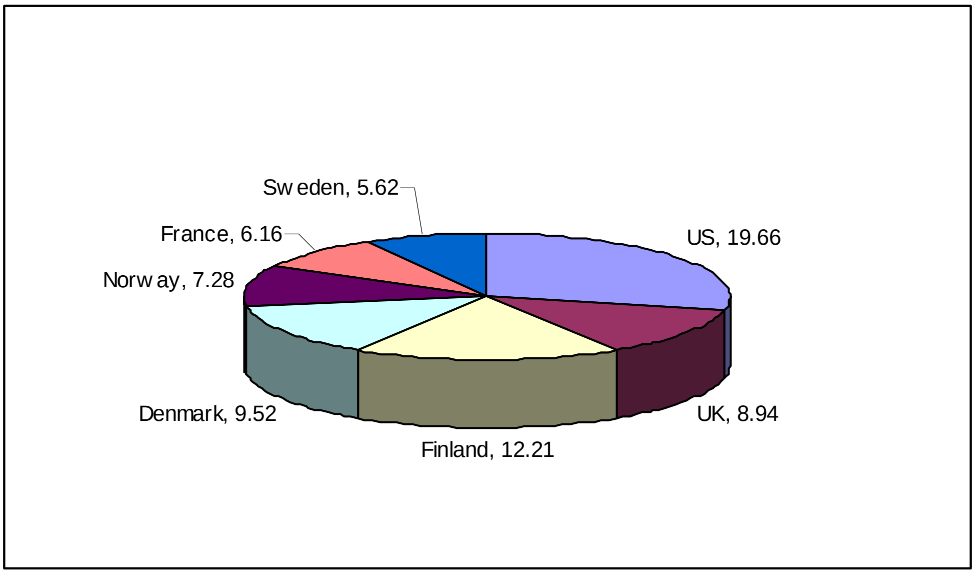


Figure 13 gives a clear indication of the contribution of different fuel types and also different energy using sectors to CO_2 emissions. Gas is the largest at 37%, followed by petroleum at 32% and coal at 25%. On the consumption side, power stations are the highest with 30% of the total, followed by industry at 23%, transport at 22% and domestic use at 16%.

Figure 13[7]

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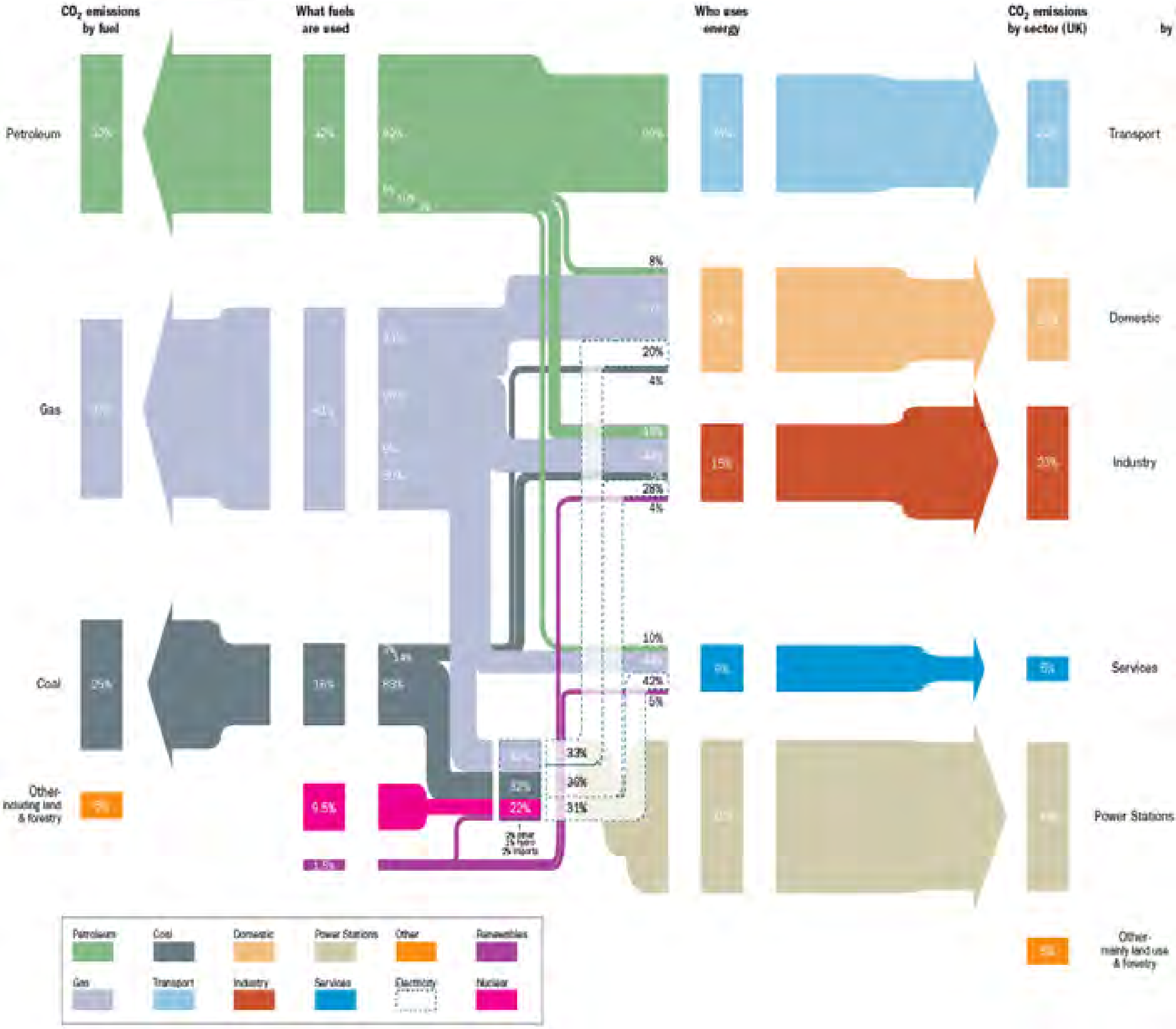
[6] Based on data form Key World Energy Statistics; OECD/IEA; 2004. CO_2 emissions from fuel combustion only



UK Energy and CO₂ Emissions

If pressure to reduce carbon emissions, from burning oil for transport, and coal, oil and gas for heat and power, intensifies, the only prospects for significant change would be for the increased use of electric and hydrogen fuel cells for transport and an increased use of renewables, hydrogen, biomass and nuclear for heat and electricity generation. Whether the electricity is used directly or to produce hydrogen, the substitution is only of value if the power comes from a non carbon-emitting source. However, it seems likely that the need for electricity is likely to grow much faster than the overall demand for energy, given the forecasted increase in number of households, from 21 million to 25 million over the next 20 years, increasing domestic

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[7] Scottish Natural Heritage

electricity use and the recent trends in car fuel efficiency and the shift from petrol to diesel.

Conclusions

We draw a number of conclusions from this analysis of UK supply and demand trends and emissions. All of these have repercussions for Scotland.

- First, the supply of energy from fossil fuels should decline to safeguard the continuity of supply and to achieve reductions in greenhouse gas (GHG) emissions. This will place great emphasis on technological innovation, especially in relation to fuel substitution, and on energy efficiency.
- Secondly, development of renewable supplies of energy from low GHG sources will become even more necessary, but it is likely that these will only be achieved with supportive government policy and with incentives to stimulate market response.
- Thirdly, the conditions for investment in the greater levels of extraction of fossil fuels should be attractive for investors at a time when rates of return will be less than in previous decades.
- Fourthly, changes in behaviour, especially in relation to transport and domestic energy consumption, will be critical. Energy prices have not proved to be a significant deterrent to demand unless high prices are sustained for very long periods and, as we shall explore in Chapter 6, changes in behaviour towards more efficient use of energy and a reduction in energy use have not proved to be easy to achieve.
- Fifthly, setting greenhouse gas emission targets poses a dilemma for countries such as Scotland. Reduction of its comparatively small emissions will have no significant global impact. For an issue where global collaboration is vital, and any contribution is potentially costly, there is an ethical imperative for all countries to share in global targets. But in the absence of a global consensus that includes all the major polluters, there are substantial costs involved for any country moving ahead of such a consensus, costs that are unlikely to see any positive impact on the issue as a whole. The Royal Commission on Environmental Pollution has argued that the UK should take a leadership role in changing its energy regime and promoting international agreements to reduce emissions. Such a policy could encourage innovations able to exploit a growing global market for low-carbon technologies, but could be costly to the UK's competitive position if not followed by other countries. We expect that the UK government will continue to be committed to a low carbon energy future and promote and honour appropriate international agreements. We assume in this report that this will also be a high priority for the Scottish Government.

3. SCOTLAND'S ENERGY SITUATION

In this chapter, we review recent and current energy supply and demand trends, and review predictions of population and economic activity to allow an estimate of the growth in energy use. We end the chapter with our view of the challenges that Scotland faces on energy issues. These guide our assessment, conclusions and recommendations in the rest of the report.

Potential future energy demand trends

The energy consumed in a country is related to its population and economic performance, so for the purpose of our Inquiry we have had to make some assumptions about the size of the Scottish population and about Scotland's GDP in future. We have no illusions about our ability to predict the future some 20 or 45 years ahead with any precision, so rather than settling on a single vision, we have decided to adopt three variants:

1. a central projection, based on the assumption that current trends will continue in future;
2. a high variant projection, assuming that economic performance improves and that a more buoyant economy is associated with a higher birth rate, lower mortality, and net inward migration; and
3. a low variant, with a less buoyant economy, a further decline in the birth rate, higher mortality, and net outward migration.

The population projections are based on the latest projections and variants prepared by the Registrar General for Scotland and the Government Actuary's Department (extrapolated from 2041/2 to 2050); for the central economic projection growth of GDP per head is assumed to continue at the trend rate of some 2% p.a., increased by about ½%p.a. for the high variant and reduced by about ½% p.a. for the low variant. We stress that the demographic and economic assumptions underlying the high and low variants are by no means extreme, and the variants should not be taken as representing the outer limits of what may happen.

Demographic Trends

The most recent projections of Scotland's population (Government Actuary's Department 2004) show a decline from 5.057 million in 2003 to 4.921 million in 2025 and about 4.6 million in 2042 (Table 2).

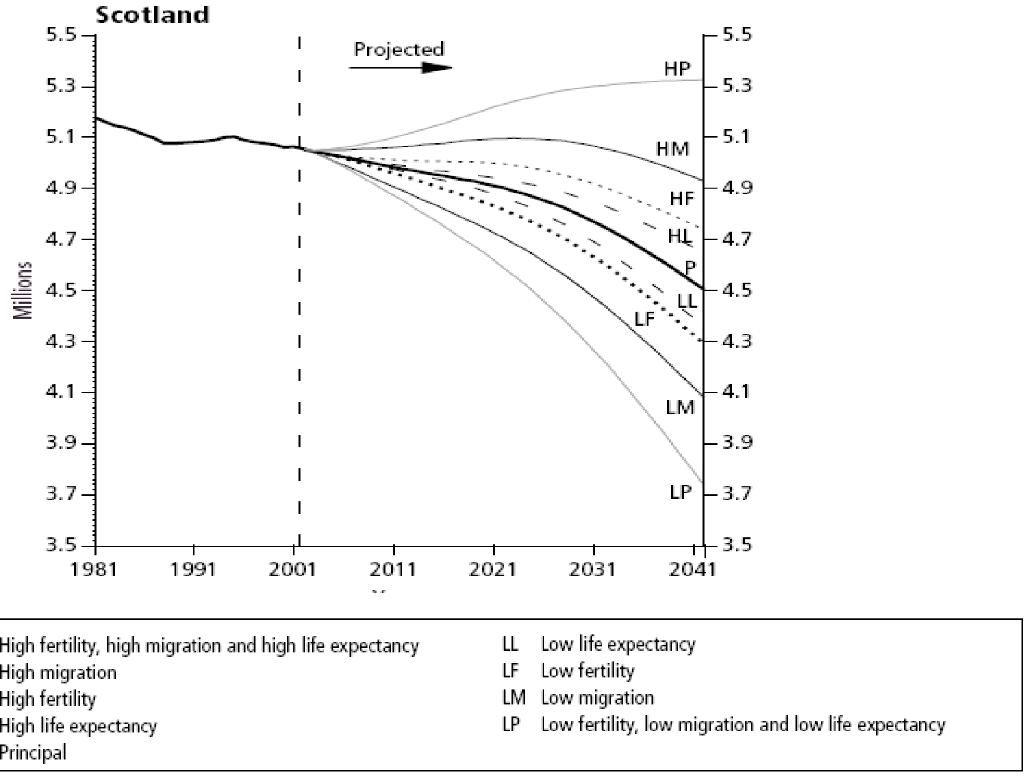
Table 2: Demographic Projections

Variant	**Population (millions)**		
	2003	2025	2050
Central	5.06	4.9	4.4
High		5.3	5.3
Low		4.5	3.3

These projections reflect an assumed continuation of the low fertility rates of recent years (completed family size 1.60 per female), an improvement in mortality rates averaging about 1% per year by 2027, and after a short period of net inward migration, net outward migration from Scotland averaging some 1,500 per year

(Figure 14). Associated with this decline in the total projected population is an increase in the proportion of people of pensionable age from 18.9% in 2003 to nearly 23.4% in 2025 and 28.9% in 2043, and a decline in children under 16 from 18.7% in 2003 to 15.8% in 2025 and 14.8% in 2043.

Figure 14: Population Projections for Scotland (2002 – based)[8]



All projections of this kind are inherently uncertain. The decline in fertility in recent decades may be reversed or may go further, mortality may improve faster or more slowly than indicated by long-term trends, and levels of net migration (inward or outward) will depend on the buoyancy of the Scottish economy. Gross migration flows in the last 10 years have averaged about 70,000, so it would not be surprising if average annual net migration in the next 25 years differed by 10,000 (up or down) from the central projection. That alone would affect population in 2025 by nearly ¼ million and in 2050 by about ½ million.

Economic Performance

Over the last 40 years, Scotland's annual average rate of growth of GDP has been 2%. The average rates for the last 10 and 20 years up to 2004 have not been materially different, and there has also been little change in Scotland's population (a 2% net decline over 40 years). A reasonable assumption, therefore, for Scotland's trend rate of growth of GDP per head is 2% p.a. On this assumption, Scotland's GDP per head would be just over 50% higher in 2025 than it was in 2004, and using the GAD's central projection of population, total GDP would be just under 50% higher. By 2050,

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[8] Government Actuary Department 2003

GDP per head would have increased by 150%, with total GDP rising by about 125% after allowing for the projected decline in population.

Table 3: Economic trends

Variant	**GDP (2004 =100)**		
	2004	2025	2050
Central	100	150	225
High		175	325
Low		125	125

For alternative high and low scenarios we assume annual average rates of growth of GDP per head of some 2.5% and 1.5% respectively. These figures are by no means extreme, and fall well within the bounds of possibility. On the high scenario, these equate to growth in GDP per head of 68% by 2025 and 211% by 2050 respectively, and on the low scenario to 37% by 2025 and 98% by 2050 respectively. Since high economic growth and a more buoyant population are likely to go together – and vice versa for low growth and population – these projections should be combined with the high and low population scenarios to produce high and low variants of total GDP in 2025 and 2050. This leads to total GDP some 75% in 2025 and 225% in 2050 above the current level for the high variant, and a little under 20% in 2025 and 25% in 2050 above the current level for the low variant.

Table 4: Demographic and economic trends

Variant	**Population (millions)**			**GDP (2004 = 100)**		
	2003	2025	2050	2004	2025	2050
Central	5.06	4.9	4.4	100	150	225
High		5.3	5.3		175	325
Low		4.5	3.3		125	125

In the high variant, fertility in Scotland is assumed to recover to little more than the current average UK level, and inward migration of some 10,000 p.a. can be contrasted with net outward migration averaging some 30,000 p.a. in the 1960s. If the Scottish economy enjoys buoyant economic conditions, both these variant assumptions could prove to be pessimistic. On the other hand, a poor economic performance could well be associated with significantly higher levels of net outward migration and a further decline in fertility.

As a generator of energy demand, any fall in population is offset by a trend to an increase in the number of households, which is expected to reach 2.5 million by 2015. While the average household occupancy is in decline, the increase in the number of households generates a small positive pressure on energy demand.

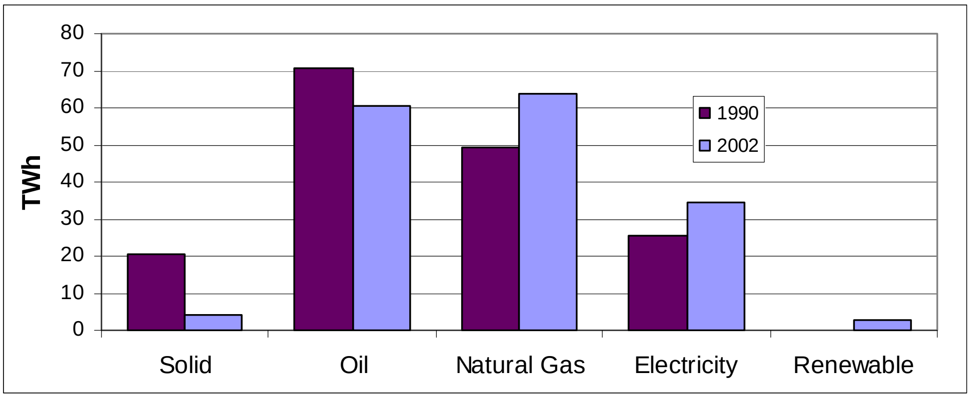
The combination of the central cases of predicted GDP growth and population projections would suggest that **total energy demand in Scotland will increase by around 50% by 2050**.

Current energy supply and demand

In 2002, Scotland consumed approximately 175 TWh of delivered energy across the main demand sectors: domestic, transport, industry and service, including 11 TWh for oil refinery operations.

The current energy supply and demand position is based upon the Scottish Executive's Energy Study. This describes the 2002 picture in Scotland and compares it with 1990 figures.

Figure 15: Energy Use in Scotland, 1990 and 2002[*]



There have been significant changes in fuel use across the demand sectors between 1990 and 2002. According to 2002 figures, oil-based fuel consumption was 61 TWh, a 15% reduction on 1990 figures. This was largely due to a major decrease in heavy industry and manufacturing over the period, whilst the demand for oil in transport has increased. There has been a considerable rise in the consumption of gas to over 63 TWh in 2002 with demand being highest in the domestic sector for space and water heating. Electricity consumption across the non-transport sectors, has increased by nearly 20% on 1990 figures to 32 TWh. In Scotland, the four main energy demand sectors are domestic, transport, industry and services as illustrated by Figure 16.

Figure 16: Sectoral Energy Split[*]

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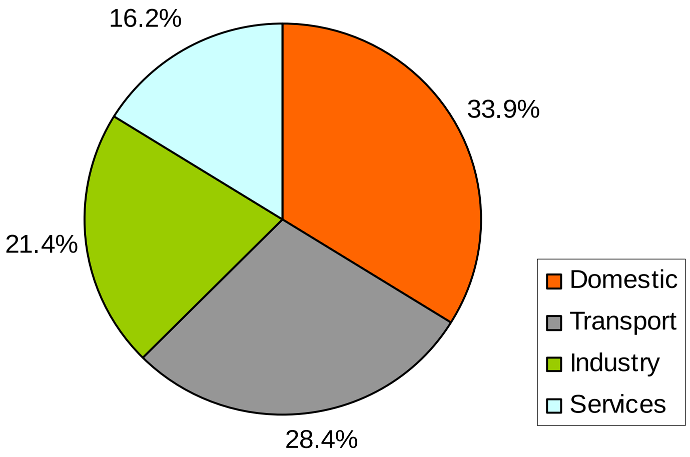
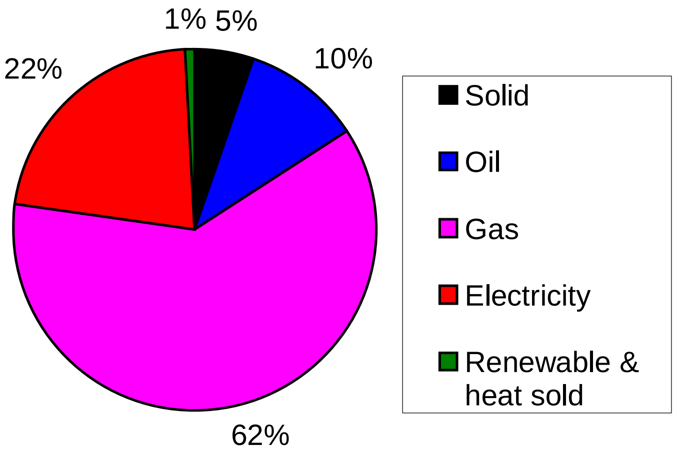


(1) Domestic sector

The domestic sector is the largest consumer totalling 56.04 TWh (Figure 17). The primary fuel consumed in the domestic sector is gas, even though a small proportion of the population, particularly in the North and North West of Scotland, do not have access to the gas grid. Gas, coal and oil are the dominant fuels used for space and water heating, which accounts for over 80% of a typical household's energy consumption. Electricity also represents a high proportion of energy consumed within the domestic sector in Scotland: 22%. This is due to the fact that electricity has a large number of uses within the home, including powering a growing number of household appliances and space heating systems.

Figure 17: Scottish Domestic Sector Energy Split*



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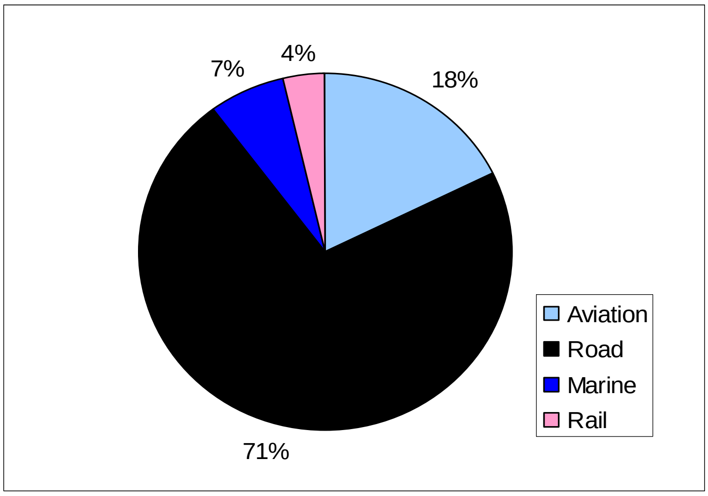
In comparison with the rest of the UK, energy used in Scotland's domestic sector is 10.1% of the UK's domestic sector energy usage, although Scotland's population is 8.5% of that of the UK. Scotland's climate and the poor standards of household energy efficiency may be the key factors.

(2) Transport Sector

Energy needed for transport has been growing year-on-year, particularly due to increases in road traffic and also significantly, air transport. This energy is almost all oil based, with a very small contribution from electricity. The total energy consumed in Scotland by the transport sector in 2002 was 47.07 TWh (Figure 18).

Figure 18: Scottish Transport Sector Energy Split[*]



Road transport use dominates the Scottish transport sector at 71%. According to the Scottish Energy Study's calculations, Scotland was responsible for 35.54 TWh of road transport energy and 8.69Mt of CO_2 emissions in 2002.

(3) Industrial Sector

Scottish GDP has grown in recent years, however this has coincided with a decline in manufacturing and growth in the service sector in the past 10-15 years. This reflects a general UK trend, however it may be more acute in Scotland due to the closure of the energy intensive steel works at Ravenscraig in the early 1990s and its knock-on effects. This is shown in Figure 19 comparing the GDP for both manufacturing and services.

Figure 19: Manufacturing and services GDP[*]

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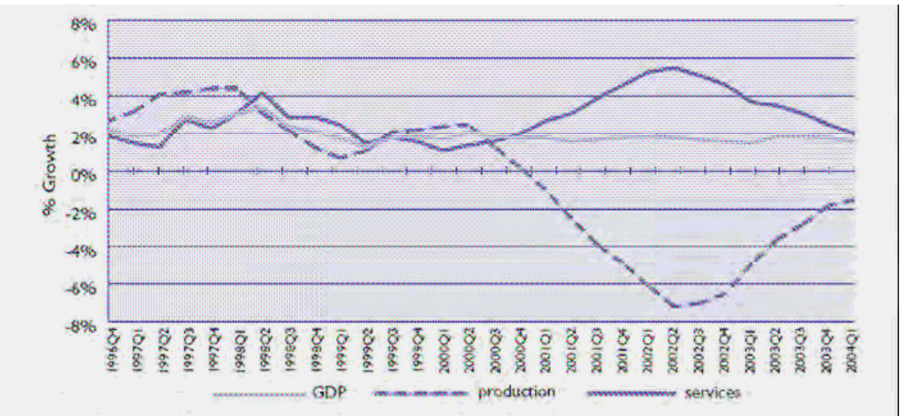
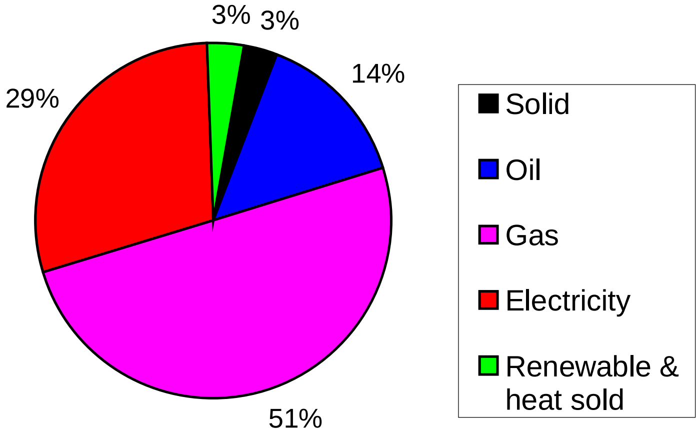


Source: Scottish Executive

Total energy use in the industrial sector is 35.32 TWh. Gas and electricity are the dominant fuel sources in the industrial sector and there has been a significant shift in the fuel mix from coal and oil in 1990 (Figure 20). This was largely a result of the relatively lower cost of gas during the mid to late 1990s and its lower emissions of GHG helping to meet more stringent environmental obligations.

Figure 20: Scottish Industry Sector Energy Split[*]



The energy consumed by the various industrial users within Scotland is shown on Figure 21 (below). The high figure for the food and drink sector is probably explained by the number of high energy users in the distilleries industry.

Figure 21: Scottish Industry Breakdown[*]

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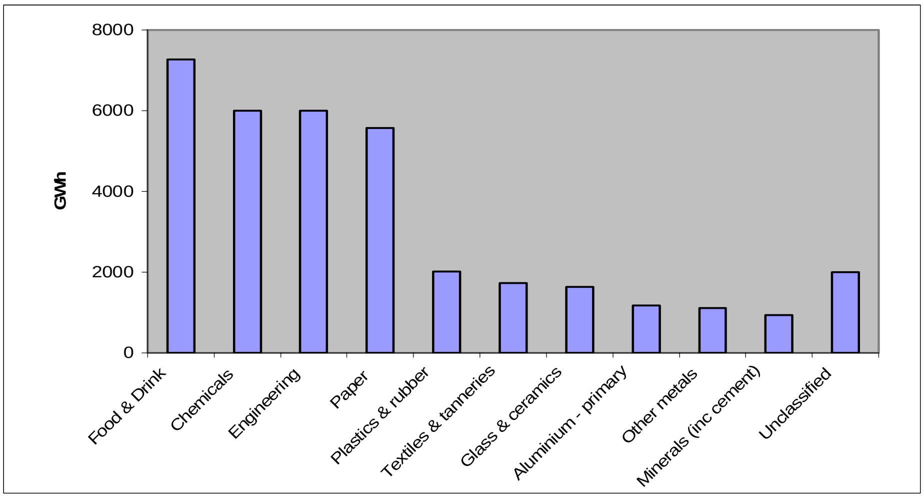
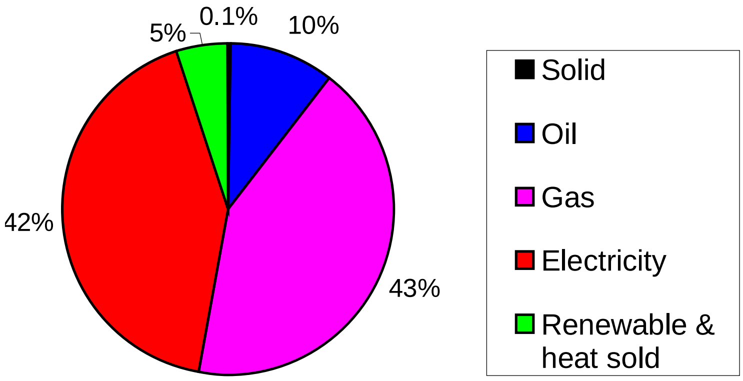


(4) Service Sector

The service sector is the smallest of Scotland's four main demand sectors and consists of commercial enterprises, including non-residential buildings, banks, call centres, retail and warehousing, as well as services operated by the public and agricultural sectors (Figure 22). Again, gas and electricity are the dominant energy sources. Electricity is used to power computers, lighting and air conditioning, whilst gas provides space and water heating.

Figure 22: Scottish Services Sector Energy Split[*]



The total energy figure for the Scottish services sector of 26.82 TWh. The change in the period 1990 to 2002 is shown in Figure 23.

Figure 23: Energy demands 1990 and 2002[*]

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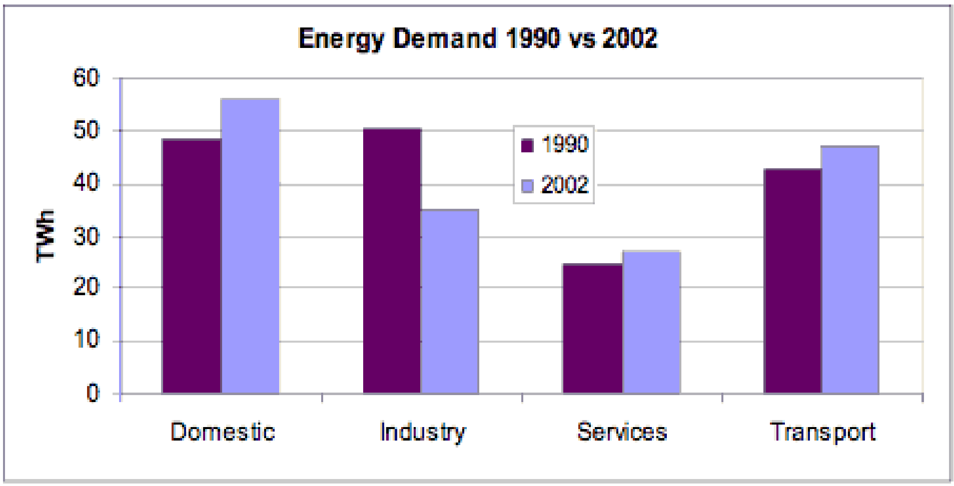

In the domestic sector, consumption rose by 15% between 1990 and 2002, from 48.5 to 56 TWh. The 2002 figures are dominated by gas. Electricity consumption rose by over 25% between 1990 and 2002. Solid fuel consumption almost halved by 2002 on its 1990 figure.

In the industrial sector, consumption fell by 31% between 1990 and 2002, down from 50 to 35 TWh. There is much greater use of gas and electricity by 2002, whereas in 1990 the fuel mix was primarily coal and oil.

In the transport sector, the principal fuel is still oil, as it was in 1990. Energy consumption for transport has risen by approximately 10%.

In the service sector between 1990 and 2002, there has been a 10% rise in energy consumption, up from 24.4 in 1990 to 26.8 TWh in 2002. The increase has been primarily driven by an increased consumption of electricity.

Overall position

Figure 24, from the 2006 Scottish Energy Study, shows a summary of Scotland's energy supply and demand with the supply of fuels on the left, their transformation to generate electricity in the middle, and their final use in demand sectors on the right. The width of the lines is proportional to the energy consumed. The main features are as follows. Coal is predominantly used in electricity generation. Oil is predominantly used for transport (or exported). Natural gas serves especially the domestic market and also industry, service and public sectors with some for electricity generation. Electricity uses a variety of fuels. The losses of energy from electricity generation are substantial; there are also losses in the oil refining process.

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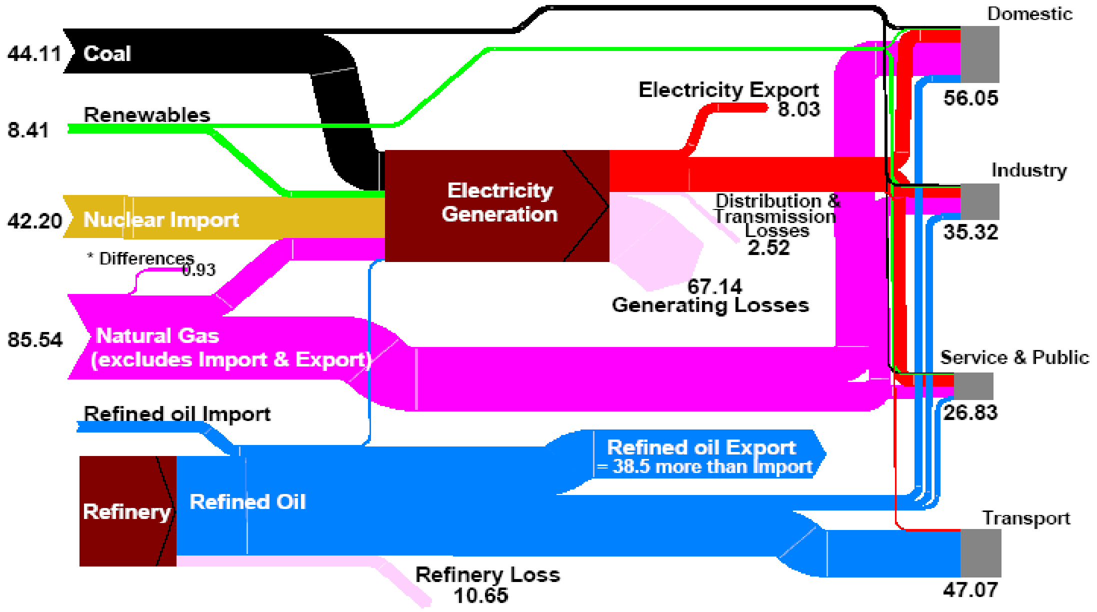
Figure 24: Summary diagram of Scottish energy flows (TWh)[*]



In 2002, Scotland consumed approximately 175 TWh of delivered energy across the main demand sectors: domestic (32%), transport (27%), industry (20%) and services (15%), including 11 TWh for oil refinery operations. However, 230 TWh of primary energy was consumed, with the production of electricity using 67.14 TWh, i.e. that is lost in the production cycle.

Greenhouse gas emissions

It is estimated that the overall contribution from Scotland of GHG emissions is 44 Mt of CO_2 (Table 5).[9] Non energy sources, particularly land use, are not included in the table but contribute high levels of emissions.

Table 5; Greenhouse gas emissions by sector

Sector	**Emissions as Mt CO_2**
Domestic	14.24
Transport	11.78
Industry	9.42
Service	7.73

Source: Scottish Energy Study 2006

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[9] Scottish Executive Energy Study Note: emissions represent CO_2 emissions from solid, oil-based, natural gas, electricity, and renewable and heat sold fuels.

Table 6: Greenhouse gas emissions in Scotland by type of greenhouse gas[*]

Gas	MtC			% change 1990- 2003	% of Scottish total emissions 2003	Scotland as a % of UK 2003
	1990	2003	change 1990-2003			
Carbon Dioxide	16.05	14.82	-1.23	*-8%*	*84.0%*	*9%*
Methane	1.83	1.19	-0.64	*-35%*	*6.7%*	*11%*
Nitrous Oxide	1.68	1.40	-0.27	*-16%*	*8.0%*	*13%*
HFC	0.00	0.19	0.19	*479154%*	*1.1%*	*7%*
PFC	0.03	0.02	-0.01	*-28%*	*0.1%*	*22%*
SF6	0.01	0.01	0.01	*159%*	*0.1%*	*3%*
Total Emissions	**19.59**	**17.64**	**-1.95**	***-10%***	***100%***	***10%***
Removals (CO_2)	-2.28	-2.75	-0.46	*20%*	*-16%*	*62%*
Net Emissions	**17.31**	**14.89**	**-2.42**	***-14%***		***8%***
Net CO_2 Emissions	**13.77**	**12.07**	**-1.70**	***-12%***		***8%***

Source: Scottish Executive

Table 6 indicates that emissions have reduced over the period 1990 to 2003, particularly significant are methane (-35%), NOx (-16%) and CO_2 (-8%). The exceptions are HFC and SF6. Scotland's share of emissions is greater than the average on a per capita basis, especially for methane, NOx and PFC.

Scottish Electricity Generation

We present here the facts and our assumptions on electricity generation in Scotland as a basis for our assessment of options in Chapter 7.

The current installed capacity for electricity generation in Scotland is shown in Table 7.

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[*] Changing Our Ways: Scotland's Climate Change Programme 2006 Reproduced under the terms of the Click-Use Licence.

Table 7: Electricity generation in Scotland(MW)[a]

Generation	**Installed capacity**	**%**	**% Total generation** [b]
Nuclear	2440	24	37.2
Coal	3456	33	29.4
Oil and Gas	1793	17	24.4
Hydro and Pump Storage	1965	19	7.4
Other	763	7	1.7
Total	10,417	100	100

Total Annual Generating Capacity: 86.7 TWhrs

(a) DTI Energy Statistics at May 2005 and Scottish renewables 1996-2006: Delivering the new generation of energy

Total Annual Electricity Generation: 49 TWhrs

(b) Key Scottish Environment Statistics 2005. The figures in the SE Energy Study quote different estimates. The equivalent figure is 45.5 TWhrs.

Load factor is defined as generating time as a percentage of total available time.

Since privatisation, the margin in installed capacity relative to peak demand has reduced from about 30% to about 20% and is predicted by the National Grid to vanish within ten years, i.e. there will be electricity rationing by 2015 unless significant new generating capacity is installed.

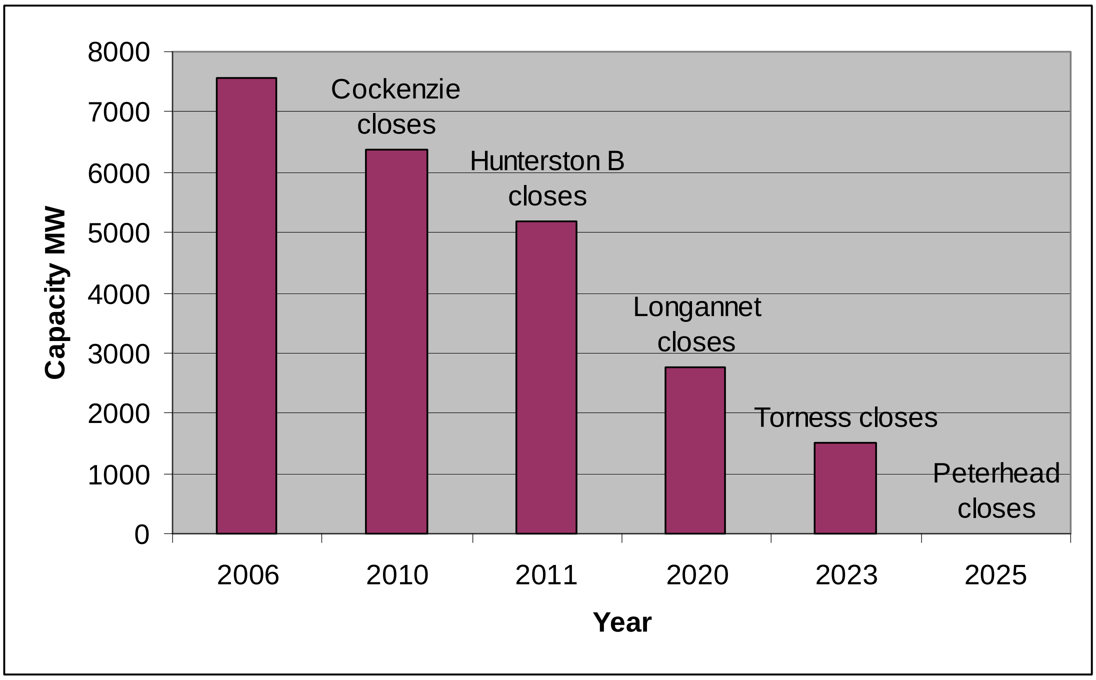
One of the key decision points on electricity generation in Scotland is the replacement of current capacity as it reaches the end of its life or fails to meet new environmental standards, particularly the EU Large Combustion Plant Directive which comes into force in 2015. The estimated closure dates of the large-scale existing plants is given in Table 8 and Figure 25. There is considerable uncertainty. The decision by Scottish Power to upgrade the equipment at Longannet will mean that it can operate for longer but probably with a lower installed capacity. The nuclear stations can have their operating licenses extended but there is no certainty in the industry on the maximum length of time this will last, as this will depend on the state of the reactor core. We use the current industry norm of an extension of 5 years.

Table 8: Major Scottish electricity generating power plants

Station	Type	Capacity MW	Assumed Closure Date
Chapelcross	**Nuclear**	200	Closed in 2004
Cockenzie	**Coal**	1200	2010
Hunterston B	**Nuclear**	1190	2011 (or the end of 2015 with proposed plant life extension)
Longannet	**Coal**	2400	2020 (or possibly beyond, following instillation of FGD)
Peterhead	**Gas**	1524	2025
Torness	**Nuclear**	1250	2023 (at the latest by 2029)

The position is correct at the time of writing, but we recognise that decisions will be made that will change these dates, for example, extension of nuclear reactor licenses and 'clean coal' technology. We illustrate the position in Figure 25 and attach the same caveats to the information as for Table 8.

Figure 25: Estimated closure of major electricity generating stations in Scotland



Challenges for Scotland

Energy demand is predicted to rise by 50% in Scotland over the next half century in the light of the central case of growth of GDP and demographic changes. Prices will rise in real terms as competition from global energy markets increases and supplies for certain sources become tighter. Oil is the most vulnerable given its dominance especially for transport and reserves could be running out by middle of the century. Other fossil fuel sources, especially coal with greater reserves, should provide no problems within our timescales provided arrangements with the exporting countries can be maintained. Environmental factors, globally and locally, are likely to result in greater constraints on the sources and on the types of energy sources, with those with low impact on global climate change, and those with low impact on local environments likely to be favoured.

It is not possible to isolate the challenges for Scotland entirely from those of the UK as a whole for a variety of reasons. The majority of energy policy is a reserved matter for the UK Government and sets the regulatory framework and provides some instruments to stimulate specific outcomes in relation to supply and demand for energy. Energy can cost more in rural Scotland compared to the rest of the UK. The UK operates in a global market for the supply of sources of energy and has a policy to allow the market to determine the price of energy and to a large extent the supply mix. There is also a UK market and transmission system for electricity.

We set out five challenges for Scotland.

The **first challenge** is whether Scotland should follow the same broad policies of the UK on energy, particularly reduction in greenhouse gases as a main objective of policy. Should this be the primary goal of energy policy and action in Scotland?

It is anticipated that Scotland will face the same security and continuity of supply issues of the rest of the UK, especially increasing dependence on imported fossil fuels, particularly gas and oil from the Middle East and from Russia. The **second challenge**, therefore, is can Scotland produce more energy from its own natural resources and at the same time reduce its greenhouse gas emissions?

Reducing the demand for energy and increasing energy efficiency has been a long term policy objective in Scotland but the evidence suggests that there has been less of a reduction in demand than hoped, particularly in the domestic sector. The **third challenge** is can significant improvements in the efficiency of energy use be achieved?

Oil is likely to remain the basic fuel for transport for the foreseeable future. The **fourth challenge** is can Scotland stimulate the development and demonstration of alternative technologies given its research and development base and the innovative activities already taking place in some parts of the country?

Electricity production currently derives from a variety of sources. The growth of renewable resources, especially onshore wind, has been a major plank of government support in recent years. However, with the closure of all of the major electricity generating stations in Scotland within the next two and a half decades, the **fifth challenge** is whether government and industry in Scotland are prepared to take the decisions needed to replace this lost capacity in a manner that ensures the security and continuity of supply to which consumers have become used? There are public concerns about some of the possible solutions, such as replacement of nuclear stations with new build, the extensive development of large-scale onshore wind turbine installations, especially in locations remote from consumers, and the grid connection infrastructure required. There is probably no one solution and the challenge for Scotland will be to ensure that the mix of sources will provide for positive benefits.

Whatever the challenges there is little doubt that Scotland has to think in a global context and act locally using the natural resources at its disposal in a manner which provides social, economic and environmental benefits.

Many of the challenges we identify can only be determined through the political process with the Scottish Executive working within a UK context. This is an onerous responsibility, but can be assisted by informed debate. We shall return to these points later in our report.

4. ENERGY POLICY FOR SCOTLAND

In this chapter, we describe briefly the governmental structure of responsibilities arising from the devolution agreement. We propose a series of policy objectives for energy and outline the constraints within which Scotland has to operate in determining government action and commercial decisions. We conclude with our strategy for energy.

The first question to address for any discussion of energy policy is why such a policy is needed in a free market economy. Policy is needed where there is market failure or where there is a desire by government to influence the market in a direction that it is unlikely to take on its own. For example, monopoly or disproportionate market power by a single entity may require regulation to prevent abuse of that power or policies that stimulate others to enter the market or to develop alternative means of serving that market. Policy may also be appropriate where there is a desire to influence the market to tackle environmental or social objectives that are seen to benefit society in general.

These considerations suggest that policy intervention requires careful thought to avoid unintended consequences. Policy intervention should therefore only be used where clear policy objectives can be defined. For example, a monopoly in energy supply that leads to higher prices and a consequential reduction in energy use can be justified if it results in lower environmental impact. However, if a monopoly has implications for security of supply, a policy that leads to more investment in infrastructure for distribution than may be indicated by purely market considerations may have benefit because the cost of loss of supply usually greatly exceeds the cost of having some excess capacity.

In terms of thinking about energy policy for Scotland, it makes sense to look first at those areas where the market failure lies within Scotland and within the remit of the devolved powers to Scotland. Thus it does not make sense to seek to influence factors that are determined on a global basis, such as the commodity price for oil or gas. On the other hand, local distribution networks, land use and planning regulation, local housing and energy efficiency, social services and fuel poverty are areas where specific Scottish policies might be appropriate. A particular example would be policies and actions that brought together local government building, social services and planning functions to improve energy efficiency in the housing stock. It is also appropriate for Scotland to seek to influence UK policy, as this has implications for Scotland.

Reserved and devolved powers on energy

With the devolution of responsibilities to the Scottish Parliament under the Scotland Act 1998, the responsibility for energy has been divided between the UK Government and the Scottish Government. By far the majority of the policies and actions are ‘reserved’ to the UK Government and the UK Parliament, with relatively few devolved to Scotland; these relate mainly to activities already devolved before the 1998 Act, specifically planning, environmental and building legislation and regulations. Scotland is therefore subject to UK legislation and policy decisions as well as international agreements and EU Directives entered into by the UK Government.

Reserved Matters:
Generation, transmission, distribution and supply of electricity
Most aspects of the ownership, exploration and exploitation of oil and gas, including pipelines, and restrictions on other activities offshore
Coal ownership, deep and opencast mining and subsidence from mining
Nuclear energy and nuclear installations including safety, security, and liability for nuclear occurrences
Energy conservation by prohibition or regulation

Devolved Matters:
Environmental protection and pollution, specifically discharges, air pollution and integrated pollution control, under the provisions of the Environmental Protection Act 1990 in relation to oil and gas, coal, nuclear
Planning approval of the development of energy infrastructure other than pipelines and transmission lines under the various Town and Country Planning (Scotland) Acts
Permissions for the manufacture of gas and non pipeline conveyance of gas
Restoration of land affected by coal mining
Emergency planning at civil nuclear power stations
Environmental regulation
Encouragement of energy efficiency

Source: Scotland Act 1998 Schedule 5

A Concordat sets out how the Scottish Executive and the UK Department of Trade and Industry (DTI) consult each other on energy issues. Scotland also liaises with the DTI and with the Department of Environment, Food and Rural Affairs (DEFRA) on wider energy policy and environmental issues.

No sensible policy for Scotland on many of the major energy issues is likely to emerge unless the Westminster and Holyrood legislative bodies and their executive arms work closely together, and that both work in close liaison with industry and with representatives of civil society, including consumers. The Scottish Executive also needs to take a view on the broader energy policy areas and to influence UK policy to reflect the wishes of the Scottish people.

UK Government energy policy context

The UK Energy White Paper *Our Energy Future – Creating Low Carbon Economy*, published in 2003, set out the UK government's current policy framework, focussing particularly on the need to reduce emissions of greenhouse gases, especially carbon dioxide, as its contribution to international effort on minimising human-induced factors that may contribute to global warming and climate change. Four specific goals were articulated:

1. reducing carbon emissions by 60% by about 2050 with real progress having been achieved by 2020;
2. maintaining reliable supplies of energy;
3. promoting competitive markets to increase the rate of sustainable economic growth and to improve productivity; and
4. making energy affordable to the poorest members of society to ensure that every home was adequately and affordably heated.

This UK policy is now under review with the publication by the DTI in January 2006 of a consultation *Our Energy Challenge – securing clean, affordable energy for the longer term*. In the meantime, the major goals remain in place, and the only significant changes have been to update the progress on the achievement of targets, and a commitment to consider the case for decisions necessary to allow new nuclear electricity generating plant to be approved for construction and operation by the private sector.

Within the UK, the gas and electricity industries are regulated by Ofgem whose statutory objective is "to protect the interests of consumers, wherever appropriate by promoting effective competition". In furthering this objective, Ofgem also has an obligation to consider security of supply, availability of finance, and the interests of certain social groups. *Subject to these*, it is required to carry out its functions in a manner best calculated to promote efficiency and economy in supply, transmission, distribution and use; protect the public from dangers; secure a diverse and long-term energy supply; and contribute to sustainable development. In order to promote effective competition and with a view to promoting efficiency and economy, the National Grid Company operates a charging principle to reflect costs; this is approved by Ofgem.

Scottish Executive policy context

In the Coalition agreement of 2003 (*A Partnership for a Better Scotland*) between the Labour and Liberal Democrat parties, a number of policy commitments were made on energy in Scotland:

1. To take advantage of Scottish resources to expand the renewable energy industry;
2. To work towards 40% of electricity produced in Scotland generated from renewable sources by 2020;
3. To support the development of wave, tidal and solar energy;
4. To support the development of technology to promote greater use of fuel from wood and other energy crops;
5. To press the UK government and energy companies to strengthen the electricity grid;
6. To encourage participation in renewable energy by communities and local authorities;
7. Not to support further development of nuclear power stations while radioactive waste management issues are unresolved;
8. Where decommissioning of nuclear power stations occurs to ensure that best practice is used;

9. To reduce the number of households in fuel poverty by 30% by 2006;
10. To develop home insulation and central heating programmes and evaluate their success;
11. To strengthen building standards to ensure energy conservation levels improve;
12. To consult on ways for new houses and public buildings to increasingly incorporate solar power and other renewable energy sources;
13. To develop an energy banding system to classify houses by energy efficiency and giving tangible benefits to owners for improvements made;
14. To help to meet UK government commitments on climate change and renewable energy; and
15. To encourage measures to reduce energy use, including increasing the use of solar power and introduce energy conservation measures in the public sector.

The target under 2 above on renewables as a source of electricity has been changed from electricity generated to electricity consumed in Scotland. According to the Forum for Renewable Development in Scotland, Scotland needs to develop a total of around 6 GW of renewable installed capacity in order to be certain to achieve the 40% target. This has been accepted by the Scottish Executive.

The Scottish Executive is currently undertaking a study into energy supply and demand in Scotland and has published statistics on supply and demand gathered by consultants as part of the ‘Scottish Energy Study’[10].

It has established the Forum for Renewable Energy Development in Scotland (FREDS) - a partnership between Government, industry and academia to advise how barriers to renewables development in Scotland might be overcome. FREDS has published reports on the actions needed to promote development of marine energy and biomass, on skills requirements, on achievement of the 2020 target, and is working on hydrogen and fuel cells.

A review of the Scottish Executive’s planning policies for renewable energy was announced in July 2005. The Scottish Executive is revising National Planning Policy Guideline (NPPG) 6, which applies to renewable energy developments in Scotland. At the time of compiling our report this is ongoing. It is considering the operation and effectiveness of policies to reach the targets for renewable energy in the most environmentally acceptable way possible. The possibility of a national spatial framework and regional targets for the location of renewable energy are also being considered.

The Scottish Executive is also developing Scotland’s first Energy Efficiency Strategy which is intended to cover all sectors of the economy.

Policy Instruments

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[10] AEA Technology, 2006, Scottish Energy Study Volume 1: Energy in Scotland: supply and demand, Volume 2: A Changing Picture: comparison of 2002 energy study findings with an earlier study using 1990 data, Scottish Executive.

There are already a number of policy instruments employed in the UK in general and Scotland in particular.

(1) Instruments related to climate change and emissions reduction
UK Emissions Trading Scheme (UK ETS)
European Union Emissions Trading Scheme (EU ETS)
Climate Change Levy
Large Combustion Plants Directive (LCPD)

(2) Instruments to encourage the use of renewable sources
Renewable Obligation Certificates (ROCs)

(3) Instruments to encourage energy efficiency
Energy Efficiency Commitment (EEC)
Community Energy Programme (CEP)
UK Renewable Transport Fuels Obligation

(4) Energy efficiency in public buildings and the housing stock
EU Directive on the Energy Performance of Buildings 2002/91/EC
Building Regulations
Home Energy Conservation Act 1995
Housing (Scotland) Act 2006 Section 179
The Warm Deal
Scottish Community and Household Renewables Initiative (SCHRI)
Loan Action Scotland (LAS)

(5) Other Instruments
Town and Country Planning System

Details of existing policy instruments are in Appendix E.

Aim and Objectives for energy policy

Any approach to the development of energy policy has to be informed by and seek to address the pattern of supply and demand. Certain future trends can be identified. Demand for energy globally is likely to double by the middle of the century and in Scotland to increase by 50%. Energy prices are likely to rise in real terms but the extent is unpredictable. Oil and gas production will decline and become insufficient to meet demand. Coal and uranium reserves will be sufficient to meet likely demand. Climate change is likely to remain a dominating factor in energy policy globally and in the UK. This would be reflected in the need to reduce GHG emissions, encouragement of low carbon technologies and greater efficiency in the use of energy.

For all of these reasons, we conclude that the **strategic aim** should be:

> **A secure, competitive, socially equitable, and low carbon emissions supply of energy for Scotland.**

By 'secure' we mean having sufficiency of supply from a diversity of fuel types and geographical sources using a variety of technologies, encouraging new technological development to marketability and having the appropriate government framework and instruments. By ‘competitive’ we mean that the cost of energy will not result in Scotland being uncompetitive in world markets and also competitive in the use of technology and innovation. By ‘socially equitable’ we mean that all sectors of society should have access to energy at a price which they can afford, implying that some economically and socially poorer sections of society will be aided to rise out of fuel poverty. By ‘low carbon emission’ we mean that throughout their life cycle technologies should produce the lowest possible levels of greenhouse gas emissions, bearing in mind that there are none that have no emissions. Our strategic aim also implies a safety component that brings at best positive environmental benefits and at worst no significant environmental degradation, and provides assurances on human health.

A reliable and continuous supply of energy at predictable prices is essential to sustain business expansion and economic growth and to meet the needs and aspirations of society as a whole. Interruption in energy supply and volatile prices are equally damaging to business confidence as they both make it difficult to forecast the basis for investment. They are also damaging to consumers in managing their resources and seeking to attain higher standards of well-being. Factors that support security and safety of supply include diversity of fuel use, diversity of fuel source both in type and geography, diversity of generating capacity and the location of that capacity, an understanding of the different operating characteristics of the various generating sources, and an adequate distribution infrastructure for transmission and distribution to the consumer that takes account of all these variables.

We have considered whether Scotland should take an independent stance for the supply of energy. We consider this approach cannot guarantee the achievement of the overall aim of security of supply, especially in relation to gas for domestic consumption and in relation to oil for transport. There is sufficient uncertainty about the scale and the continuity of supply from wind and other renewables for electricity generation that they cannot be relied upon to provide a baseload supply (see Chapter 8).

Our preferred approach is one of interdependency within UK, European and global markets. Scotland should supply as much of the energy it needs from own low carbon resources provided that there are competitive advantages for doing so and that the social and environmental benefits well outweigh any social and environmental costs. It should also take the opportunity at times of energy, and especially electricity, surplus to export this to adjacent countries. We believe that this interdependency approach will bring technological benefits to Scotland, will stimulate enterprise, and will deliver social and environmental gains.

Any policy should begin with setting out clearly the objectives that the policy is intended to achieve and against which different policy options can be judged in terms of their likely effectiveness in achieving those objectives. We consider that the following objectives should form the basis of an energy policy for Scotland.

(1) To encourage energy efficiency to the benefit of economic development

Energy demand continues to rise and it is likely that energy prices will reflect this demand. One way to manage this price increase is to reduce the amount of energy consumed for each unit of activity or production. There are clear opportunities for doing this.

Energy policy should promote energy savings and reduction measures, especially by small and medium-sized enterprises and by domestic consumers. The benefit of greater efficiency goes beyond the overall cost to the consumer; it includes reducing the need for new infrastructure and the investment that goes with it and, by lowering the output cost of each unit of production, it allows for greater economic activity.

Recent years have seen the development of many energy-saving technologies, and energy-efficient goods and services. With so many opportunities for energy saving and energy conservation, it must be asked why the take-up of such measures by domestic consumers has been so slow, particularly when compared with business. This is an area where Scottish energy policy may be able to make a major contribution through policies that encourage Scottish consumers to monitor their energy costs in the way that this is done by business. We develop these points and make recommendations in Chapter 6.

(2) To ensure that energy availability contributes to improvements in social benefits to Scotland's people

Many people struggle to be able to afford to pay for energy, in particular for domestic space heating, to keep them and their families in a healthy state; this phenomenon is often termed 'fuel poverty'. This has implications not only for greater costs to the health services, but also for society in general. We consider this to be a crucial objective of energy policy.

The availability and cost of energy, and the safety standards in its production and delivery to consumers, are therefore major contributors to improving the health of Scotland's people.

(3) To minimise adverse environmental effects, both locally and globally

All forms of energy production and energy use have some environmental impact. However, there are technologies for energy supply where the environmental impacts are better or worse than others, and it therefore makes sense that future energy policy should favour those technologies that have a reduced environmental impact.

Clearly, environmental impact cannot be taken in isolation of other policy considerations but policy should seek to move the production and use towards a low carbon economy without imposing significant cost and reliability constraints on economic growth.

Scotland has an abundance of natural energy resources and the challenge for Scotland is how to develop an energy policy framework that allows these resources to be developed cost competitively and to make a significant contribution to a low carbon economy for the UK.

(4) To capitalise on the natural energy resources of Scotland in an economically viable and environmentally sensitive way

Although Scotland is a small market and is at the end of the supply chain for some energy sources, it has many natural resource opportunities, and technological and scientific capabilities that, if carefully nurtured, should allow it to make a major contribution to a low carbon economy for the UK. With its smaller population, it has the opportunity to encourage integrated solutions for energy supply and for meeting energy demand in the different parts of the country.

Energy supply, however, is sometimes times seen as a battleground between different factions of public opinion. Improved collaboration is needed and, to achieve this, joint action by government, by research funders and by industry is required to stimulate scientific development and technological innovation in energy and promote it effectively first across the Scotland and then internationally.

This is where an energy policy for Scotland can play a central role by spelling out the objectives and the conditions required to meet those objectives. In particular, policy instruments should be developed that encourage entrepreneurship and leadership in the implementation of micro-scale energy developments suited to dispersed consumers, for example run-of-river hydro, and in integrated solutions rather than dependence on single supply sources, for example combined heat and power derived from waste heat and waste products. This has the capability to put Scotland ahead of the field in terms of thinking about what energy generation and use means for the 21st century.

Constraints on energy policy

Energy policy does not and cannot operate in isolation and there are a number of constraints that have to be recognised. These constraints are matters that are non-negotiable as a result of international agreements, global trade realities, trade deals or other matters that have to be taken into account because they have an impact on policy choices and decision making. Many of these are time limited, but some in the regulatory field are likely to continue for many decades. Their existence reduces the choices available both to suppliers and users of energy and also reduces the discretion available to government.

Supply factors

The raw materials for the production of energy are largely supplied from sources outside the UK. There are a number of reasons for this situation. With the supply of hydrocarbons from the UK Continental Shelf now in long term decline, the UK will become increasingly dependent, on current projections, on imported oil and gas.

The majority of our current need for coal is imported and is of higher quality and with fewer impurities and so provides environmental advantages over coal mined in Britain. There may be social reasons for stimulating the use of indigenous coal resources, but it will have to overcome the lower costs of imported coal.

The geopolitical ramifications of the distribution of fossil fuel reserves are substantial. With reliance on these fuel types for transport, space and water heating and for electricity generation, the constraints imposed by the political, competitive, trading and transport considerations pose uncertainties to the continuous and reliable supply of these fossil fuels at affordable prices. These are largely UK issues because of the structure of the supply industry and of the international trading links, but Scotland does need to be aware of and understand the issues involved.

Economic constraints

Economic constraints are largely due to the fact that energy raw materials are traded commodities on the international market. Scotland cannot opt out of the global market. Barring political disruption, there are supplies of fossil fuels available to the UK at the prices determined in the global markets, but there are likely to be constraints on the quantity of oil and gas available by the middle of the century.

Public Attitudes

Price can have a major impact on public attitudes. Affordable prices for energy for all sectors of society is a key policy of both the UK government and the Scottish Executive. The approach to delivering this commitment is through the competitive market, both for transport fuels and for electricity and gas supply. However, public attitudes to price increases can be a major influence in policy decisions as was seen in the petrol blockades of 2001.

Public attitudes to safety have also been a consideration in determining policy relative to nuclear power generation over recent times. Nuclear power is safe with reliable operating systems and reliable operators. Any energy policy that includes nuclear as one of its components needs to make the safety case to the public.

Societal Well-Being

Energy policy should take account of broader societal considerations relating to the health and well-being of the population. This requires an understanding of the relative risk to health from different technologies for the production and transmission of energy to consumers.

Price is again a factor in societal well-being as this relates to the ability of people to meet the costs of their basic energy needs. No government can afford to tolerate a situation where either the cost to its citizens is markedly out of line with its competitors or where a significant proportion of its citizens are left in fuel poverty.

Environmental factors

The UK Government has consistently taken the view that high levels of compliance with environmental agreements at international and EU levels should be achieved. Recognition of these environmental agreements, therefore, represents another constraint on policy and action in the UK as a whole and in Scotland, particularly where these directives have environmental objectives that provide planning obstacles to the approval of new energy developments.

It is worth noting a few examples. The EU Water Framework Directive accords high ecological status for river water and near-shore waters, and could therefore constrain major hydroelectricity development and those activities where discharges are expensive to control or where biomass production could increase run-off of soil into rivers. The Habitats and Species, and Birds Directives impose constraints on the location of facilities such as wind turbine installations which might seriously impact on the many birds, and other species and habitats that these Directives are designed to protect. Although only advisory in concept, the European Landscape Convention allows civil society to argue for the protection of pan-European and regionally significant landscapes. This could prove an impediment to development of any renewables, such as onshore wind turbine installations, that are likely to have an impact on the landscape.

Implementation of all of these regulations will constrain the locations where energy-related activity can take place and its type and extent; inevitably it will mean that certain types of energy-related activity will not be allowed in some localities.

Climate Change Targets

The UK's obligation under the Kyoto Protocol is for a 12.5% reduction in greenhouse gas emissions on 1990 levels by 2012. However, the UK Government has gone beyond this obligation to commit itself to the goal of reducing emissions of carbon dioxide to 20% below 1990 levels by 2010. Furthermore, the UK has adopted the goal of cutting the UK's CO_2 emissions by some 60% by about 2050, with real progress by 2020.

The UK is on track to meet its Kyoto target but not its own domestic CO_2 target (March 2006). It is estimated that in 2004, CO_2 emissions were about 5.6% lower than in 1990. The UK Government and Devolved Administrations have recently completed and published reviews of their respective Climate Change Programmes.

Decision-making framework for energy for the UK and for Scotland

A UK energy policy that also works for Scotland is needed for a number of reasons: to ensure security and continuity of supply, to stimulate competition for lower prices, to provide regulation that benefits and protects the consumer, to ensure that environmental effects are minimised, to ensure that societal needs are met, and to stimulate enterprise through the efficient use of energy for commerce and industry.

Given the important aspects of energy that are reserved powers to the UK Government, and also that energy is an internationally traded commodity, it is clear that Scotland is not able to develop its own policy and action in isolation from the UK as a whole. Nor is it in the best interests of the energy consumers of Scotland for it to do so within the present legislative and administrative arrangements. However, that does not mean that the Scottish Executive does not have a major role to play by presenting itself as a major voice that influences the outcome of the current UK policy debate.

Energy policy for Scotland should be developed as part of the Scottish Executive's commitment to sustainable development and its strategy on climate change. There are many other policy statements that impinge on energy policy but all of these should be set within these two broader frameworks.

Government should refrain from any measures which increase energy costs relative to competitors, whether in other parts of the UK or overseas, unless there are clearly identified and quantifiable benefits economically, environmentally or socially. Where policy decisions are taken that place a higher cost burden on consumers for reasons of social or environmental benefit, these costs should be capable of being monitored and tracked to be sure that the intended outcome is achieved.

Fortunately, most of these decisions can be left to the market because that is the business that energy companies are in, provided that Government establishes a clear framework within which industry can make these decisions.

The following recommendations summarise this perspective:

> **Recommendation 1**: It is essential that decisions are taken by the UK Government by the middle of 2007 to provide a more stable and longer-term policy framework to give greater assurance to the consumer on continuity of energy supply and to give confidence to the providers of energy to make investment decisions.

We consider, like many others commentators, that the energy policy objectives established by the UK Government in its 2003 Energy White Paper should be maintained.

> **Recommendation 2**: The UK Government should maintain the energy policy objectives set out in the 2003 White Paper: to ensure an adequate, safe and secure supply of energy, to reduce the emission of greenhouse gases with the setting of unambiguous long-term targets, to promote economic development, and to protect vulnerable sections of the population from the adverse effect of market forces.

Given the number of existing policy instruments, we believe that it is incumbent on Government to review these periodically to assess their effectiveness in achieving the objectives for which they were intended, and also to ensure that they have not resulted in any unintended consequences that are counter to those objectives.

> **Recommendation 3:** The UK Government should periodically review the instruments and targets used for implementing the policy framework to assess their effectiveness in achieving their intended objectives, and to ensure that unintended consequences have not arisen.

For Scotland, we welcome the wide range of aspirations in the Partnership Agreement of 2003. We also welcome the many and varied measures that have been announced since that date to ensure delivery on some of these issues. Energy aspirations and objectives form part of new statements on climate change *(Changing Our Ways: Scotland's Climate Change Programme)* and on sustainable development *(Sustainable Development Strategy; Choosing our Future)* and specific initiatives relating to energy are part of, for example, the revised agriculture strategy for Scotland *(A Forward Strategy for Scottish Agriculture: Next Steps)*. However, there is no overview statement of the strategy, policy and objectives for energy in Scotland by the Scottish Executive and without this many of the developments and decisions appear to be piecemeal. It is essential and urgent that a clear statement of energy strategy and policy and an articulation of specific objectives in the context of the Scottish Executive's approach to sustainable development and climate change is made by the end of next year. The statement should cover all aspects of energy and spell out the opportunities related to social well-being, economic development, enterprise and life long learning, education, environment, and research and development. In addition, the statement should embrace and link all of the separate initiatives and incentives that are available in support of energy related activity in Scotland. We understand the sensitivity of this recommendation given the reserved powers on energy, but we consider that the strategy can be framed in such a way as not to traduce the statutory requirements and responsibilities. Clearly, it should be developed in consultation with the UK Government.

> **Recommendation 4**: We strongly recommend that the Scottish Executive develop a comprehensive energy strategy, within the boundaries of its powers and responsibilities and in consultation with the UK Government, by the end of 2007. This should embrace specific strategies on energy efficiency, transport, heating, electricity generation and the use of renewables. This should also include the strategic aim of a secure, competitive, socially equitable, and low carbon emissions supply of energy for Scotland, and the four supporting objectives we propose.

Action for energy

To achieve the strategic aim we have proposed will require, as we have argued above, a comprehensive and integrated strategy on energy for Scotland.

We consider that there are four key components of action required to achieve the aim in the context of the Scottish programmes for sustainable development and for climate change.

First, **the efficiency of energy use should be much more effective**. Policy, instruments and action, including societal behaviours, should all aim to reduce the amount of energy used to provide a given outcome compared with the present.

Secondly, **cleaner sources of energy should be used.** This can be achieved by reducing the proportion of fossil fuels, implementing technologies that will reduce the level of emissions from their continuing use, and developing effective instruments to encourage low carbon fuels and discourage greenhouse gas emissions. Fuel substitution, both to achieve emissions reduction targets and to achieve security and safety of supply of energy, will be a key activity.

Thirdly, **research, development and demonstration of new technologies will be needed.** This should build on existing intellectual and technological prowess and should also play to Scotland's strengths on renewable energy technologies.

Fourthly, will be the need to **implement more effective means of improving the operation of the market.** We will argue for instruments that have clearly defined objectives and outcomes, and are precisely targeted in relation to efficiency, fuel substitution and research, development and demonstration.

The remainder of this report addresses each of these issues as follows:
Chapter 6 considers the behaviours and mechanisms needed to improve efficiency of energy use;
Chapter 7 reviews the options for transport, heat and electricity, particularly in terms of fuel substitution and the instruments;

Chapter 8 reviews research, development and demonstration in relation to low carbon approaches and Scotland's leadership; and

Chapter 9 identifies the range of decisions needed when and by whom, the institutional structure changes needed, and the inclusion of the public and the articulation of societal values in the decision-making process.

As a prelude to these chapters, we first review in Chapter 5 the range of technologies and assess their likely availability to the middle of the century.

5. ASSESSMENT OF ENERGY TECHNOLOGIES

Introduction

In this chapter we review some of the technologies for energy. Our summary is in Table 9. In Appendix F we present a detailed assessment of the energy supply option for coal, oil, gas, hydroelectricity, nuclear, wind, marine, biomass (including waste), solar and geothermal energy. We begin with a synopsis of our conclusions. However, the technical considerations do not end there. Many of the fuels have to be sourced, processed and brought to the market and these activities also have technical issues associated with them. Full lifetime assessments must take these into account.

There are technologies which, at first sight, appear to be tangential to energy issues but have the potential to source and process fuels much more efficiently and, hence, reduce lifetime costs. As we shall see later, there are technologies that reduce massively the need for energy. All these technologies are at various stages of development and we conclude with estimates of timescales over which they may become relevant.

Table 9: Supply Technologies Assessments

Energy generation technology	**Coal**
Primary Source	Global: 907Bt coal reserves; UK: The estimated established reserves amount to 222 Mt with a further known potential of 380 Mt; in addition currently un-accessed deep mine and open cast resources potentially provide many years of future production at present levels (The Coal Authority)
Demand	Global: 6060 TWh in 2002; UK produced 25 Mt and imported 36 Mt of coal in 2004 (DUKES); Scotland: 7 Mt in 2003 (The Coal Authority)
Final Consumption	Global: 39% of world's electricity is provided by coal (WEO); UK: 36% of electricity; Scotland (2002): 32% of electricity (Scottish Energy Study 2006). In 2004, 50.5 Mt of coal was consumed by UK power stations.
Reserve life span	Over 200 years
Environmental Issues	Bings of tailings; Opencast mines; smoke contains sulphur, NOx, CO and CO_2
Energy generation technology	**Gas**
Primary Source	Global: 180 trillion cubic metres at the beginning of 2004 (WEO). Proven gas reserves are equal to about 66 years of production at current rates (WEO). At 2003, estimate of remaining UK reserves in present discoveries was 1,241 billion cubic metres (DTI UK Energy in Brief 2005).
Demand	Global: 2622 bcm in 2002 (WEO); Scotland- in 2002 nearly 400TWh of gas was extracted and transported through Scotland- mostly to England (Scottish Energy Study 2006)
Final Consumption	Scotland: 84.94 TWh (Scottish Energy Study 2006). Global: Gas fired generation accounted for 19.1% of electricity in 2002 (IEA); UK: 37% of electricity supplies in 2003 (DUKES); Scotland: 19% of electricity generation in 2002 (Scottish Energy Study 2006). Total UK natural gas

	consumption in 2004 was 1,119.8 TWh. In UK, Electricity generation accounts for 30% of all natural gas consumption (DTI UK Energy in Brief 2005).
Reserve life span	30-50 years dependent on the rate of new finds and rate of consumption
Environmental Issues	Combustion produces CO, CO_2; Oil and gas exploration effects on sea bed from platforms and pipelines
Energy generation technology	**Oil**
Primary Source	Global: BP puts global oil reserves at the end of 2003 at 1,148 billion barrels (WEO). At 2003, estimate of remaining UK reserves in present discoveries was 1,267 Mt. (DTI UK Energy in Brief 2005)
Demand	Global: 77 million barrels per day in 2002 (2% growth per year) (WEO). UK: In 2004, 87.5 Mt of crude oil was produced, 55.9 Mt was imported and 60.7 Mt was exported (DUKES).
Final Consumption	Scotland: 61.1 TWh in 2002. 46.77 TWh of this was consumed as transport energy. Its use for electricity is primarily for nuclear standby (Scottish Energy Study 2006)
Reserve life span	30-50 years dependent on the rate of new finds and rate of consumption
Environmental Issues	Combustion produces CO, CO_2; Oil and gas exploration effects on sea bed from platforms and pipelines; particulates; Fires at storage depots.
Energy generation technology	**Hydroelectricity**
Primary Source	Rivers and lakes
Demand	Global: 2,726 TWh (IEA); UK large scale hydro generation (2004): 4,648 GWh (DUKES); Scotland (2002): 3,696GWh (Scottish Energy Study 2006)
Final Consumption	Global: 16.2% of global electricity; UK: Hydro accounted for 1.25% of electricity generated in the UK in 2004 (DTI UK Energy in Brief 2005). Scotland: Hydro accounts for approximately 10% of electricity generated.
Reserve life spans	Infinite
Environmental Issues	Flooding and water flow impacts; effect of EU Water Framework Directive; CO_2 impact of construction and demolition
Energy generation technology	**Nuclear fission**
Primary Source	Global (2003): 4.59 million tonnes of known conventional resources of Uranium <130 $/t (OECD NEA/IAEA Uranium Resources, Production and Demand 2003)
Demand	Global (2003): 2635 TWh - 16.6% of worlds electricity (IEA); UK (2004): 73.6 TWh - 19% of electricity (DTI UK Energy in Brief 2005; DUKES); Scotland (2002): 15.8 TWh - 35% of electricity (Scottish Energy Study)
Final Consumption	Electricity
Reserve life span	>60 years Uranium
Environmental Issues	Radioactive waste/emissions; CO_2 impact of construction and demolition

Energy generation technology	**Wind**
Primary Source	Wind
Demand	Global (2003): 63001 GWh (IEA); UK (2004): 0.93 GW (1935 GWh) (DUKES); Scotland: 0.71GW installed, 0.39 GW under construction, 0.89 GW consented and a further 5.6 GW in planning (Scottish Renewables Forum 2006)
Final Consumption	Electricity
Reserve life spans	Infinite
Environmental Issues	Noise pollution; bird kills; landscape impacts; CO_2 impact of construction and demolition
Energy generation technology	**Hydrogen and Fuel Cells**
Primary Source	Natural gas, coal, biomass and water
Demand	Demonstration projects to power vehicles; Peterhead power station
Final Consumption	Electricity
Reserve life span	Depends on primary source: 30-50 years to infinite
Environmental Issues	Disposal of fuel cells; clean emissions; danger of hydrogen leakage with consequent production of methane
Energy generation technology	**Biomass and waste**
Primary Source	UK (Defra Biomass Task Force 2005): 47.4 - 55.8 TWh Heat&Electricity potential from forestry waste, waste wood, energy crops, cereal straw, municipal solid waste, sewage sludge, animal and bird manure; Scotland (Scottish Parliament Information Centre Briefing): 1.5 - 3.4 TWh potential from wood fuel
Demand	Global (IEA Gross electricity production 2003): Solid biomass 120 TWh (247.5 TWh Gross heat production), Municipal Waste - 44.7 TWh (142.5 TWh heat), Industrial Waste - 17.7 TWh (17.7 TWh heat); UK (2004): 7.3 TWh (643 ktoe heat) (DUKES); Scotland (2002): 0.2 TWh (Scottish Energy Study 2006)
Final Consumption	Electricity and heat
Reserve life span	Infinite
Environmental Issues	Close to carbon neutral depending on fuel transport requirement. Potential air pollution from industrial and municipal wastes
Energy generation technology	**Marine (Tides and Waves)**
Primary Source	The sea
Demand	Global (IEA 2003): 572 GWh; UK (2004): 0.5 MWe installed capacity (DUKES); Scotland: 0.27 MW (Scottish Renewables Forum 2006)
Final Consumption	Electricity
Reserve life span	Infinite
Environmental Issues	Depends on technologies used and locations. Potential impact on water flows, sediment movement and marine biota
Energy generation	**Solar Heat and Photovoltaics**

technology	
Primary Source	The Sun; UK: 300 W/m2 available solar energy
Demand	Global (IEA 2003): Solar Photovoltaics 555GWh, Solar Thermal 548 GWh; UK (2004): 4 GWh generated in 2004 and 24.6 ktoe in solar heating (DUKES)
Final Consumption	Heat or electricity
Reserve life span	Infinite
Environmental Issues	Manufacture uses hazardous substances.
Energy generation technology	**Geothermal**
Primary Source	Radioactivity in rocks or trapped background heat in groundwater
Demand	Global (IEA 2003): 53.7 TWh; UK (2004): 0.8 Ktoe heat generation (DUKES)
Final Consumption	Water heating and electricity
Reserve life span	Infinite
Environmental Issues	Potential release of dissolved gases such as carbon dioxide (CO_2) and hydrogen sulphide (H_2S). Disposal of waste waster (which contains potentially toxic dissolved minerals from subterranean rocks)

(1)Fossil Fuels

Global resources of oil and gas are limited and dependent on new finds and, on current consumption rates, could run out in 30 to 50 years. Coal reserves are available for at least two centuries.

With the introduction of the Large Combustion Plant Directive, requiring the introduction of supercritical boilers and flue stack desulphurisation, many of the concerns about emissions from coal-fired power stations will be allayed. For coal, a number of proposals exist for lowering the carbon emissions to the level of the least polluting fossil fuel, gas. One of these is the integrated gasification proposal; there are four demonstration plants in the US, but commercial stations are some way off. New boilers markedly increase efficiency from the industry norm of about 35% to the industry target of approximately 50%. Co-firing coal stations with biomass also reduces the total level of carbon emissions. A demonstration plant exists in Canada where carbon dioxide is disposed in coal seams displacing methane and thus producing a cleaner fuel. These measures are part of a carbon abatement scheme.

For all fossil fuels, there remains the question of greenhouse gas emissions and the impact on global climate change. The carbon abatement programme may lead to cleaner coal, but coal cannot be considered ‘clean’ until there is carbon sequestration. Carbon capture and storage would be applicable to all fossil fuel combustion and, in the case of biomass, would actually lead to a reduction in atmospheric carbon dioxide.

The Peterhead power station/Miller field proposal to use the carbon dioxide emissions to assist the enhancement of recovery from depleted oil and gas fields is attracting world-wide interest and a similar project is being established in California. However, this means of sequestration depends on the proximity of a suitable field.

Besides storage in depleted oil and gas fields alternative proposals include deep saline aquifers, unmineable or redundant coal fields, and storage in porous sandstone under a impermeable rock seal). These technical developments could be made in 5-10 years, although there are technical problems still to be overcome. Carbon dioxide must be concentrated from flue gases, this is not yet technically feasible. Portland cement reacts rapidly with carbon dioxide. Thus borehole cement plugs must be developed to prevent leakage, as highlighted in the House of Lords Science and Technology report.

Deep oceanic disposal is now considered environmentally unsound due to the risk of acidification. A similar concern would apply to any geological storage that might contaminate fresh water aquifers.

For oil and gas extraction from more hostile environments, there will need to be continual technical development, for example of extremely deep geological drilling, often in extremely deep offshore waters; of oil extracted from regions of extreme cold where it does not ‘flow’, again often from deep offshore wells; and, as the delivery of natural gas is increasingly in liquid form, of techniques for safe storage and transportation.

(2) Nuclear Fuels

The first thermal nuclear generating station in the world was opened in the UK at Calderhall, Cumbria in 1956. The first technical problem to be overcome was the isotopic enrichment of uranium and, in the future, possibly thorium. This barrier is removed by any nuclear reactor since, in the natural fuel cycle of a fission plant, fissile plutonium is created. If the reactor is shut down, the plutonium can be removed by relatively simple chemical processes and used to seed uranium as a fuel in future reactors or accumulated for nuclear weapons.

There are two sources of nuclear fuel. The primary source is freshly mined and enriched uranium. The secondary source is plutonium stockpiled during the Cold War and reactor core material that can be reprocessed. Currently 40% of nuclear fuel comes from secondary sources. The UK with its early entry into nuclear power and with its stockpiles of weapon grade material holds significant sources of secondary fuel The availability of future supplies of secondary fuels depends on the reprocessing capacity, the cost of uranium, and the development of fast breeder reactors. The principal suppliers of primary fuel are Australia and Canada.

Having established a source of fuel the next technical question is the selection of a moderator to slow the terminal velocities of the neutrons. Water, or rather the hydrogen it contains, would seem to be ideal. However, hydrogen absorbs neutrons and increased, expensive, enrichment is required, to maintain the chain reaction. The next best moderator is heavy water, containing deuterium, a heavy isotope of hydrogen. This does not absorb neutrons but heavy water is expensive to produce. Finally, there is carbon which, while not as effective as hydrogen or deuterium, is inexpensive and easily worked in the form of graphite.

The last element is the choice of coolant to carry the heat from the core to the generator. Water would seem to be the natural choice except that it absorbs neutrons, but it also acts a moderator and hence more compact reactor cores can be designed. Alternatively, carbon dioxide gas can be used to carry the heat and act as moderator.

The various reactor technologies evolve around the degree of enrichment, choice of moderator and selection of coolant. Commercially the most successful technology has come from the US developed High Pressure Water Reactors (PWR). The Canadians have developed a family of CANDU reactors with minimally enriched uranium fuel and deuterium moderation. The bulk of the UK nuclear fleet consists of graphite-cored reactors cooled by carbon dioxide and called Advanced Gas Cooled Reactors (AGR). The last nuclear reactor to be commissioned in the UK was the Sizewell PWR (1995) based upon a design that is nearly forty years old.

A number of countries, the USA, Japan, South Korea, Russia and France, are developing advanced versions of the pressurised water reactors. The USA and a Swedish, French and German consortium are developing advanced boiling water reactors, while Canada and India continue the development of heavy-water moderated designs. Close to market developments include the Russian fast breeder reactor (FBR) and the South African pebble bed modular reactor (PBMR).

Current and future types of reactors all have passive safety features making a Chernobyl type incident impossible. Indeed, the in-built design of safety engineering is what led to the Three Mile Island reactor safely closing down without any human damage while its absence led to the Chernobyl explosion. In both cases, the incident was triggered by human failure, indicating that the engineering should never be dependent on human intervention but should rely on built-in, fail-safe engineering.

Current and future types of reactors are all considerably simpler in design and are half the size and half the cost of their predecessors. For example a comparison of the AP1000 with the Sizewell PWR shows: 50% fewer valves, 35% fewer pumps, 80% less pipe-work, 80% fewer heating vents and cooling units, 45% less building volume and 70% less cabling. They do use less fuel and produce less radioactive waste. There is capacity for simplicity in procurement through standardisation of components and simplicity in operation and maintenance through the use of proven systems and components and advances in operator-machine interfaces.

Over fifty years experience of nuclear reactors in the UK have demonstrated a level of safety unmatched by any other industrial activity of comparable scale. The reactors themselves are designed to withstand the direct impact of a Boeing 747 and hence should be considered secure against a 9/11-type terrorist attack.

There remains, however, justifiable concern about the management of radioactive materials outside the reactor. There have been a number of widely reported incidents at the temporary waste stores at Sellafield and Dounreay and at the reprocessing plants at Sellafield. In the vast majority of these incidents, the effects of the incident have been contained within the site boundaries. The security of radioactive materials stored at reactor sites outside the reactor itself also requires consideration. Above all, there are concerns about the long term handling of nuclear waste.

Much has been made in Scotland of the absence of a solution to the safe disposal of radioactive waste from nuclear power plants. In fact, a great deal of geological, geochemical and engineering work has been undertaken internationally on the transport, encapsulation, storage and geological disposal of waste, and ways of determining the integrity of repository sites for very long time periods. In practice, solutions to many of these issues have been determined in several countries, and management and disposal strategies agreed. The UK Committee on Radioactive Waste Management (CoRWM), after an extended period of public consultation, has made its preliminary conclusions (April 2006) that phased, retrievable, deep geological disposal is the preferred mechanism, and that a relatively large proportion of the area of Britain could be geologically suitable compared with countries where long term management has been agreed. The way is now clear for a detailed long term management strategy for radioactive waste to be developed. Final decisions on this should not be used as an objection to the re-development of nuclear-fuelled electricity generation.

(3) Biomass and Waste

The combustion of biomass and waste is a mature technology, even if it is not a large feature of the UK energy mix. While there is always the possibility of incremental improvements in the efficiency of combustion plants, the real technical challenges lie in the advanced technology for producing biofuels.

There are two principal sources of biomass generated transport fuels; bioethanol and biodiesel.

Bioethanol is most efficiently produced from rapidly growing, high sugar content crops (sugar cane in Brazil, maize in the Prairie States of North America). Enzymic systems for producing bioethanol from lignin are being studied, particularly in Canada. In a Scottish context, bioethanol is not likely to be a significant part of our home grown energy supply, especially as the sugar beet industry is no longer in operation. Bioethanol is likely to use more energy than it saves in its production and this is made worse if it is imported.

Biodiesel can be produced from a wide range of waste sources, tallow from meat rendering and used cooking oil, etc. and oil crops, such as rapeseed. More realistic for Scotland is biodiesel produced from oil crops such as rape, and also linseed, sunflower and others. Plant oils can fetch a good price for industrial or food uses. Farmers must get a guaranteed market and good price if they are to sell for biodiesel production. There are small-scale plants that can produce biodiesel for on farm use. In Scotland, the use of biodiesel is most efficient close to the source and will probably find its niche market for agricultural machinery.

We accept that the tradition of using peat as a fuel for domestic use will continue in certain parts of Scotland. The level of extraction should, as far as possible in any one locality, be equivalent to the natural regeneration in the locality.

(4) Wind and Marine

Wind technology is well developed. Traditionally, the greatest pollutant from wind has been noise. There are significant mechanical and civil engineering problems associated with quieter wind turbines and with the stresses arising from larger turbine blades.

There is considerable interest in microgeneration from wind power. The Edinburgh based Renewable Devices Ltd (RDL) was formed just under six years ago. Described as "the world's first silent, building-mountable wind turbine," the SWIFT Rooftop Wind Energy System, developed by RDL, is an upwind horizontal axis turbine that can generate 1.5kW – and produces noise of less than 35 dBA regardless of wind speed. The company Proven is also active in this field.

The European Marine Energy Centre (EMEC), located in Orkney, has a strong record of contributing to the development of wave and tidal power generators from Salter's duck through the Oscillating Water Column to Pelamis. Pelamis, the world's first full-scale wave power station, was designed and proven in Orkney before construction in Lewis and in Fife for delivery to Portugal The field of marine power is in need of technical development at all levels from novel, reliable generating systems to the issues of power harnessing. The major technical issues may lie in the areas of accessibility and reliability of large-scale plants operating in remote and often highly violent hydrodynamic environments. There are strong academic links between the EMEC and the Institute for Energy Systems at the University of Edinburgh, Universities of Strathclyde and Glasgow and the Centre for Research in Energy and the Environment at Robert Gordon University.

(5) Solar power

Scotland is not well placed to exploit the heating power of the Sun: sunshine is needed for heat but photovoltaics can perform in sunlight (albeit at lower efficiency). However, the development of photovoltaic materials offers interest as stand alone microgeneration systems where cable connections are not a practical proposition. Research into photovoltaics is being pursued by universities and other laboratories.

(6) Hydrogen

Currently there is considerable interest in developing an alternative to fossil fuels as a means of transporting non-electrical energy. The use of hydrogen as an energy carrier has a number of benefits in this respect, notably:

- It can release energy with minimal pollution: the only by-product of combustion is water.
- It can produce both heat and electricity (in fuel cells).
- It can transfer more energy per unit mass than fossil fuels.
- It is readily transported by pipelines, and can be converted to solid form (e.g. Liquid Hydrogen).

Hydrogen is a vector for fuel and is not a fuel in its own right. To produce hydrogen requires the consumption of energy either from fossil fuels, or by electrolysis. The only by-product of hydrogen combustion is water when used in a fuel cell. However, in an internal combustion engine the high combustion temperature results in the formation of oxides of nitrogen, and to overcome this problem, new hydrogen burners will require to be developed.

The cheapest commercial process for the manufacture of hydrogen is by reforming methane, but this does produce CO_2 at the point of production. Production of hydrogen using wind energy is not carbon-free, as carbon is produced both during the manufacture and the decommissioning stages, and is also an expensive way to produce hydrogen. Using nuclear energy in the electrolysis of water and, in the future, high temperature thermochemical production using nuclear heat are possibilities, but are also very costly.

There has been a great deal of speculation about the development of a hydrogen economy. But there are a number of hurdles to be overcome first: investment in production, transport and storage infrastructure, and stimulation of demand.

Major progress is being made in using hydrogen as a fuel for transport, thus preventing the production of CO_2 emissions. Whilst hydrogen can be used in a normal combustion engine, and trials have been carried out in cars, in the medium term its main use will be via fuel cells. The commercialisation of fuel cells represents the greatest development to initiate the use of hydrogen. In a fuel cell, hydrogen and oxygen react together to produce electricity at relatively low temperatures with the only waste product being water. As part of the EU CUTE programme, the largest hydrogen bus demonstration in the world, three fuel cell buses are being run by London Transport. These are supplied by the only hydrogen fuelling station in the UK, operated by BP at Hornchurch.

However, until costs are reduced and mass production is developed, the evolution of a hydrogen economy will be slow. Considerable progress is being made in other countries, notably the USA, Canada, Germany and Japan.

There are many technical problems associated with safe combustion of a gas that would normally burn explosively in air. A major difficulty is that, unlike LPG and LNG, it will probably never be practical to provide it in liquid form except for niche utilisation, such as space launchers. However, it can be stored at densities greater than its gas form by absorbing it in solid hydrides and creating a fuel cell. The principal technical issues surround the capacity of fuel cells that limit transport to low performance and short journeys. A major advance would be the development of a hydrogen-powered aero-engine. As an aviation fuel, hydrogen has the advantage of being lighter than air and its replacement of kerosene would allow the continued development of air travel without the consequent destruction of the ozone layer and would remove one of the most damaging sources of atmospheric pollution.

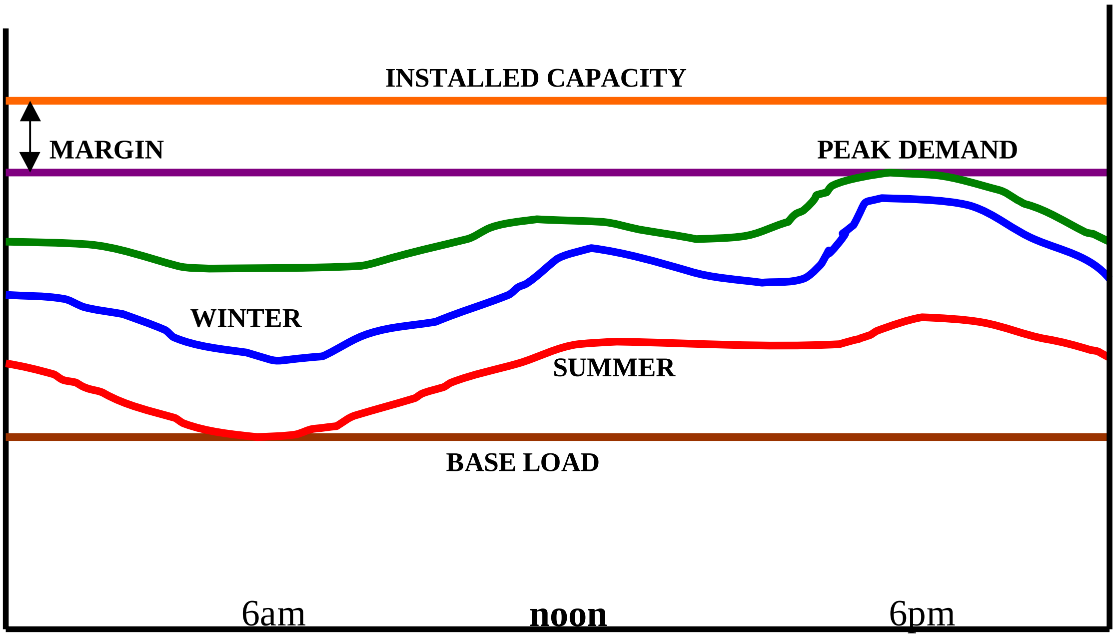
‘Clean’ hydrogen can be produced from water by wind power or nuclear power and could thus be used to flatten completely the demand curve for electricity, much as pumped storage is used to improve the load factor for hydroelectricity. However, hydrogen, being a small molecule, leaks easily. Such escapes into the atmosphere, would result in an increase in methane. Escapes would also have an effect on nitrogen fixing in the soil.

(7) Electricity

Almost all the source technologies, with the possible exception of geothermal energy, can be used to generate electrical power. This power uses a common carrier, the national grid, to deliver energy to the consumer. To understand the choices that may be available, it is necessary to understand how the various generation alternatives contribute to overall security of supply.

Since electricity cannot be stored in large quantities, supply must be capable of following the changes in demand, often over a few minutes, and in this respect all means of generation are not equivalent. Different sources of electricity generation are not interchangeable. The demand for electricity varies throughout the day, the week and the season. This is illustrated in Figure 26 showing the typical variation in electricity demand through the day and between seasons.

Figure 26: Daily and seasonal electricity demand variation



Source: derived from various sources, including The National Grid Company Seven Year Statement

The summer minimum defines the base load that is always required. There is always a loss of electrical energy during transmission and some of the power is used by the generators themselves. Adding this loss and self use to the winter demand curve gives the green curve. The maximum of this curve represents the peak demand imposed upon the system. In order to ensure supply, allowance has to be made for generating stations that go offline instantaneously due to faults, or for the need for planned or unplanned maintenance, or interruptions to fuel supplies, etc; this requires a margin of installed capacity over the peak demand. For the UK, the typical base load is 30-40% of peak demand; operating considerations mean that it is desirable to have a minimum margin of about 20%. For example, nuclear power does not have the flexibility to efficiently follow load demand and is therefore only suitable for base load provision. At the other extreme, hydroelectric power can respond extremely rapidly to load changes and is ideally suited for dealing with rapid variations in demand. Base load can be assured by any combination of fossil fuels, biomass, hydroelectricity, nuclear and, when available, marine.

We give our estimates of electricity generating capacity in Table 10 below.

Table 10: Scottish power plants: existing, consented, and planned

Plant Type	Existing (MW)	Consented (MW)[1]	Planned (MW)[1]
Coal	3456	0	0
Nuclear	2440	0	0
Oil & Gas	1793[2]	400	0
Pump Storage	700	0	0
Landfill Gas	39	45	0
Hydro	1265	118[3]	17[3]
Onshore Wind	712[3]	1106[3]	5,678
Offshore Wind	0	180	10[3]
Biomass	12	45	60[3]
Wave/tidal	0.27[3]	0	0
TOTAL	**10,417**	**1,894**	**5,765**

1. 2006 Scottish Energy Study
2. This figure does not include Scottish Power's Inverkip oil-fired power station which has not operated since the 1980s due to the price of oil and is retained as a strategic reserve. The station consists of three generation units with a combined rating of 1900 MW.
3. Scottish Renewables; 1996-2006: Delivering the new generation of energy; March 2006.
4. The figures for wind include all of the proposals reported to National Grid Company in early 2006.

In terms of supplying the variable component of demand, the most efficient use of these alternative sources comes from matching the resource response speed to the rate of demand variation. The response times of fossil fuel generators are similar although, in ascending order, gas has the fastest response time followed by oil and then coal.

Wind power is inherently intermittent and hence cannot be relied upon to provide demand load requirements and is best suited as a substitute for fossil fuel sources, with those fuels being held as backup generation when wind power is not available, in order to reduce greenhouse gas emissions or promote diversity of supply. We emphasise that the need to provide backup capacity is a cost for electricity generation from wind that must be accounted for, and in economic terms represents a loss of efficiency in capital investment.

A diversity of supply is essential to achieve maximum efficiency, minimum cost and security in the supply of electricity.

The variability of demand means that, apart from exclusive base load provision, there are periods when expensive capital generating capacity is not being utilised. It is therefore most cost efficient to take out of service the least capital costly plant at times of lowered demand.

Supply costs

Cost is often cited as a key factor in future energy choice. We have reviewed a wide range of estimates of the cost of different technologies for generating electricity; a summary of these is presented in Table 11. We are aware of criticism from some sources about the Royal Academy of Engineering's figures. We agree with this criticism as far as renewables are concerned and have used instead the OXERA figures.

We conclude that coal, oil, gas, nuclear, waste and biomass (not fuel crops) co-firing all fall within the same cost envelope of 2-3p/kWh, with onshore wind at 3-4p/kWh, and other options either not yet proved or much more expensive. It should be noted that for fossil fuels, 60% of the cost is in the price of the fuel. Since the costings were carried out, the spot price for crude oil has risen from $35-40/barrel to over $70/barrel and gasoline (petroleum spirit) and gasoil has risen proportionately, while heavy fuel oil has shown less volatility. During this period coal has risen from around $35/tonne to around $50/tonne and natural gas from $4-5/MBtu to around $7/Mbtu.

Table 11: Electricity generation costs (Costs are p/kWh)

TECHNOLOGY	Current cost estimate	Medium term Scenario Cost	Potential contribution
Coal			
Coal-fired PF	2.6	4.3	Baseload / Load Following
Coal-fired CFB	2.6	4.4	Baseload / Load Following
Coal-fired IGCC	3.2	4.7	Baseload
Gas			
Gas-fired OCGT	3.1	4.9	Peak load
Gas-fired CCGT	2.2	3.6	Baseload / Load Following
Nuclear			
Nuclear fission	2.3-3.4	2.4-3.5	Baseload
Renewables			
Onshore wind turbine	2.9-3.8	2.3-3.0	Intermittent
Offshore wind turbine	5.8-7.4	3.9-5.0	Intermittent
Marine	10.7-12.8	5.0-6.0	Intermittent
Energy Crop	4.9-5.5	4.1-6.2	Baseload / Load Following
Waste	2.0-2.4	2.0-2.4	Baseload / Load Following
Landfill	2.7-3.2	2.7-3.2	Baseload
Co-firing	0.9-1.1	0.9-1.1	Baseload / Load Following

Notes: (1) Current coal, gas and nuclear costs are based on data from the Royal Academy of Engineering report, The Cost of Generating Electricity (2004), and subsequent estimates. The capital charges assumed for coal and gas were 7.5% plus depreciation over the assumed life of the plant and for nuclear were 7.5%, - 12.5% plus depreciation over 40 years. Fuel was costed at £30 per tonne for coal and at 23p per therm for gas.

(2) The costs of Renewables are based on the OXERA report, Results of Renewables Market Modelling (2004), carried out for the DTI. The renewables figures have been adjusted to exclude cost reductions due to capital grants and cost increases in respect of balancing. OXERA charged capital at 6% for waste, landfill and co-firing; 8% for onshore wind; 11% for offshore wind and 14% for energy crops and marine. The fuel cost of energy crops was taken as £18-36/MWh. Depreciation was straight-line over 20 years.

(3) The medium term scenario for the conventional plants incorporates reductions in cost due to expected increases in efficiency, increases in the price of fossil fuels - by 25% for coal and uranium and by 50% for gas - and carbon costs of £20 per tonne of CO_2. This is much the same as the price of EU-ETS units at the time of compiling the table, and can also be regarded as a proxy for the cost of carbon capture, though not storage. The estimates for renewables take account of projected learning economies as the world-wide total of installations increases.

(4) Oxera figures are used for biofuels as thought to be more accurate than RAE figures.

(5) None of the figures include subsidies, such as ROCs.

(6) The costs of nuclear fission includes estimated decommissioning costs at the time of construction approval.

(7) None of the figures include the cost of carbon.

The relative costs of the various supply options would also clearly change with the addition of a carbon emission charge; this rose from £20/tonne to £30/tonne, but at the time of writing (June 2006) has declined to around £12/tonne. We discuss our proposals for a carbon levy applied at the point of carbon production in Chapter 7.

Capital costs make up a high proportion of the total costs of the more capital intensive generation technologies. As regards nuclear, there is considerable uncertainty over the actual cost per MW of new plant, as well as over the interest rate to employ. The lower figure of 7.5% in Table 11 is consistent with a supportive political climate, some assurance that carbon costs would in future be reflected in electricity prices, and long-term contractual arrangements with suppliers guaranteeing future demand. The higher figure of 12.5% is consistent with an unsupportive political climate and an absence of long-term marketing arrangements for the energy produced.

None of the costs include full life time costs. While this is frequently a criticism of nuclear costings, it applies to all technologies. It is a significant cost factor in coal for bings and pumping of mines, and for hydro in the maintenance and eventual removal of dams. It is highly desirable that a common methodology is developed and applied to all fuel technologies (see below).

Onshore wind is clearly cost-competitive with the addition of the ROCs subsidy. However, the costings presented do not include the intermittency costs to the grid nor the cost of standby provision. The National Grid Company estimates intermittency costs at 0.2p/kWh, but this is market penetration and location dependent. At a 20% penetration, for plant in the North of Scotland the figure could be about 0.7p/kWh. The RAE now estimate the additional standby cost, at 35% wind penetration, as 1p/kWh.

The capital costs of constructing onshore wind turbine installations are now reasonably predictable, but the economic lives are still uncertain, and the capacity factors achieved are heavily dependent on the location. In preparing their estimates, OXERA assumed lives of 20 years, and load factors of 30% and 35% for onshore and offshore wind turbine installations respectively. These figures are both higher than the 27% actually achieved overall in Great Britain but, particularly for onshore wind, are considerably less than has been achieved by individual wind turbines in the Northern Isles, where capacity factors above 50% have been realised. If onshore wind turbine installations could achieve a 40% capacity factor the current cost estimate range would fall to 2.1- 2.8p/kWh.

Waste and landfill gas are cost-competitive on a small-scale local utilisation.

On supply costs we conclude that:

(1) Amongst the fossil-fuel technologies gas-fired CCGT is likely to remain the cheapest, unless gas prices rise very substantially relative to coal. The advantage of gas over coal will also depend critically on the level of carbon costs.

(2) Nuclear fission is a relatively cheap source of electricity, even in unfavourable conditions, as the fuel costs are a small proportion of the total costs.

(3) Onshore wind turbines in suitable locations are also likely to be a cheap source of electricity, even if some standby back-up capacity is required.

(4) Offshore wind turbines, marine sources and energy crops are currently uncompetitive. Offshore wind generation will always be much more costly than onshore generation because of the much higher construction, maintenance and connection costs.

Carbon Abatement Technologies

Against the background of rapidly increasing CO_2 emissions from China, the US and India, where large amounts of fossil fuels are used for electricity generation, Carbon Abatement Technologies (CATs) are a group of innovative technologies that can enable fossil fuels to be used with substantially reduced CO_2 emissions. These include CO_2 capture and storage (CCS), fuel switching to lower carbon alternatives - such as the switch from coal fired power generation to gas turbines and to co-firing schemes using biomass; and higher efficiency conversion processes.

Carbon Capture and Storage (CCS)

Carbon capture and storage is rapidly emerging as a significant CO_2 emission option with potentially important environmental, economic and energy supply security benefits (IEA; Prospects for CO_2 Capture and Storage 2004). But there are still significant technical, safety, commercial and legal issues to resolve. With the major projects up to 15 years away, CCS could be particularly useful in electricity generation, industrial processes and fuels processing.

There are three generic process routes for capturing CO_2 from fossil fuel combustion plants (House of Commons Science and Technology Committee 2006).

(1) Post-combustion capture – this involves the separation of CO_2 from flue gas. The preferred technique at present is to scrub the flue gas with a chemical solvent (usually an amine), which reacts to form a compound with the CO_2. The solvent is then heated to break down the compound, releasing the solvent and high purity CO_2.

This technique is well established in the chemical process industry but, as yet, no large scale capture of CO_2 at coal-fired plants has been carried out.

(2) Pre-combustion capture – involves reacting fuel with oxygen or air, and in some cases steam, to produce a gas consisting mainly of carbon monoxide and hydrogen. The carbon monoxide is then reacted with steam in a catalytic shift converter to produce more hydrogen and CO_2. When this has been done, the CO_2 is separated and the hydrogen is used as fuel in a gas turbine combined cycle plant.

(3) Oxyfuel combustion – consists of burning fuel in an oxygen/carbon dioxide mixture rather than air to produce a CO_2–rich flue gas. Generally, the oxygen is derived from an air separation unit, and the oxygen/CO_2 mixture is produced by re-circulating some flue gas to the combustor. The captured carbon dioxide is pressurised to become a dense phase supercritical fluid and is transported to the point of storage normally by pipeline.

Once captured potential ***Storage Options*** have to be considered.

Oil Reservoirs are a good solution since prior to exploitation their seals have retained hydrocarbons over geological timescales. Also they will have been extensively investigated and mapped during production, thus providing essential knowledge for selecting suitable reservoirs and managing their utilisation. The capacity of an oil reservoir to store carbon dioxide is made up of the pore space vacated by the oil, together with additional pore space occupied by ‘bottom waters’ lying below the oil formation. Enhanced Oil Recovery (EOR) may use CO_2 to mobilise some of the oil remaining in a reservoir after primary and secondary production is complete. It should be noted that the use of this storage method does give rise to CO_2 emissions.

Gas fields exist because they have seals that prior to exploitation prevented migration over long periods of time. Although CO_2 injection could help with some additional gas extraction from a field, the benefits are less than for EOR and storage would generally be considered when the field was largely depleted.

Deep saline aquifers offer the largest potential storage capacity. They could be used because, due to their depth and high dissolved mineral content, they have little, if any, foreseeable value as a source of water for drinking or irrigation.

Unmineable coal seams are a strong storage option, where the CO_2 is preferentially absorbed by the coal, displacing previously absorbed methane. This is currently at the research stage. In addition to offering CO_2 storage, there is potential to collect the desorbed methane, thus gaining a financial return.

Deep saline aquifers, depleted oil reservoirs and gas fields and unmineable coal seams offer the best options for underground CO_2 storage. Deep saline aquifers have hundreds of years worth of storage capacity of between 1000 and 10,000 Gigatonnes. There are opportunities, both onshore in Scotland and offshore in the northern North Sea.

The only large scale aquifer storage demonstration project currently operating is the Sleipner field in the Norwegian sector of the Northern North Sea. It has shown no leakage over the last eight years. However, there are still concerns that leakage could reduce emission reduction effectiveness and there are public concerns that such leakage could be dangerous.

Worldwide there are a number of CCS projects in place, as illustrated by Table 12 (IEA; Prospects for CO_2 Capture and Storage 2004), although more needs to be done on the transportation of the CO_2 and its storage to improve the economics of this technology as each project has its own distinctive advantages and problems and cannot automatically be replicated. In Norway, for example, all future gas turbine plants to produce electricity will have CCS fitted probably for EOR schemes.

Table 12 : Number of Worldwide CCS Projects

CO_2 Capture Demonstration Project	11
CO_2 Capture R&D	35
Geologic Storage Projects	26
Geologic Storage R&D Projects	74
Ocean Storage R&D Projects	9

The costs of generating electricity from current coal and gas fired plant without any penalty for CO_2 emissions and with a penalty of £30 per tonne for CO_2 emissions are shown in Table 13.[11]

Table 13: Current Electricity Costs with and without carbon penalty

Technology	**Zero Cost**	**£30 per tonne**
Coal fired pulverised fuel	2.5 p/kWh	5.0 p/kWh
Coal fired circulating fluidised bed	2.6 p/kWh	5.1 p/kWh
Coal fired integrated gasification combined cycle	3.2 p/kWh	5.2 p/kWh
Gas fired open-cycle gas turbine (OCGT)	3.1 p/kWh	4.8 p/kWh
Gas fired combined-cycle gas turbine (CCGT)	2.2 p/kWh	3.3 p/kWh

Table 14[12] gives the estimated cost of Carbon Capture and Storage, and Table 15 (House of Lords Select Committee on Economic Affairs 2005), gives the illustrative costs of emission-reducing technologies.

Table 14: Cost of carbon capture and storage

	3 USc/kWh (2.5 Euro c/kWh)
Current buy-out price for UK renewables	Over 3p (5 Euro c)/kWh
Premium for wind power under the German Renewable Energy Law	9 Euro c/kWh

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[11] The Royal Academy of Engineering RAE response to DTI Consultation Document; October 2004.
[12] World Coal Institute

Table 15: Costs of emissions reducing technologies

Technology	**Marker**	**Cost Unit**	**Cost of Marker**	**Cost of Substitute**	**Net cost**
Near term estimate (10 years time):					
Nuclear	NG/CC	c/kWh	3.5	6.0	2.5
Hydrogen from coal or gas + CCS	NG	$/GJ	4.0	8.0	4.0
Electricity from fossil fuels + CCS	NG/CC	c/kWh	3.5	5.0	1.5
Wind	NG/CC	c/kWh	3.5	5.0	1.5
Photovoltaic (solar input = 2000kWh/m2)	Grid electricity	c/kWh	10.0	15.0	5.0
Biofuels	Petrol	$/GJ	12.0	15.0	3.0
Distributed generation	Grid electricity	c/kWh	10.0	15.0	5.0
Long term estimate:					
Nuclear	NG/CC	c/kWh	4.0	5.0	1.0
Hydrogen from coal or gas + CCS	NG	$/GJ	5.0	10.0	5.0
Electrolytic Hydrogen (onsite and distributed)	NG (distributed)	$/GJ	10.0	30.0	20.0
Electricity from fossil fuels + CCS	NG/CC	c/kWh	4.0	6.0	2.0
Wind	NG/CC	c/kWh	4.0	6.0	2.0
Photovoltaic (solar input = 2000kWh/m2)	Grid electricity	c/kWh	10.0	8.0	-2.0
Biofuels	Petrol	$/GJ	12.0	15.0	3.0
Distributed generation	Grid electricity	c/kWh	10.0	10.0	0.0

Notes: NG = natural gas; NG/CC is natural gas – combined cycle power plant; CCS is carbon capture and geological storage; c = US cents (The Marker is the technology that would be displaced by the technology named in the first column.)

Table 16 on the other hand, indicates the increased costs where using carbon sequestration (RAE 2004)

Table 16: Costs of carbon sequestration

Technology	Basic Cost (p/kWh)	Cost with Carbon Sequestration (p/KWh)
Coal Fired Pulverised Fuel	2.5	5.0
Coal Fired Integrated Gasification Combined Cycle	3.3	5.2
Gas Fired Combined Cycle Gas Turbine	2.2	3.3

Cost of Generating Electricity with respect to CO_2 emission costs (£30 per tonne)

It has been estimated that Carbon Capture and Storage will reduce the overall efficiency of the electricity generating process by between 10% and 20%.

Development of Carbon Free Technologies

Scenarios for the reduction of CO_2 emissions have been developed by the Tyndall Centre (Tyndall Centre for Climate Change Research 2005). Changes in carbon emissions are related to the efficiency with which energy is used, the change in carbon intensity of the energy supply system and the change in the energy service provided which is very dependent on changing behaviours and social practices. The formula used is as follows:

CO_2 emissions = carbon intensity x energy intensity x consumption intensity x population

A strategy for developing carbon abatement technologies when using fossil fuel has been reviewed and labelled in a DTI document (DTI; *A Strategy for Developing Carbon Abatement Technologies for Fossil Fuel Use* 2005). This study concluded that the technologies needed to make progress are available today. A delay of 10-15 years is unnecessary, and 3-5 years would be more realistic if CO_2 reduction is to be achieved. The barriers are not technical, but are created by the government's definition of incentives needed to stimulate investment and achieve the goals. A carbon levy may be the most effective driver.

A comprehensive review of the situation in the US, covering current and future technologies for coal fired plant, together with costings and the methodology for estimating the costs has been carried out by Williams and Hawkins (2005).

In the case of transport, routes to CO_2 reduction include (Kemp 2004):

- Increasing efficiency of road and rail vehicles to use less fuel per passenger-km or tonne-km,
- Reducing the overall amount of personal travel and movement of goods,
- Transferring passengers and freight from high-consumption modes (for example, from road to rail), and
- Obtaining energy from non-carbon sources.

A recent meeting of International Experts (International Scientific Steering Committee 2005) concluded that:

> "Technological options for significantly reducing emissions over the long term already exist. Large reductions can be attained, using a portfolio of options whose costs are likely to be smaller than previously considered. Substantial development strategies can make low-level stabilisation easier. There are no magic bullets; a portfolio of options is needed and excluding any options will increase costs. Multi-gas strategies, emission trading, optimal timing and strong technology development, diffusion and trading are all required to keep costs of low-level stabilisation relatively low. Inclusion of technological learning in models suggest that projected costs of such reductions can be reduced by over half. To make required action

> more specific and transparent the challenges could be broken down into discrete wedges covering for example, energy efficiency, nuclear energy, low emission transport fuels and fossil fuel power plants with CO_2 capture and storage.”

New tangential technologies

The fastest-growing energy demand sector is transport and this is 98% dependent on oil-based fuels. Carbon sequestration from power plants may become available in the near future, but it is unlikely ever to be applicable to millions of independently powered vehicles. The fuel replacement options of electricity and hydrogen, if they can be proven, will take decades before there is significant market penetration. The most damaging, and second fastest growing, element in the transport sector is aviation. One part of this sector is becoming obsolete. An alternative to people travelling to meet people is becoming available through the extremely rapid development of digitally based communication systems. This becomes a more acceptable alternative to travel as the images improve. Life size high definition images are now available, at a price. We can imagine in the near future, laser powered, three-dimensional, holographic images. Given the staggering rate of development in the communication technologies over the past twenty years, it is possible that this option may become available sooner than the application of new transport fuels.

Another element in the transport sector is the global carriage by air of exotic and perishable fruits and vegetables. It may be possible to use the enormous quantity of currently wasted heat from industrial processes and especially from current and future electricity generating stations to produce goods closer to the plants and the consumer.

Many industrial processes require the use of heat and would benefit from a source that could concentrate its application. High-powered microwave generators have the capacity to provide focussed concentration of heat far more effectively than traditional heat sources.

In the mining of coal and ores, enormous quantities of energy are used to pulverise rock. Again extremely high-powered microwave sources have the potential to break up rocks far more efficiently than conventional mechanical methods.

In the future energy utilisation efficiency will require fast monitoring and control of fuel systems provide by ever more sophisticated electronics.

In summary, new technologies will be required to provide solutions to energy issue problems. Some relevant technical areas are easily identified, others will take us completely by surprise. The case for maintaining a broad technical skills base is overwhelming.

Assessment methodologies

We are concerned that there are no robust procedures in place for assessing energy technologies. Many assessments undertaken are not sufficiently objective to inform the decision-making process and to reassure the public that openness and objectivity have been applied in practice. To overcome these problems a number of developments are necessary.

A common methodology should be developed. We identify nine factors that should be used in all future assessments:

1. state of technology,
2. infrastructure requirements,
3. security of supply,
4. carbon benefit,
5. effects on water quality,
6. use of waste produced,
7. costs to the consumer,
8. effects on communities, and
9. effects on natural heritage assets.

In addition, the assessments of technologies must take into account the full lifetime costs, and an audit of their carbon effects. The methodology should be applied in an independent manner. For these reasons, we make the following recommendation.

> **Recommendation 6:** A common methodology could and should be developed by the proposed Energy Agency for Scotland to assess the relative merits of energy technologies, using the nine factors identified. It should include full lifetime costs and a carbon audit. Assessments using the methodology should be undertaken independently of specific interests and be open to public scrutiny.

The variety of technologies and their varying speed of development for the market often create uncertainty for decision-makers and for the public. We recommend that the proposed Energy Agency for Scotland (see Chapter 9) is tasked with providing an on-going energy technology scrutiny and advisory service.

> **Recommendation 16:** An energy technology scrutiny and advisory service should be established by the Scottish Executive. Ideally this should be part of the functions of the proposed Energy Agency for Scotland with ITI Energy.

6. EFFICIENT USE OF ENERGY

We argue in this Chapter that improvements in energy efficiency offer the easiest and most cost effective way over the next few decades to minimise the impact of climate change and to conserve fossil fuel stocks. This can be done while maintaining economic growth and a good quality of life which, without energy efficiencies, would be at risk.

We define energy efficiency as the ratio of the energy we extract from a fuel to the total amount of energy available in that fuel. Energy saving is slightly different and means reducing the absolute amount of energy used for any purpose. Inefficiency can occur over the whole range of acquiring, generating and distributing energy as well as in the technology and consumer behaviour associated with exploiting energy (see for example House of Lords Science and Technology Committee report on *Energy Efficiency* 2005). So there is a wide range of opportunities for efficiencies. We use the short-hand 'energy efficiency' to include reducing energy use, making energy use more effective, and reducing waste in an energy context.

The House of Lords Science and Technology Committee *Energy Effieicency* report suggests that energy efficiency and energy saving need much more careful definition so that they can be measured and monitored in an objective manner. Only then will it be clear about how the steps being taken to save energy are actually contributing to Government targets in saving energy or reducing emissions.

The end-user - business, industry, local authorities, domestic users - is often seen as the main point at which energy saving can be applied. However, energy savings could be achieved upstream in energy generation and transmission. The Tyndall Report on *Decarbonising the UK – energy for a climate conscious future* states that, from the point of view of long-term sustainability, low-energy scenarios are preferable to scenarios with a high energy demand. Energy saving and efficiency can therefore contribute to a sustainable future.

There is a strong consensus amongst all commentators that energy efficiency and energy savings are critical components of all future options for energy. As noted in Chapter 4, the promotion of energy efficiency is a devolved responsibility, whereas the achievement of energy conservation by prohibition and regulation is a reserved matter. The Scottish Executive is currently developing its first Energy Efficiency Strategy for Scotland which is due to be published later in 2006. We warmly commend this initiative. There is also an Energy Efficiency Commitment signalling the government's recognition of this key energy issue.

Over the last century, the efficiency with which energy is used has increased many times over. This has been a result of better technology. However, unless there are active steps taken to improve our present efficiency of energy use, the predicted rise in economic activity and domestic consumption will inevitably be accompanied by an increasing use of energy and this, in turn, implies a threat to the environment and our quality of life. This has been clearly recognised by the Scottish Executive and the UK Government, as well as by the European Union, all of whom have put in place myriads of measures to improve energy efficiency. Any Inquiry into energy issues for Scotland must recognise that the efficient use of energy is a high value tool in addressing the challenges to energy use which we are facing already and which will intensify in the future.

Drivers of energy efficiency

There are several drivers towards increased energy efficiency and energy savings.

The first is that the use of some energy sources, mainly fossil fuels, are now known to contribute to pollution of the environment and have a profound effect on global climatic change. We should look, therefore, at ways of cutting this pollution before it has unacceptable or even irreversible effects. Much of our interest in energy efficiency is therefore about achieving targets for reductions in emissions of greenhouse gases which are known to be contributing to global warming and hence climate change. Human behaviour can be modified to reduce greenhouse gas emissions. However, this is far from easy and the result of any action to control global warming requires global collective action and will take decades to have an impact. This is so important that reduction of greenhouse gas emissions is proposed as a proxy for energy efficiency in the House of Lords *Energy Efficiency* Report. 2005, (see p. 14-15). Also the Scottish Executive intends to measure the effectiveness of its Energy Efficiency Strategy for Scotland through the carbon savings it delivers.

The second driver is that many of the sources of energy we currently use, usually termed non-renewable, are clearly finite. We have given our best estimate of future fossil fuel reserves in the light of predicted consumption patterns in Chapter 2. Human ingenuity cannot be discounted in predicting the future. And new energy sources or technologies may be developed which make us less dependent on these finite sources. Until these technologies or sources are available, it is prudent to plan on the assumption that we must manage without or with less of them. If the rate of energy consumption can be slowed, the finite sources will last longer. While we recognise the potential, for example, of renewable energy resources, we cannot rely entirely on these sources until they have been tested, commercialised and the extent of their contribution to energy is better understood quantitatively. Meanwhile, society should take steps to improve the efficient use of non-renewable energy resources and exploit the opportunities to make savings in the energy consumed.

Thirdly, in several cases the time taken to implement decisions on energy sources is measured in decades, for example, developing new technologies such as hydrogen as an energy carrier, or nuclear fusion. It is imperative, therefore, that decisions are made now in order to avoid the unwelcome impacts on society of energy shortages in 10 years' time and beyond. It also takes decades to reduce greenhouse gas levels in the atmosphere and hence to arrest levels of global warming. Energy efficiency and energy saving can give a little more time. We should make it clear that there is no energy crisis in Scotland at present, but given the refractory nature of the global climate system, and the time taken to plan, gain approval and build power stations, action will be required in the next year to avert a crisis developing in 10 years' time.

Fourthly, there are no technological barriers to using less energy now. Many means of achieving energy efficiency and energy saving – switching fuels, cutting heat wastage, improving the efficiency of frequently used devices such as electronic and white goods, using smart switches – are already available but are not being fully exploited.

There are some technologies, such as hydrogen, carbon sequestration and nuclear fusion, that have promise for the future, which yield more cleaner energy but which are not yet fully available and still require research and development.

Fifthly, it appears that developing and implementing technologies for cutting our energy consumption may, in any event, offer a cheaper way of using the amount of energy required to maintain our present lifestyle. Amory Lovins of the Rocky Mountain Institute (Lovins *et al* 2005) argues that focusing on energy efficiency will do more than protect the earth's climate, it will make businesses and consumers richer. He points out that homes and cars that use less power can be less expensive to build and to run. This does not necessarily translate into economic benefit since using less energy may depress parts of the economy. The House of Lords Report recommends that some work is done on gaining a better understanding of the economics underlying energy saving. Energy prices will be a major factor in the speed of adoption of energy efficiency measures. Government intervention through targeted approaches should be able to assist.

Improving the efficient use of energy

There are many means of achieving more efficient use of energy: constraining demand through price and other mechanisms; reducing demand through technology; improved levels for building standards and their enforcement; more effective use of waste energy; and changes in behaviour. We focus on the last three topics as we consider that these are likely to have a greater impact on the efficient use of energy in Scotland than others. In addition, there have been many other studies and also submissions to our Inquiry that have made valuable proposals for energy efficiency and we see no merit in repeating their arguments and suggestions. We consider energy improvements for transport and heating through fuel substitution and efficiency measures in the next chapter.

Improvements in energy efficiency in buildings

Performance in Scotland in energy efficiency in existing buildings and designing energy efficiency into new buildings falls well below best practice in other countries. For example, Scandinavian and German buildings are considerably more energy efficient than those in Scotland. Lovins has achieved it in a very low energy intensive building at the Rocky Mountain Institute; Woking in England has been successful at the urban level by developing combined heat and power, micro-generation and distributed energy systems; and California at the wider state level. In some areas such as home insulation, a whole country, such as Sweden, has demonstrated what can be done and by comparison shows that we have some way to go in Scotland.

The starting point has to be the housing stock. An average Standard Assessment Procedure (SAP) has been developed to guide the level of energy efficiency in housing. The rating of the existing housing stock is a SAP of 45 compared to approximately SAP 95 for new build housing. Best practice reaches SAP 115 on a scale that goes up to 120. The energy efficiency of both existing houses and new build needs to be improved. Existing houses have the largest absolute potential for emissions savings, but nine-tenths of existing houses fail to meet current new build building standards, and at the current rate of building it will take 100 years until all of the existing houses in Scotland are up to the current standard for new build. A high proportion of recent houses designed to meet the standards are not actually built to meet them, and evidence suggests that there is also a need to ensure higher standards of installing insulation; this requires better information and training of the installers.

Raising building standards in Scotland to the level of those in Scandanavia and Germany could save 20% of domestic energy consumption.

Scottish Ministers are presently considering proposals for amending regulations under the Building (Scotland) Regulations 2004. A review of the energy standards is underway and has gone to public consultation (March 2006). Proposals include introducing a CO_2 emissions standard for new buildings; allowing designers more flexibility with insulation levels in new buildings if they adopt low and zero carbon building; integrated energy generating technologies such as wind turbines or photovoltaics; using condensing boilers for replacement and alteration work in dwellings. Introduction of the revised Building Regulations will not occur until May 2007.

In the UK context, in order to achieve the Government’s target of a 60% reduction in greenhouse gas emissions by 2050, then, although it is possible to build zero energy housing, a more likely target is to achieve a reduction to 40% of present levels of energy use.

It is essential that existing standards and regulations are enforced. We received evidence that building standards are in fact dropping, that actual standards in new buildings are not checked, that insulation is often badly fitted or limited, and that no penalties are imposed for failing to meet the Building Standards Regulations. In Aberdeen, for example, we were shown thermal images that illustrated the extensive heat loss from recent housing.

Unfortunately, these proposed new standards only apply to new buildings; they do not apply to existing buildings or the existing housing stock. Consideration needs to be given to the measures that would stimulate improved performance, for example, through the Council Tax, as all of the evidence we have examined suggests that current measures are not effective. We recognise that part of the problem lies with the attitudes and behaviour of householders and we return to this point later in this chapter.

The design and building of low-carbon buildings requires a good deal more training. There is potentially a role for the new Scottish Building Standards Agency (SBSA), perhaps utilising the experience gained from the Carbon Trust’s Low Carbon Design Initiative trialled in Northern Ireland.

We heard evidence that there is a lot of grant money for domestic energy saving, but it is not easily accessible. Few of the grant mechanisms are coordinated with one another, to the extent that some sources of funds may even compete with each other. A further problem is that people on marginal incomes may not be able to access a 100% grant and so the funding assistance fails because they cannot afford to pay their contribution. We were told that, if all these anomalies were removed and the various sources of funding were combined, then it would be possible to make houses ‘energy poverty proof’.

Although local authorities have a planning remit that can require energy conservation to be an element in any planning application, we heard evidence that many applications come back ignoring energy conservation requests. It is possible that contractors think that local authorities focus primarily on cost in awarding construction contracts and that local authorities reflect public opinion and tend to be out of date in terms of what current technology can do. Consequently, there is a lack of awareness of the potential for energy conservation in new buildings.

Over the next 50 years, the existing heating sources in the housing stock will be replaced. There is a need to ensure the replacement equipment is appliances that are increasingly energy efficient and that combined heat and power, irrespective of fuel source, becomes the norm. This is particularly relevant to communal systems such as apartment buildings, either as apartment blocks or housing conversions.

Making small-scale renewable energy technologies mandatory in new homes through the Building Regulations is worthy of consideration. It could lead to lower costs per unit; stimulate tradesman to gain familiarity with their installation; and act as a showcase to encourage their use by homeowners upgrading existing homes. The investment needed will be significant, but could be stimulated by innovative partnerships between developers, (energy) equipment manufacturers, utilities, and local authorities. Commonly acknowledged standards, such as efficiency labelling for buildings, could maximize the potential of such measures; however, we recognize that proposals for such schemes have been contentious.

The Home Energy Conservation Act 1995 (HECA) designated all Scottish local authorities as energy conservation authorities, with a duty to devise strategies to achieve significant improvements in the energy efficiency of their housing stocks over a 10-15 year period. But, many local authorities in Scotland have failed to meet both their original and renegotiated energy efficiency improvement targets.

The EU Directive on the Energy Performance of Buildings 2002/91/EC requires that whenever a building is constructed, sold, or rented out, a certificate detailing its energy performance must be made available. Member States have the option of derogating from the Directive for three years if they believe there are insufficient qualified or accredited experts in the whole of Europe to carry out the certification. Currently, the introduction of Energy Performance Certificates has been delayed until at least 2007 due to the lack of availability of independent experts. It is unlikely that Energy Performance Certificates will be made available to existing dwellings before January 2009, and it is highly unlikely that people will undergo or establish training until there is a job for them to do. The Scottish Executive has been aware of the Directive for several years now, but has not brought forward means to resolve the training issue.

Another way for energy suppliers to contribute to energy efficiency is through energy use measures For example, better engineering solutions could enable demand management, such as energy efficient equipment, intelligent metering, and smart appliances. Placing an obligation on suppliers for investment into such systems is preferable to expecting them to contribute to building standards over which they have little or no direct control. Educational programmes on efficient energy use could also be made part of the suppliers' obligation.

There is a good deal that the Scottish Executive can do to remedy this situation. First, it can enforce tougher standards on local authorities on energy conservation in buildings, within a specified time frame, with minimum standards within the Building Regulations and with a plan stating how these Regulations are to be enforced. Second, the Scottish Executive could also set a timetable for meeting Scandinavian standards across Scotland. And third, the Scottish Executive should look at the framework in which these activities take place and ensure that the management of building regulations, planning consents, social services and fuel poverty is coordinated and implemented effectively.

In addition, the Scottish Building Standards Agency should carry out research to ascertain how quickly the building industry can be trained to design and build new and refurbish old buildings for low emission and high energy efficiency.

We make the following recommendation in relation to improving the efficient use of energy in buildings.

> **Recommendation 8:** Local Councils should stimulate more energy efficient housing designs through the Building Regulations system and should substantially improve the enforcement of Building Regulations in relation to energy efficiency.

Reducing demand for energy

The Report from the Tyndall Centre, referred to above, points out that reduction in demand allows greater flexibility than low carbon supply. This is because the development of better end-use technologies is spread across millions of users whereas the initial capital outlay on supply alternatives is usually borne by a small number of companies or by Government.

Reductions in demand can be achieved in various ways:

- through switches in the mode of travel,
- tax or incentives on vehicular use,
- energy efficiency incentives and regulations in new and existing public buildings,
- domestic and commercial building through planning consents and Building Regulations, and
- energy reduction in the design of new consumer products.

Manufacturers need to be encouraged to ensure that frequently used electronic devices, such as televisions and video recorders, are constructed to avoid needless use of energy in stand-by mode. We welcome the measures that have been taken through an EU-wide voluntary agreement to reduce stand-by power on TVs from 3-8 watts to 1 watt. We hope that similar approaches can be agreed and implemented for other electrical equipment, especially that used in domestic situations given the low take up rate and high potential for energy savings by households. Information and labelling on electrical goods are important in educating energy users. This is a key area in which the role of schools and the media is paramount.

Reducing waste of energy

As the energy flow diagrams presented in Chapters 2 and 3 (for the UK and for Scotland respectively) clearly show, by far the greatest loss of energy is in the generation of electricity. Almost two thirds of the energy content of the fuel is dissipated as unused heat into the atmosphere. This position could be improved through the application of existing technologies, some of which have been researched and developed in Scotland. Obvious areas are the reduction in the transmission loss in the electricity grid, and especially in distribution to consumers, reduction in the loss of heat and other energy in the generation of electricity, energy saving devices such as smart meters to require less energy input for the same output. These and other applications would save a great deal of energy that is currently dissipated into the atmosphere.

We note the much greater use of combined heat and power in many overseas countries to provide both electricity and heating to the consumer. The advantages of combined heat and power stations where the heat is used locally are evident. Serious consideration should be given, for example, to the use of waste heat from industrial processes, including from electricity generating stations. We see no reason, other than inertia by Local Councils and by lack of market stimulus for the generators, why the position cannot be radically improved. This should apply to existing plants through linking with other enterprises, such as providers of domestic and commercial energy, and horticultural businesses. Also new plants should be designed to reduce energy loss and link waste energy to a useful purpose.

> **Recommendation 7:** Industry should be persuaded, through economic instruments and approval mechanisms in the statutory planning system, to utilise waste energy, especially heat, for beneficial purposes. In particular, we recommend that all future small thermal generating plants, near to population centres, should have specific arrangements for the use of waste heat.
>
> **Recommendation 24:** Local Councils should undertake the following to improve fuel substitution for heating:
> (1) amend Structure Plans and Local Plans to stimulate the development of combined heat and power and district heating schemes in urban areas;
> (2) do not approve Planning Permission and Building Warrant to developments on Brownfield and Greenfield sites without these facilities;
> (3) work with the building construction industry to put into effect systems for the delivery of combined heat and power and district heating systems; and
> (4) increase the targets for the reuse of municipal waste for energy production coupled with a reduction on material sent to landfill sites in Local Waste Plans.
>
> **Recommendation 25:** The UK and Scottish Governments should introduce a tax disincentive on waste disposal, especially to landfill, and a greater tax incentive for the reuse of waste for space and water heating as part of District Heating and Combined Heat and Power Schemes. They should also introduce

> a tax credit system to stimulate the use of biomass and waste for the production of heat for all buildings; and should consider an energy efficient dependent stamp duty and Council Tax as incentives for improvements in building design and construction.

Organisational change

We believe a new organisation should be established to champion energy efficiency in Scotland. Our reasoning is as follows. There is a plethora of support schemes with very low up take that require more effective delivery. Scottish performance is far below what it should be in comparison with many similar European countries. The mechanisms available, such as the planning and building regulations systems, are not being used effectively. And, there is a great deal of good practice in Scotland that is not widely known. We specifically recommend the establishment of a Non-Departmental Public Body, at arms-length from government, on energy efficiency. If the Scottish Executive accepts our recommendation for the establishment of an Energy Agency for Scotland (see Chapter 9, Recommendation 5), then energy efficiency should be a key part of its remit.

> **Recommendation 10:** The Scottish Executive should seek Parliament's approval for the establishment of an Energy Efficiency Agency for Scotland as a Non-Departmental Public Body. It should have both advisory and executive powers with authority to scrutinise and make recommendations on energy efficiency action in the public sector, disburse incentives for reducing energy use, increasing efficiency and supporting novel initiatives, and for disseminating best practice.

We note within Scotland a considerable variation in the priority given to energy efficiency by Local Authorities. We commend good practices seen, for example, in Aberdeen applied to Council building stock and in Lerwick to waste management.

> **Recommendation 11**: The Scottish Executive should require Local Councils to achieve specific and measurable improvements in the efficient use of energy through the town and country planning system and building regulations.

Human behaviour: the main obstacle to energy efficiencies

The main challenge to energy saving is human behaviour. The general public need to see that energy saving is so strongly in their own interests that it is essential to change behaviour. Business must also be convinced that it is consistent with a thriving and even more profitable enterprise. It is not easy to bring about changes in human behaviour and neither should it be in a democratic society. Often it takes a major crisis - war or life-threatening disease - to bring about changes in behaviour, but even more modest but still substantial crises, as that in the electricity shut down in California in 1991, can bring about voluntary and effective change. A fuller discussion of the role of the general public is in Chapter 9.

The House of Lords Committee report on *Energy Efficiency* points out the gains in energy efficiency are not necessarily accompanied by reductions in energy use. At the macroscopic level, it has been argued that improvements in energy efficiency effectively reduce the price of energy and as a result stimulate increased economic growth and increased energy consumption. They believe that Government has yet to engage with these complex behavioural issues.

There are financial and other benefits to the suppliers of plant and equipment, owners of property, and the public in the development and use of energy efficiency devices. We strongly support action for improving the efficiency in the use of energy. However, there is a plethora of schemes and a relatively poor take up, especially by small- and medium-sized enterprises and domestic consumers. Part of the reason for this is that energy efficiency requires behavioural change. We consider that this requires a package of education, information and financial incentive. Educational material to be made available to the public, especially schools, would be a valuable component. We note that information, such as the energy efficiency labels, is now displayed on electrical white goods and cars. We believe that this practice could profitably be extended to cover all energy using devices and buildings. We also consider that both financial incentives and penalties, designed to promote behavioural change, should be introduced. There are a number of possibilities for consideration. Energy efficiency labelling of buildings, linked to an energy efficiency-dependent stamp duty and Council Tax band could prove a powerful market incentive for more energy-efficient buildings. An energy efficiency-dependent VAT system should also be considered.

There is reason for optimism that energy efficiency in Scotland can make a positive impact. Scotland is a small country and only produces 0.2% of the world's greenhouse gas emissions. Scotland at very least should play its part. Energy saving in Scotland may yield economic benefit and may conserve fuel stocks. The Tyndall Report is firmly of the view that a vibrant UK society is technically and economically compatible with a true 60% reduction in carbon emissions by 2050 but major behavioural hurdles must be surmounted by society if this is to be achieved.

In promoting behavioural change, the language needs to be made consumer friendly. For example, it should be in terms of the impact on people, not in terms of statistics. After all, what people look for, and pay for, is not energy as such but heat, light, hot water, and also the convenience of personal transport. If they can acquire these for a lower cost from any other means, then they would do so.

Changing societal behaviours is not easy and it cannot be done by government dictat, but it can be aided by government intervention. This has been the approach on energy efficiency for many decades, with countless energy savings and energy efficiency campaigns in the media and through the domestic letter box.

We consider that greater effort should be made through education programmes, especially at primary and secondary levels. Classroom support materials should be provided to help with this educational effort.

Energy efficiency and energy saving has been a central plank of government energy policy in the UK and in Scotland for many decades. This has been reinforced in the UK Energy White Paper of 2003 and in the UK Energy Review consultation paper of 2006. *The Energy Efficiency Innovative Review* (2005) produced by HM Treasury suggests that there are significant opportunities to be had from energy saving/efficiency. The cheapest, cleanest and safest way of meeting the 2003 White Paper targets could be through using less energy rather than trying to cope with the effects of using more energy. It is suggested that in the UK we could cut energy consumption by 20% in the domestic sector alone without a negative effect on our life style and that energy saving alone could enable us to meet 70% of the Government targets. Expert analysis has shown that business and consumers waste about 20% of Scotland's total energy spend each year, representing £1.3 billion in resources lost to the Scottish economy on energy alone (Scottish Executive News 7/12/2004).

At present, there is a great variety of schemes and initiatives devised by Government to encourage responsible use of energy. The evidence available to us, however, shows that many of the schemes, and particularly those directed at the domestic sector, are not very effective with resultant low take up rates. There appear to be a number of reasons for this situation: there are many different schemes; there is no obvious linkage and coherence between schemes; and information available is not user friendly. All of this suggests to us that improvements in the targeting and accessibility of schemes, in providing better information and greater coherence would increase up take beyond the present levels. Also, we consider that a more quantitative assessment should be undertaken of the relative effectiveness of these measures in order to improve future performance. This should focus on the evaluation of costs and benefits of existing schemes, evaluation of consumer, especially domestic, resistance to using schemes already available, and recommendations for improvement. In addition, full environmental and economic costing of efficiency and savings proposals should be undertaken before implementation. Account must be taken of the environmental as well as the immediate financial costs and the market prices.

As part of the energy strategy for Scotland that we recommend is developed urgently by the Scottish Executive (see Chapter 4 and Recommendation 4), there is an urgent need for a more coordinated and effective programme of action on energy efficiency for Scotland. We welcome the announcement that the Scottish Executive is to develop an Energy Efficiency Strategy and consider that this should be a key element in the overall energy strategy.

> **Recommendation 9:** A more comprehensive and integrated package on energy efficiency should be developed at both UK and Scottish levels to reduce the current confusion and increase effectiveness. This should be linked to strengthening the targets and ensuring their achievement under a revised Energy Efficiency Commitment.
>
> **Recommendation 12:** As part of encouraging the change of behaviour needed on energy efficiency, a comprehensive set of measures including education, information and incentives should be developed by the proposed Energy Agency for Scotland (or failing that by the Scottish Executive).

In support of this Recommendation we propose the following actions:

(1) Learning support materials on energy efficiency should be provided to primary and secondary schools through Learning and Teaching Scotland;

> (2) an independent assessment should be undertaken to ascertain the causes of failure of energy efficiency schemes as a basis for implementing more cost effective schemes; and
>
> (3) the UK Government should consider financial measures to stimulate changes in behaviour on energy efficiency.

These actions should be taken by the Energy Agency for Scotland.

7. CLEANER FUEL OPTIONS FOR SCOTLAND

Introduction

If Scotland is to fulfil the Scottish and the UK Governments' policies, and if our proposed specific policy objectives are to be met, then the single most important change on the energy supply side has to be the substitution of fossil fuels with renewable and non-polluting sources of energy. This has been stated by many commentators over recent years, so we are saying nothing new. However, we do consider that the analysis needs to address all of the key demand sectors, not just electricity, and to consider all of the supply technologies, not just renewables, in order to assess realistically the diversity of potential sources of energy both now and in the longer term to the middle of the century.

Much has been made of the potential of renewable supplies of energy for Scotland, but this has been unduly focussed on electricity with inadequate consideration to other higher energy-use sectors, particularly transport and heating. In this chapter, therefore, we appraise the potential contribution of renewables in general before giving more detailed consideration to the supply of energy for transport, for domestic water and space heating and for electricity. For each sector, we assess the range of instruments currently in use and make recommendations for improvements in the operation of the market and for increasing the effectiveness of the government's contribution.

Renewables

There is no need to repeat the oft-quoted statistics of the potential of renewable energy resources available on land and at sea in Scotland. Suffice to say, that it is not their intrinsic existence that is at issue, but the availability of technologies and infrastructure to harness them, and the development of markets, with or without government stimulation, to bring them to the consumer.

We note that renewables technologies will substantially help to achieve reduction in greenhouse gas emissions and we strongly support their use. It is clear already that some technologies have the versatility to supply different energy sectors, such as biomass in its various forms for heat, transport and electricity, whereas others are more suitable at present for specific sectors, such as wind for electricity. We examine the specific renewable technologies later in this chapter for transport, heat and electricity, and also the possibilities for use of renewables as part of distributed systems. For all of these and for the non-renewable alternatives, we consider that a full assessment of all of the costs and benefits should be undertaken as stated in Chapter 5 where we have made specific recommendations.

We welcome, in principle, the commitment by the Scottish Executive, announced originally by the First Minister in March 2002, for a target for electricity to be supplied from renewable resources. We examine this is more detail later. However, as electricity is a small component of the energy market in Scotland, we are surprised that the Scottish Executive has not developed a strategy and targets for the use of renewables for transport and heat. These are high energy consumption sectors, there is potential for supply from many non-fossil fuel sources, and there are obstacles to their development despite the number of small scale initiatives (over 100 according to

Scottish Renewables). We welcome the fact that the Scottish Executive has finally announced (in February 2006) its intention to develop a renewables strategy for heat with targets; it should do the same for transport. Both should be key components of the Scottish Energy Strategy which we recommended that the Scottish Executive develop as a matter of urgency (see Chapter 4, Recommendation 4).

> **Recommendation 18:** The Scottish Executive, as part of the development of its energy strategy, should develop fuel substitution targets for all of the main energy consumption sectors: transport, heating and electricity.

We note that, although the present Renewables Obligation Contracts (ROCs) and the Climate Change Levy are available for energy from most renewable sources, decisions taken to date strongly favour market technologies rather than those further from market adoption. As a result, onshore wind turbines have become commercially viable, but this mechanism has not stimulated development of other renewable sources other than for local use. We note that the ROCs targets are not guaranteed beyond 2015, although ROCs are set to continue to 2027. We consider that once a technology has been market proven then it is an unwise policy to continue what amounts to a long-term subsidy. Introducing specific ROCs, for example for marine power, amounts to trying to 'pick winners'. We have profound doubts about the rationale and validity of the ROCs system. It is designed to be technically neutral at the point of production of renewables, but is not designed directly to stimulate the reduction of carbon emissions. It seems, in practice, that the mechanism provides technology-led outcomes rather than emissions reduction outcomes.

We propose, therefore, that ROCs are replaced with a scheme targeted on the reduction of carbon emissions. Incentives and disincentives applied at the point of production, in direct support of objectives, leave the market to decide how best to meet the national requirements, are truly technology blind, and may encourage investment in research to find new and more efficient means of meeting the objectives. There are various mechanisms which could be implemented to achieve this such as, trading schemes or levies.

> **Recommendation 20:** We recommend that the UK Government, supported by the Scottish Executive, replace ROCs as soon as possible with a carbon emission-reducing measure, such as a carbon levy applied at the point of carbon production. This should build on the existing EU Emissions Trading Scheme. Existing commitments should be honoured.

Transport

The transport sector is the most important if there is to be a reduction in the emission of greenhouse gases and also in fuel use from non-fossil sources.

Twenty eight percent of energy demand in Scotland is from the transport sector and the majority of this (71%) is from road transport. In 2002, the transport sector consumed 28.4 % of energy used in Scotland; the fuel was almost entirely oil based (99.4%) and the sector consumed 76.6% of all oil consumption in Scotland (Scottish Energy Study 2006). The most significant consumers are: road transport vehicles

71%, air 18%, shipping 7%, and rail 4%. Most commentators consider that oil-based resources will remain the main fuel source for next 25 years, with gradual market penetration of biofuels, hybrid engines, and hydrogen.

The transport sector also produces the largest emissions of greenhouse gases after energy supply and land use; for the UK as a whole this is about 20% of total emissions. Within the sector, road transport is the main source accounting for about 85% of greenhouse gas emissions (with cars and taxis producing about 2½ times more emissions in total than heavy goods vehicles as a whole).

There has been a year-on-year growth in the transport sector from 1992 to 2002 with road, and more recently air, being the main components of the increase.

Any energy strategy for the transport sector should, therefore, focus primarily on the reduction in carbon and other greenhouse gases, and in higher fuel efficiency; these two components should go hand-in-hand. There are a range of measures to stimulate progress already in existence by the UK Departments of Transport, and Trade and Industry, and the Scottish Executive. Those relating to energy savings and energy efficiency have been reviewed in the previous chapter.

Previous analyses, for example by the Tyndall Centre, demonstrate that air and shipping have very high and rising levels of use and a high level of contribution to greenhouse gas emissions. These are not matters that can be resolved at the Scottish level, or indeed the UK level, alone. We agree with the opinion of many analysts that measures to reduce the speed of growth of the air travel sector are best tackled through either a fuel or an emissions levy on aviation fuels. We welcome therefore the decision of the EU, strongly supported by the UK Government, that aviation will be included in the Emission Trading Scheme at a date to be determined.

We note that the Scottish Executive has established the Route Development Fund to stimulate in-bound air traffic. We can understand why this may be beneficial for the Scottish economy. However, this measure is totally inconsistent with its sustainable development and climate change policies and its targets for renewables in other parts of the energy sector. The Scottish Executive should review the justification of its Route Development Fund in relation to its sustainable development and climate change policies.

We recognise that there are special cases for Scottish island communities as life-line services by air and sea for people and for goods and services are an essential part of the support infrastructure for the population. Any schemes to reduce energy use and reduce greenhouse gas emissions in the transport sector should take into account the special needs of these areas.

We note that there has been some progress in switching freight from road to rail as a result of the Scottish Executive's Freight Facilities Grants introduced in 1993. Independent assessment (MDS Transmodal Ltd 2002) claims that this has been successful, albeit with not many schemes in place at the time of evaluation. However, the assessment notes that the scheme is applicant-led rather than strategically led by the Scottish Executive and that there is a need for better intermodal facilities at key points. We hope that the scheme can be improved in the light of this assessment.

As emissions have risen in heavy goods vehicles and buses, according to NAEI statistics, then this would seem to suggest a lack of effectiveness in current price and tax mechanisms for diesel fuel to bring about shift to low carbon fuels and lower consumption of fossil fuels.

Diesel fuel dominates the heavy goods vehicles market (vehicles over 7.5t gross weight). The high efficiency of diesel type engines, and their proven ability for emission control at modest cost, will mean that they will retain their dominance for all surface transport. Diesel fuel is an increasingly large component of haulage charges now accounting for up to 40% of overall costs depending on the nature of the operation. The majority of commercial vehicle manufacturers are investing R & D into improving diesel engines and this will most likely remain the dominant power source for the foreseeable future. We note the general view that it is unlikely that alternatives will form more than a niche market for many years for. Transport is a very competitive market and investment in alternative fuels is high risk Natural gas will continue to have a small penetration into the market but there is a generally held view that the UK Government's very rigid interpretation of the EU rules has effectively killed any expansion.

Government policy favours buses over other forms of road transport for passengers in urban areas presumably on the grounds that there will be an expected reduction in emissions and in fuel use. However, it appears that deregulation has brought about competition on high volume routes, with the consequence of over capacity in service provision (except at peak hours) and therefore higher emissions levels than necessary to meet demand. We consider that there needs to be greater support from government and from companies for low carbon emission fuels and for vehicles with lower energy consumption. As Stagecoach and Firstbus provide more than 70 % of the bus market in Scotland, then changing the system to reduce both fuel use and greenhouse gas emissions will be reliant on their willingness to agree to greater regulation and more incentives. There is also a need for more flexible fleets capable of adjusting to variable levels of passenger use, especially at off-peak periods.

> **Recommendation 14:** Bus transport operators should be given greater incentive through the Scottish Executive's current service support mechanism to operate a wider range of vehicle types to cope with variable passenger loads.

As the single greatest source of greenhouse gas emissions in the transport sector, it is essential that cars become both more fuel efficient and have lower emissions. We consider that a range of incentives and restrictions is needed to stimulate the Market for hybrid engines, technologies to capture energy from otherwise wasted sources such as braking, incentives for higher car occupancy, and measures to reduce speed in order to reduce consumption.

> **Recommendation 13**: The UK Government should consider measures, such as the use of lane preference and variable charging systems, to encourage higher-occupancy vehicles.

In this context, we welcome the UK Department of Transport Powering Future Vehicles Strategy (PFV) introduced in 2002 and the range of restrictions and incentives for reduction of fuel consumption and GHG production. In particular, we welcome the lower road tax for lower carbon emission vehicles, the target for 10% of new cars to have reduced CO_2 emissions, the Powershift grants encourage purchase of higher cost low C cars, the New Vehicle Technology Fund and Ultra Low Carbon Car Challenge to encourage especially hybrid fuelled and hydrogen fuel cell vehicles. We recognise it will take time for new vehicles and new fuels to become commonplace and the need for joint working with the motor industry and other relevant stakeholders. The review of the PFV Strategy during 2006 should ensure that setting of testing targets and appropriate incentives stimulates greater speed of progress on fuel and greenhouse gas reduction. In particular, we propose that there should be revisions to the fuel duty to increase the differential between oil-based and renewable sources of fuel.

> **Recommendation 21:** The UK Government should review and improve the incentives to encourage fuel substitution in transport and for the production of biofuels and associated infrastructure.

The first large scale commercial biodiesel plant started production in March 2005 at the Argent Energy Plant near Motherwell. The fuel is made from cooking oil and tallow: by-products of other industries which have limited alternative uses. A contract between Argent Energy and Petroplus means that up to 25,000 tonnes of biodiesel a year could be heading to Grangemouth and Teeside refineries. At the refineries, the fuel will be blended with mineral diesel and marketed under the Bio-plus brand on filling station forecourts.

More information can be found at: http://www.argentenergy.com

We have a preference for the development of biodiesel but at present the basic feedstocks, such as oil-seed rape, achieve higher prices for other uses. Incentives are needed as these should be part of the reformed EU Common Agriculture Policy package to stimulate both the market and the development of the processing facilities. Although reference is made to the possibilities for energy crops and use of biomass in the Scottish Executive Forward Strategy for Scottish Agriculture 2006 and in the Rural Development Programme for Scotland 2007-2013, there appear to be no specific incentives for the development of these sources and the supporting infrastructure needed to develop their market potential. We note that the Scottish Executive intend to produce a Biomass Action Plan by the end of 2006 and hope that this will include means for encouraging the development of crops and associated infrastructure for energy from biomass.

We consider that there is potential in hydrogen as an energy medium in the longer term provided that it is produced from low carbon emissions sources. When used in fuel cells, the only waste product from hydrogen is water. However, the extremely high temperatures produced in hydrogen combustion can result in NOx emissions. We note the importance of the EU PURE project on hydrogen powered buses in major cities and we especially commend the Unst project (see box in Chapter 8) producing hydrogen from sea water for use as engine energy, despite its small scale.

A number of commentators have proposed a Renewables Obligation Certificates-type approach for the transport sector in order to stimulate the shift in fuel use from fossil based to renewables based. We note that the UK Government agreed in late 2005 to introduce a Renewable Transport Fuels Obligation. This will require all transport fuel suppliers to ensure that 5% total aggregate of their supplies is from biofuels or other renewable transport fuels by 2010. The date of introduction had not been announced at the time of writing this report. We agree that incentives are needed for changing to low emission fuels, to reduce fuel consumption, and to stimulate more fuels from renewable sources becoming readily available. Given our general unease about the ROC approach, as discussed above, we would prefer an approach which is more effectively targeted at fuel substitution and greenhouse gas reduction. This could be achieved in a number of ways. For example, there could be a greater differential than at present in Vehicle Excise Duty as we consider that the maximum £100 per year difference is not sufficient as an incentive/disincentive.

We consider that the proposed UK Department of Trade and Industry target, announced in late 2005, for the introduction of a road fuel target from renewable resources by 2010 is a good step forward provided that the target (to be determined following consultation during 2006) is testing and achievable. We also consider that the duty on biofuels and biodiesel should be much lower than at present relative to fuel from oil-based sources (a 20p per litre reduction is not really sufficient to stimulate the switch in use or to stimulate the development of the market for biofuels or the construction of the processing plant and other infrastructure). Complementary to this proposed change, would be to consider increasing fuel duties to stimulate the development of greater efficiency in the internal combustion engine. The EU Biofuels Directive requires Member States to have targets for 2005 and 2010. We welcome the setting of targets by the Scottish Executive under this Directive and hope that these will be kept under review and progressively tightened.

The funding of the transport sector by the Scottish Executive seems to us to be very heavily weighted towards motorways and trunk roads to the extent that it does not sit easily alongside the Executive’s climate change policy. We note, for instance that, following the most recent Spending Review, the budget for the current year, 2006/07, and the proposed budget for 2007/08 shows rail with 17% and 14% of the total respectively, and bus 4% and 3%, compared with motorways and trunk roads at 50% and 47% of the total. This underlines our earlier recommendation for the urgent formulation of an integrated strategy for energy for Scotland by the Scottish Executive.

> **Recommendation 22:** In the next Spending Review, the Scottish Executive should change the priorities in its transport budget to more adequately reflect its climate change priorities.

For the rail sector, we note that passenger numbers have been stable over the last two decades but there has been a welcome increase in recent years of the number of passengers carried by Scotrail. We recognise the relative lack of flexibility in the rail based system, and therefore welcome decisions to open new lines to substitute for road transport where there is a market or one will develop. Forward estimates of passenger numbers have not always been accurate. Demand has outpaced estimates in some cases, as the proposed doubling of the Edinburgh to Bathgate line and the increased demand for car parking at railway stations demonstrates. There remains a need to link public transport at key points, such as bus and rail at the same termini. We also see the importance of making the rail infrastructure more energy and carbon efficient by changing from lines that can only take diesel powered traction to those that take electric traction provided the energy is generated from low carbon sources. Given the recent transfer of responsibility for railways to the Scottish Executive, we consider that it should define energy policy and targets for railways in Scotland as part of Scottish Railway Strategy.

> **Recommendation 23:** The Scottish Executive should develop an energy policy and targets for the railway system as part of the Scottish Railway Strategy.

Domestic space and water heating

The domestic sector is the largest energy consumer in Scotland (33.9% of energy consumed in 2002 (Scottish Energy Study 2006)). Within this sector, it is estimated that around 80% of household energy consumption is for space and water heating and that 69% of the fuel used is gas. Gas is the key energy source because it has a low price relative to alternatives, and is readily available to about 85% of Scottish households. However, concerns about the price volatility of gas because of the small number of major global producers and relatively high greenhouse gas emissions, attention is also being given to alternative energy sources.

The most significant options for alternative fuels appear to be from solar power, from biomass and from waste in the immediate future. For the longer term, there is the possibility of using hydrogen power given its very high thermal efficiency, as long as it is produced from low carbon emission sources.

Solar power and the use of heat pumps are both well established as a source for water heating and its is estimated that these could contribute up to 50% of Scotland’s domestic annual water heating needs (Scottish Energy Study 2006). However, both are only a partial solution and quite costly with estimated rates of return on capital investment being well over a decade, but this period would be reduced by grants available. It is more economic to fit the solar panels and other equipment, such as heat pumps, into new buildings or when buildings are being refurbished.

It has been argued that biomass has potential as an energy source for water and space heating both in remoter areas and in urban areas. Both *energy crops and forestry material* (with the exception of co-firing) are best suited for distributed systems in heat-only or combined heat and power plants. Distributed does not mean confined to rural areas, as there are many examples of biomass plants in cities (e.g. Sheffield). Most plants use biomass in the form of pellets, which can be made from a large variety of woody materials. The high cost of transport of relatively bulky material with relatively low energy content means that woody material should be converted to energy within about 50km of its source. Although this is not an entirely carbon-neutral source of energy, with proper management carbon costs can be kept very low. Wood fuel is being promoted especially in rural areas with no access to the gas grid and where there are plentiful supplies of wood at least for the next two decades.

There is a great deal of waste material that is a potential but unused source of energy. Domestic waste in urban areas, waste from arable stubbles on farms, and waste from restructuring in forests are among the sources. These are best used close to their source as transport costs are high and the energy value per unit volume is relatively low.

The definition of waste is crucial in ensuring that all possibilities can be pursued. There appears to be a disagreement between the Scottish Environment Protection Agency and the Forestry Commission Scotland on the definition of ‘forest’ waste. This is impeding the use of this source of energy.

> **Recommendation 18:** The Scottish Executive should ensure that the definition of forest waste used by SEPA enables state and private forest owners to utilise forestry thinning and other wood materials in energy production.

Use of municipal waste from domestic and commercial sector sources is also an option. At present, this is only being used in Lerwick (see box) for district heat and power, and in Dundee for electricity production fed into the national grid. Although incinerators have been controversial and older designs have not been pollution effective, newer designs help to overcome these problems. It is noticeable that in the National Waste Plan for Scotland 2003, although there was only limited reuse of waste for energy, most local authorities had plans to increase reuse for energy over the next 15 years. In total in 2002 only 2% of municipal waste was reused for energy but it is projected in the Plan that this will rise to 14% by 2020. Although the objective of government policy is to reduce the amount of domestic waste, we take the view that, as there will still be large quantities of waste material, then it is far preferable to reuse it for energy than it is to place it in landfill sites with all of the environmental disadvantages from the transport, storage and emissions from the waste material. We see potential, therefore, for the development of district heating and combined heat and power schemes around Scotland with modern emission effective incinerators fuelled by municipal waste.

We would also like to see ways of utilising the substantial amounts of waste energy, largely in the form of heat, that are lost at electricity generating plants and from industrial processes such as at distilleries. Many of the plants are near to settlements. We support the type of scheme developed in Wick (see box) using the waste heat from the distillery. There are plenty of opportunities for this type of development on Islay and on Speyside from distillery waste heat. More specifically, as around two-thirds of the energy generated in our coal fired electricity generating stations is lost then at the very least we suggest that Scottish Power develop a scheme for the use of this waste heat for the communities around its Longannet plant. Ideally, this should also occur at Cockenzie but we recognise the relatively short life span of the plant. For other plants, such as at Grangemouth refinery and petrochemical complex and at Torness, we would like to see the operators take the initiative, along with the local enterprise companies, to stimulate the development of businesses that have high energy requirements, including the horticultural sector.

Lerwick District Heating

Lerwick, Shetland, has a district heating system, based on the incineration of waste, that supplies economic heat to householders, community buildings and industrial premises. The Scheme has been operating since 1998. The heat is removed using water and the hot water is pumped around Lerwick into heat exchangers in the buildings. These heat exchangers take the place of the boiler. This scheme offers savings to users in terms of reduced heating costs and space needed to house heating equipment. Furthermore, income from the system is also recycled back into the local economy. District heating offers sustainable heating options and creates local jobs in the fuel supply chain as well as lessening adverse environmental impact. In October 2000 the scheme won the Engineering Council's Environmental Award for Engineering Alternatives. By June 2005 the scheme had 535 domestic and 88 non-domestic customers including the Gilbert Bain Hospital and both of the primary schools in Lerwick. This brings the total number of customers the scheme serves to 623. An insulated hot water storage tank will store heat at off-peak times and the stored heat will be used at peak times.

More information can be found at http://sheap-ltd.co.uk/

Wick District Heating

The Wick District Heating Scheme will be the first scheme in the UK to use wood to generate both heat and power. It will be the first district heating scheme in the world to be centralised on a distillery using green energy. The scheme will utilise the waste heat from the distillery and from wood-burning power generation to heat nearby dwellings. The scheme is a partnership between the local authority, the distillery and the local community. Phase one of the scheme is using the waste heat from the distillery, this will result in energy savings of around 40-50% in the distillery and the heat recovered will be used to supply 60% of the annual space and water heating requirements of 600 dwellings. The remaining heat will be sourced from wood-fired boilers. Woodchip boilers will eventually replace the distillery's dependence on heavy fuel oil boilers. Phase two of the scheme is to build a woodchip-fired combined heat and power station. Once this is built the scheme will be able to heat another 1500 dwellings as well as some major commercial and institutional buildings. The electricity generated at the combined heat and power plant will be able to power half of the town. It is hoped that this phase will be completed by the end of 2006 with several hundred houses already connected to the scheme. The woodchip used in the combined heat and power plant will be taken from the renewable forestry in Scotland. The Wick district heating scheme has won best community initiative at the Scottish Green Energy Awards.

More information can be found at: http://www.caithnessheatandpower.com/

Lockerbie biomass power station

The energy company E.ON has announced plans to build a £90 million, 44 MW biomass power station at Lockerbie, Dumfriesshire. The power station will be the largest of its kind in the UK and it is expected to power 70,000 homes. The plant will generate electricity by burning locally sourced crops, with up to 45,000 tonnes coming from willow trees harvested by farmers. The power station will require around 220,000 tonnes of fuel each year The project will create 40 direct jobs at the plant, while 300 are expected to be created in farming and forestry. It is anticipated that the plant will become operational in December 2007.

More information can be found at: http://www.eon-uk.com/

Whitegates District Heating Scheme, Lochgilphead, Scotland

In Lochgilphead, Argyll, the local housing association Fyne Homes has built 51 new homes including a 460 kW central woodchip district heating system for the development. The Whitegates development is the first large wood fuel heating scheme in Scotland.

The woodchip is delivered on a regular basis to a silo next to the boiler house. The woodchip is fed into the boiler, heating up water. The hot water is distributed around the development via underground-insulated District Heating Mains. Meters are attached to each house to monitor and charge for consumption of hot water, which is fed into each household's under-floor heating systems.

Fyne Homes won the Scottish Green Energy Award for Best Project in 2003.

More information can be found at: http://www.claren.org.uk/downloads/Lochgilphead.pdf

We are particularly mindful of the opportunities in our larger towns and cities for Direct Heat and Combined Heat and Power schemes fuelled by waste in summer and municipal waste and/or biomass in winter. Lerwick and Wick have shown what can be achieved where there is innovation and where the various interests work effectively together. We strongly commend these initiatives and hope that other urban areas will adopt similar approaches. It is noticeable to the casual observer that the amount of new-build of residential accommodation, retail and offices on brownfield sites has not been accompanied by energy-efficient systems for heating, and power. It is somewhat ironic, for example, that within 1½ miles of the old Edinburgh incinerator at Powderhall and adjacent to the point where compacted municipal waste is loaded onto freight trains for transport to a landfill site south of Dunbar, many thousands of square metres of new buildings have been constructed without linking them to the waste material with its energy potential. This wasted opportunity is repeated in most Scottish urban areas. It is in stark contrast to the integrated approach to the low-emission and energy-efficient building in many countries on the European mainland, but most notably Denmark (50% of the residential housing stock), Sweden (35%) and Finland, where these systems are the normal part of new build and reconstruction. The failure of the building industry to see the market potential and the failure of the planning and building authorities nationally and locally to put a system of stimuli and regulation in place should not be allowed to continue.

It is clear that to achieve a shift from gas for space and water heating to fuels with lower emissions will require changes to the decision making and incentives regimes. Many commentators on this subject have highlighted the lack of a proven market and the timidity of the developers, the poor experiences of the 1970s and 1980s, and the lack of appropriate incentive regime from government as the causes. The Community Energy Programme was established in recognition of the high capital costs of these schemes. Insufficient use is made of the town and country planning system, both in plan making especially in Local Plans, and in the development control decisions of encouraging greater energy efficiency into building; this is a major failure of the system and should be overcome as a matter of urgency. In addition, the incentives for use of biomass and waste for heat and power systems are inadequate to stimulate the market. Scottish Renewables has suggested that an Energy Efficiency Commitment is placed on suppliers of heating equipment. We are not clear how this would work to stimulate the market. The Royal Commission on Environmental Pollution (2004) recommended Heat Obligation Certificates modelled on the ROCs system. We agree with the principle behind this recommendation but consider that a tax credit on the use of low emission technologies would be far more effective. This could apply through the stamp duty for new houses and in house transactions, or it could be part of a revised and modernised Council Tax system.

We hope that the proposed Scottish Executive strategy on renewables for heat will be produced for consultation soon as part of the wider Scottish energy strategy which we recommended in Chapter 4. We hope that the strategy will not be restricted to renewables fuel sources but will also consider the related issues of stimulating district heating, and combined heat and power schemes, and the incentives that are needed to overcome the market failures and attitudinal postures of government and the building industry which impede their development. We note also that Scottish Renewables consider that a target of 10% of heat generated from renewable resources by 2020 should be set. We commend this approach but hope that a broader based set of targets can be produced in relation to the different heat consumers and to the use of waste heat and other waste products, as we have argued earlier in this section.

We make the following recommendations on heating.

> **Recommendation 24:** Local Councils should undertake the following to improve fuel substitution for heating:
> (1) amend Structure Plans and Local Plans to stimulate the development of combined heat and power and district heating schemes in urban areas;
> (2) do not approve Planning Permission and Building Warrant to developments on Brownfield and Greenfield sites without these facilities;
> (3) work with the building construction industry to put into effect systems for the delivery of combined heat and power and district heating systems; and
> (4) increase the targets for the reuse of municipal waste for energy production coupled with a reduction on material sent to landfill sites in Local Waste Plans.

> **Recommendation 25:** The UK and Scottish Governments should introduce a tax disincentive on waste disposal, especially to landfill, and a greater tax incentive for the reuse of waste for space and water heating as part of District Heating and Combined Heat and Power Schemes. They should also introduce a tax credit system to stimulate the use of biomass and waste for the production of heat for all buildings; and should consider an energy efficient dependent stamp duty and Council Tax as incentives for improvements in building design and construction.

Electricity

The demand for electricity is rising faster than the demand for energy in general. In economically-developed countries, a higher proportion of the energy consumed is in the form of electricity than in developing countries. This popularity of electricity is reflected in Scotland where total energy demand has fallen slightly with de-industrialisation (for example, the closure of the Ravenscraig steel works which was the single largest consumer of electricity in Scotland) but the demand for electricity continues to grow at more than 1% per annum. The reason for this is the flexibility that electricity presents to the consumer; the same socket provides heat, light and the power to fuel a multitude of appliances and devices that have become necessities in modern life.

(1) Supply options

Currently Scotland has an installed electricity generating capacity of about 11GW against a peak demand of about 7GW, leaving a comfortable margin for transmission and distribution losses, industry self use, and export (on average about 20% of electricity generated in Scotland is exported to England and Northern Ireland).

There is a single market for electricity in Great Britain under the British Electricity Trading and Transmission Arrangements (BETTA) made possible by the national grid which interconnects all major generating stations and load centres throughout Great Britain. It can be regarded as a number of interconnected regions of which Scotland is one. The required amount of spare generating capacity, in several states of readiness, is spread throughout the GB system and is, amongst other things, dependent on interregional transmission capacities. Few, if any, regions have an even balance between generation and load. In Scotland’s case there is, on average, a substantial surplus of generation available to feed into the rest of Britain through the so-called Scotland/England interconnectors.

Scotland’s electricity is provided by six principal generators: 38-40% (in terms of energy output) from the two nuclear stations at Hunterston and Torness, 33-35% from the two coal stations at Cockenzie and Longannet, 16-18% from the Peterhead gas station and 8-10% from distributed hydroelectric stations. In 2004 the contribution from all renewable sources (excluding hydroelectricity) was less than 1%. This has risen sharply as biomass is increasingly used to co-fire coal stations and the number of onshore wind generators has increased. The current total renewables (excluding hydro) contribution is about 2%.

The data and assumptions on large generating plant closures in Scotland are given in Figure 25 and Table 8 in Chapter 3. If all these closures were to occur, then Scotland would need to replace about 30% of its generating capacity within ten years, about 75% of its large plant capacity within twenty years and all of its capacity in twenty five years. It should be noted that the likely programme of closure of existing coal and nuclear stations in England and Wales is not dissimilar to that in Scotland.

On present forecasts of demand growth, and to ensure that the required spare plant margin is in place to meet the likely peak demand in 2030, Scotland will need to be able to access upwards of 12GW of generating capacity at that time. Some of this loss of generating capacity will be offset by commissioning a significant amount of wind generation, notwithstanding its inherently intermittent nature.

Depending upon the location of any future new-build plant in Britain, increases in the capacity of the Scotland/England interconnectors will be essential to guarantee electricity supplies in Scotland and to ensure flexibility in the selection of power station sites. In the circumstances, decisions on the location of capacity should be taken by the market in relation to costs of production and transmission. There is a single market for electricity in the UK and hence no imperative to build new generating capacity in Scotland relative to other parts of the UK. Whichever direction is taken by the market, it is clear that some major decisions on new generating capacity need to be taken in the next 12 to 18 months if Scotland is not to find itself short of electricity at periods through the day or the year.

On the timescale outlined above, the options for large-scale replacement plant are extremely limited. Clean coal technology, including carbon sequestration, is unlikely to be commercially competitive within the ten-year period. Nuclear replacement is an option subject to agreement on the very long time management of waste. The relatively short timescale needed for decisions will almost certainly require that near term replacement is on the site of a current, or recently decommissioned, nuclear site, where the local population has grown accustomed to working in, and with, the nuclear industry and has had first hand experience of the health and safety record of nuclear power stations, and where the grid infrastructure already exists. Even with the most favourable attitude to the nuclear option, the timescale for new nuclear build is such that decisions will require to be made within 2 years if the nuclear option is to contribute within the ten-year time frame.

This leaves the generating industry’s preference: gas. Where gas replaces coal, this is consistent with the ambition to reduce greenhouse gas emissions, but where it is to replace nuclear, it is directly counter to the desire to reduce carbon emissions. If all replacement plant in the next ten years is gas-fired, this brings us to a 70% dependence on this single fuel by 2020. Some 80% of this gas will be imported. We consider this a high-risk strategy in relation to security of supply.

Apart from biomass co-firing of coal stations (not an option if the coal stations close), none of the renewables will be marketable and capable of meeting the loss of base load requirements within ten years. Onshore wind is making an increased contribution to Scotland’s electricity generating mix, but its intermittency makes it an unsuitable candidate for ensuring continuity of electrical supply without new-build conventional standby.

(2) National Grid connection and transmission charges

Throughout Great Britain, electricity from the major power stations is delivered to the consumer via a single integrated national grid system comprising a large number of interconnected high-voltage circuits linking individual generation stations and bulk supply points. The purpose of the grid, besides providing bulk supplies to consumers, is to interconnect the major sources of generation. This ensures that security of supply is maintained in the event of generator failure and disconnection or the occurrence of faults on the system itself. The grid is one of the largest electrical circuits in the world. It is not simply a linkage of conductors, but comprises sophisticated systems of control, scheduling and despatch of generation.

Currently, the majority of the grid’s transmission circuits operate at 400 kV. However, there are several transmission circuits which have not yet been enhanced to this level in Scotland and still operate at 132 kV. Power to consumers is supplied through grid bulk supply points. Transformers reduce the voltage to 132 kV and below to distribute a continuous and secure supply to industry and domestic consumers through the separately owned distribution systems, operating at different voltages, depending upon the magnitude and extent of demand.

The National Grid acts as a common carrier for the electricity market. All potential generators, once accepted, have a right to connect to the Grid. In the event that the Grid decides to deny connection, it must compensate the generator for loss of income in denying them access to the market. The Grid must therefore also balance the costs of connection against the costs of compensation; either way the generator cannot lose.

Operation of the grid system is regulated by Ofgem which has approved a charging methodology, established by the National Grid, to recover the costs for connection to and use of the Grid. This charge is based on estimates of the power flows at times of peak demand, on the assumption that this will determine the necessary transmission capacity and on the distance from the generating plant to the ‘centre of demand’. In addition, in order to provide a secure network, in accordance with specified technical standards and to maintain the ability to continue to deliver if part of the circuit goes down, a locational security factor is applied to reflect the costs of meeting these standards. Currently this factor is 1.8, creating an annual connection charge cost of £18/MW/km. Since Scottish generating plant is further from the centre of demand, the connection charges are considerably greater than for equivalent plant built in the south of England.

We find the current Ofgem charging system reasonable in the context of the UK unified market and Scotland’s current excess capacity of supply relative to its own demand. It is this excess capacity that allows Scotland to export electricity to England. However, there are a number of consequences that flow from this. One consequence is that adding generating capacity, as opposed to replacing existing capacity, will require reinforcement of the grid and the higher costs of access to the grid. Another consequence is that, in order to maintain existing connection charges to the grid for replacement generating stations in Scotland, this replacement generating capacity should be built on the sites of decommissioned power stations where infrastructure connections already exist and for which additional charges should not apply. However, this replacement capacity in Scotland will still be much more costly than the same replacement in the South. The addition of a multitude of small-scale renewable generating plants, especially intermittent wind generation, will increase the costs of grid management and require further grid development. The National Grid Company has estimated that if the wind generation proposed in Scotland was all realised the cost to the Grid could be as high as £1.5 billion in the foreseeable future. This would have to be reflected in higher connection charges and hence ultimately higher costs to the consumer.

> **Recommendation 33:** The Scottish Executive should carry out a review of the electricity infrastructure implications of its renewables policy, especially in light of the National Grid Company’s grid connection charging policy.

(3) Environmental considerations

We note that the Scottish Executive has set a target of 40% of electricity to be produced from renewable resources in Scotland by 2020. There is confusion on the definition of the target. We doubt the feasibility of supplying 40% of electricity on a continuous daily basis from renewable sources. We note the conclusions of recent advice to the Scottish Executive from the University of Edinburgh (2006) that renewables can, in principle, supply 40% of the required electricity in Scotland on average annually. However, this supply would be intermittent and the level of supply from renewables would be 40% or over for only 40% of the time. As a result, considerable excess capacity would have to be installed to cover for the relatively low load factor from these sources. We have been informed by many wind power developers that their plans are dependent on receiving ROCs at 1-2% of electricity supplied by wind. This amounts to a subsidy to the producer and higher prices to the consumer.

We have concerns about the appropriateness of this as a target. It is an indirect measure and there is no explicit rationale for setting an environmental target in these terms, particularly in relation to carbon emissions. We consider that environmental targets are better defined in terms of fuel substitution and/or carbon emissions. Onshore wind would benefit, both absolutely and relatively, from a target mechanism related to carbon emissions because it would put all electricity generation alternatives on a level playing field with respect to carbon emissions, so that onshore wind would benefit and fossil fuel plants would be disadvantaged.

> **Recommendation 27:** The Scottish Executive should redefine the 2020 target for the proportion of electricity generated from renewable resources in terms of reduction in greenhouse gases to meet the UK's 2050 target on emissions reductions, and set out a detailed and comprehensive strategy for meeting it.

We have grave doubts about the overall economic rationale for large-scale wind turbine installations in locations remote from the consumer. We note from the evidence provided to us that these developments are only commercially viable as a result of the ROCs. Remotely-located wind turbine installation will require costly new or substantially upgraded grid connections, resulting in greater transmission loss of electricity from the source to the consumer compared with more centrally-located installations. Such investments run the risk of becoming stranded assets if the connection infrastructure is not put in place. We also have concerns about the effects of such developments on landscapes, habitats and wildlife, much of which are of European and International importance. It would make greater economic sense, and is also likely to be more environmentally friendly, if the decision-making system and decision support instruments resulted in the installation of renewables generation close to the main consumption areas and to the grid.

It is worth noting that the largest wind power generation facility in Europe has just been approved for Whitelee, south of Glasgow, close to both a major area of consumption and the Grid. This 322MW plant, planned to be operational by 2009, will require the construction of 140 turbines and occupy a land area of 55 square kilometres. It will receive an annual subsidy of about £3.5m. To achieve a 20% contribution to Scotland's electricity generation would require 1,500 turbines covering a land area of around 600 square kilometres, and a subsidy of about £35m/year.

> **Recommendation 28:** A locational strategy and accompanying planning guidance for onshore wind development should be drawn up immediately by the Scottish Executive to guide Local Councils, investors and third parties, and speed up the process of decision-making.

(4) Conclusions and recommendations on electricity generation

With the need for large-scale replacement of electricity generating plant in Scotland within ten years, decisions on the viable options are urgently needed. The choice between the sources has to be on grounds not only of costs but also of public acceptability, of security of supply of the raw fuel, the relative lifetime costs and the overall risk of individual technologies to society and to the environment. Within the next ten years, we do not consider that most renewable technologies, including current wind technologies, have the capacity to give the secure and continuous supply of electricity demanded by consumers. Thus the decision has to lie between clean coal (including biomass co-firing), gas and nuclear.

Marine power and clean coal technology (including carbon sequestration) are unlikely to be available within ten years and a significant market penetration by hydrogen is improbable in less than fifteen years.

Modern nuclear plant is now available and would take about five years to construct. However, there is a large global demand for nuclear stations and a limited number of firms capable of delivering them; the UK would have to join a waiting list. Even if the UK moved to the top of the list, the Sizewell experience suggests that it would be more than ten years before a new nuclear station could be commissioned. This timescale could be shortened by building on existing sites and pre-licensing an approved list of preferred designs (common in France and the USA). We understand that there has been an offer from France to build nuclear powered electricity generating stations in the UK in a deal based on revenue return.

There are 6 GW of onshore wind proposals approved. Load factors mean that on average this will be equivalent to around 2 GW of conventional installation. However, standby capacity of about 1 GW will still be required and we have not taken into account the necessary grid developments. On current estimates, the cost of electricity would double.

This failure to plan for the long term replacement of generating plant and the time left between now and the need for generating plants to come on-stream, means that gas is the most likely source. However, gas-fuelled generating stations built before carbon sequestration will probably mean an inability to meet our targets on carbon abatement.

There are plentiful supplies of quality coal from reliable sources, such as Australia, throughout the time frame of this Inquiry. Coal has the advantage that it can be safely and economically stockpiled, giving protection to short-term interruptions. The large global reserves and the variety of sources of supply mean that the risks to securing the required level of coal supply at an affordable price appear acceptable. However, any investment in new coal fired generation should take account of clean coal technology or carbon sequestration to reduce emissions. Collaborative effort will be needed to increase the speed of implementation of new "clean coal" technology, perhaps with Longannet as the test bed. Biomass co-firing only remains an option if there are coal fired power stations.

New gas-fired power stations should be an option. We consider that they are more realistic than coal to meet the range of energy policy objectives. Despite the recent price increases, industrial and other informed sources suggest that the prices will remain volatile. Our support is on the proviso that there is an effective means of dealing with carbon emissions. We support the Peterhead power station/Miller field project which provides the opportunity for CO_2 injection into hydrocarbon reservoirs for tertiary recovery of oil and gas. We note that there are many sources of gas supply, including continuity of supply to Scotland from Norway for the next 25 years and the provision of Liquified Natural Gas (LNG), especially under the new agreement with Qatar, into the UK market from a variety of sources, so that Scotland and the UK do not have to become entirely dependent on the so-called end of pipeline supply from Russia.

A new generation of nuclear power stations being built in Scotland should be an option, given their low emission levels compared with coal or oil-fired stations. We note that the level of radioactive waste which would be produced if new stations replaced the entire current nuclear electricity generation capacity would be significantly less over their life times than the accumulation of waste to date. The lack of carbon emissions from nuclear fuelled generating plant is not formally recognised in the carbon emission arrangements. We consider that this anomaly should be rectified.

The UK Committee on Radioactive Waste Management has recently published (May 2006) its headline recommendation that its preferred option is geological storage. The full Report is due in mid 2006. It will then be important to have a wide public debate followed by political decision on how to proceed with the nuclear option. However, should the debate be too protracted resulting in delays to investment decisions, then this option will be closed as a crisis of electricity supply approaches.

> **Recommendation 29:** Subject to agreement on implementing a satisfactory solution to the very long-term treatment of radioactive waste, we encourage both the UK Government and the Scottish Executive to keep open the nuclear electricity generating option in the interests of diversity and security of supply and suppression of greenhouse gas emissions.

We stress that this debate is not a confrontation between competing technologies and to present it in this light is to do a disservice to the public. Realistic decisions will have to take into account public safety, environmental impact, security of supply, full-life costs and the ability to deliver an adequacy of supply. These considerations apply to whatever energy technology is being considered and it is essential that a common method of assessment is developed.

It is clear from the above analysis that the long term planning for future energy needs requires a framework allowing confidence in long term investment. If that process is not started now, then there will be a severe crisis when industry plans for the replacement of plant due to close between 2015 and 2025.

Our overall conclusions on electricity generation are two-fold. First, a combination of large generating plant and renewables will be needed, so the options for the use of technologies, both existing and new, should be kept open. And, second, improvements in the decision-making systems to provide public engagement and ultimately to provide greater public reassurance on the decisions are needed.

It is for the private sector to make decisions on the technologies to be used, the preferred location of plants, and the transmission and distribution systems necessary to take the electricity to the market. However, decisions will not be taken unless the UK Government's policy and regulatory framework is unambiguous and long-term and the Scottish Executive's contribution, especially through the planning system and the environmental and other consents needed, must be to provide an integrated approach within Scotland. Bearing in mind our strong advice that security of energy supply is a critical factor for Scotland, then decisions on new generating plant need to be taken urgently by all of the relevant parties: the Scottish Executive, the generating companies and The National Grid Company.

A public debate on the electricity supply choices for Scotland within a UK context should be stimulated by independent organisations to inform and make more robust and practical decisions on the diversity of supply sources and the transmission and distribution systems is achieved.

> **Recommendation 30:** Government, industry and political parties should retain options for new build electricity generation from a variety of technologies, specifically renewables, clean coal, gas and nuclear, subject to public engagement to decide whether any technologies should be excluded from consideration.

> **Recommendation 31:** The Scottish Executive should discuss with the major generating companies and National Grid Company the decisions required by UK and Scottish Governments and also by generators for the replacement of large-scale electricity generating stations in Scotland. They should take into account the public engagement in Recommendation 30.

If the utilities build gas plants in the south of England, then the UK will move towards a 70% dependence on gas for electricity generation. We consider this a high-risk strategy for security of supply. Also, if new plant is not built in Scotland then Scotland will be unable to benefit from the considerable efficiency gains from new CHP plants.

> **Recommendation 32:** Government authorities with approval powers, and generating companies, should favour the construction of new large-scale electricity generating plant adjacent to existing plant, with easy access to the grid.

> **Recommendation 26:** The UK and Scottish Governments should ensure that the framework for energy at both UK and Scottish levels encourages investors to produce electricity from a diversity of supply sources.

Scotland has the richest wind and marine power resource in Europe. Much of this resides in the Northern and Western Isles and the seas around them. Whether this resource is exploited or not will depend not only on proving the technologies, but on the economics of grid connection. The existence of a source of energy does not guarantee that it can be delivered economically to the market. The continuation of a programme of encouraging the development of renewable sources must include an assessment of the infrastructure implications.

In conclusion, we cannot overemphasise our belief that single solutions will hinder Scotland achieving the range of energy policy objectives for electricity that we have recommended. We consider that a diversity of supply sources is essential**.**

Distributed energy systems

There is great potential for integrated energy solutions for inner cities, other urban and peri-urban, denser rural, and remote rural areas of Scotland through what are commonly called 'distributed systems' that are not connected into any national grid system for electricity or gas. The term microgeneration is being applied to these approaches as they are in marked contrast to the large-scale power generation from central stations. There are a number of energy sources that can be developed for community use, whatever their location in Scotland. The most obvious are waste heat from industrial processes and from power generation, energy production from domestic and commercial waste through incineration, energy from biomass, energy from solar power, small scale wind turbines, micro hydro schemes, and tidal and wave generators. The forms of energy supply and distribution can vary dependent on local needs and circumstances. Space and water heating, electricity for domestic use, and electricity for the production of hydrogen are some of the examples already in operation.

The objective is to utilise the waste heat from industrial and generation processes adjacent to the site rather than allowing the heat be dissipated into the atmosphere. Development of horticulture and other enterprises requiring low-cost heat are examples of such opportunities. There would also seem to be many opportunities for individual systems for households from many of the same sources.

The main problem in their adoption appears to be the capital cost, even taking into account grant assistance from government, compared with the perceived length of time to achieve a return on the investment. There is plentiful knowledge of pay back periods and plentiful sources of information, especially through Energy Efficiency Advice Centres and from the Energy Savings Trust.

There are many enterprising schemes already in existence around the country and we commend the initiative that has brought them to fruition. The boxes showcase a range of initiatives in the hope of inspiring others to take forward similar schemes in their own locality. Compiling a dossier of best practice would be a good way of assisting groups around the country move from ideas to action on distributed energy and micro-generation systems.

Recommendation 34: The various energy use advisory bodies should compile examples of distributed systems and ensure their wide dissemination.

Recommendation 35: Joint initiatives by local enterprise companies, applied research and development groups, private enterprise, and especially local communities, should be established to exploit locally available energy resources for local use.

Microgeneration

Edinburgh-based firm Renewable Devices Ltd (RDL) was formed just under six years ago. Described as "the world's first silent, building-mountable wind turbine," the SWIFT Rooftop Wind Energy System developed by RDL is an upwind horizontal axis turbine which can generate 1.5kW – and produces noise of less than 35dBA (decibels relative to the threshold of audibility) regardless of wind speed. To put this in perspective, 35dBA lies somewhere in between a quiet office and a quiet conversation, and is 10dBA lower than the "threshold of distraction", according to the UK's Environmental Protection Act.

The patented solution, which makes the turbine virtually silent, is a plastic ring which fits around the edge of the blade on the rotor and redirects the flow of air around the blade to minimise noise. To fix the turbine safely on the rooftop and "eliminate unwanted vibration," RDL has also developed its own special mounting technology, and the planning-compliant design also offers a 20-year, low-maintenance lifetime.

RDL's chief business partner to date is utility company Scottish & Southern Energy, which has a five per cent share in the company and plans to up its stake to 20 per cent by August 2006.

More information can be found at: http://www.renewabledevices.com/

Highlands and Islands Community Energy Company

Over the last two years, HIE has delivered the Scottish Executive's Scottish Community and Household Renewables Initiative (SCHRI) in the north of Scotland. Projects supported cover a wide range of technologies for a diverse range of use, including geothermal heat pumps, photovoltaic and solar heating, biomass boilers and district heating schemes, small scale wind and hydro. In the main, these projects have allowed communities to replace conventional forms of heating/power in community facilities and to reduce running costs. Increasingly, however, communities have shown interest in owning larger scale plant. To satisfy that growing demand HIE has now established a Community Energy Company (HICEC) to continue to deliver the SCHRI and to support community ownership projects. The company aims to support communities develop and own their own commercial scale projects (typically less than 5MW) through offering a mixture of advice, grant/loan support for pre-development costs and equity investment to support capital costs. The funding model has already been successfully used to support the Isle of Gigha to develop its own 3-turbine wind installation. That project will buy back HIE's equity investment over the next 4- 5 years. The funds currently held by the Company will allow it to invest in a small number of projects in the initial 2-3 years of operation but key to its success and wider roll-out of the programme will be the ability to substantially increase the funds available to it. Efforts are already in hand to that end.

More information can be found at: http://www.hie.co.uk/community-energy.html

Westray Development Trust

Westray has a population of about 570 and The Westray Development Trust is researching the potential of energy self sufficiency and in particular producing bio-fuel from Orkney energy crops. An 850 KW wind turbine has also been built. Furthermore, an anaerobic digestion plant has been developed to produce bio-gas for heating, transport and electricity from slurry and other organic wastes.

More information can be found at: http://www.westray-orkney.co.uk/thetrust/thetrust.html

North Ayrshire Council Community Benefit Fund

Whilst not directly attributable to energy production or distribution, North Ayrshire Council has promoted a Community Benefit Fund linked to wind generating sites. The fund assists local communities who are directly affected by wind turbines to secure local environmental improvement works, support for energy efficiency measures and an element of educational benefit. This project is in its infancy but could secure important benefits at the local level.

More information can be found at: http://www.north-ayrshire.gov.uk/

8: RESEARCH, DEVELOPMENT AND DEMONSTRATION: OPPORTUNITIES FOR SCOTLAND

The changes in systems of energy generation and supply envisaged in this report represent major shifts in a fundamental determinant of economic wellbeing. They will create strong pressures for change in the economy and industry, as well as opportunities for those able to capitalise on the change by developing, supplying and implementing new energy technologies in a growing global market. The response to this challenge in a liberalised energy market, such as that of Britain, will largely be determined by the economic instruments developed by government to give the long-term signals that encourage private companies to make major investment decisions and appropriate public investment in infrastructure, research and development. Public investment in physical infrastructure and in the national research and skills base can have a major influence on the potential to exploit the opportunities these changes will create and on patterns of private investment that could considerably benefit the Scottish economy. The key issues are whether there are technology sectors that should be the focus of public investment and at what stage of the research and development process to concentrate investment.

There are internationally leading edge research skills in many relevant areas of science and technology in Scotland, particularly in the Universities. Major players in the global energy industry are involved in North Sea operations, supported by a diverse supply industry and locally sourced engineering skills. The challenge to Scotland is to exploit and develop these skills and to encourage investment from energy companies by appropriate policies and its own public infrastructural and personnel investments. We must be aware, however, that the scale of investment elsewhere provides massive competition. For example, the USA President’s recent *Advanced Energy Initiative* includes a 22% increase in Federal energy research funding, focusing on clean coal, nuclear, renewable solar and wind, advanced batteries, biofuels and hydrogen vehicles. Most other advanced economies have analogous initiatives. If Scotland is not only to achieve its direct energy goals, but also to become a significant player in the international energy market, it is unlikely to be able to compete in areas that are the focus of major funding from states elsewhere, except as part of consortia. It must, therefore, choose carefully where it can competitively exploit its research-based skills and where it has the industrial infrastructure readily available to support development.

The stage of maturity of different technologies is a key determinant of the appropriateness and character of research support. A simple taxonomy is as follows:

1. R&D investment in *mature technologies*, such as onshore wind power, is a matter for commercial companies. The role of government is through its responsibility for planning regulations and permissions and any economic instruments used to favour sustainable energy sources.
2. *Near market technologies*, such as large CO_2 sequestration in geological formations, still depend upon basic and strategic research to characterise all the parameters that will be important in fulfilling its potential, engineering solutions for some aspects of its operation, and operational demonstrations to determine how financially efficient it can be in minimising net emissions from burning fossil fuel, particularly coal. They depend on massive strategic investments from private companies, but their potential for development in

and by Scotland can still be influenced through strategic, public/private funding of skills and capabilities in the national research base.

3. *Up-stream technologies*, such as large storage battery technologies, are still in the basic research phase, but with the potential to yield valuable opportunities that can yield economic benefit from opportunistic investment.

We suggest, therefore, the following approach to investment and technology stimulation.

1. *Mature domain* This is primarily an issue for private investment, encouraged by whatever appropriate planning, financial and regulatory devices lie in the hands of the Scottish Executive.
2. *Near market domain* Where there are particularly important opportunities likely to deliver substantial economic benefit, it is appropriate to invest public funds, in cooperation with commercial groups, to ensure that particularly strong Scottish skill centres can be part of the leverage that captures development for Scotland. We go on to suggest target areas where such initiatives might be most effective.
3. *Upstream domain* Excellent groups in Scotland that win research grants from public sources should be monitored by the Intermediary Technology Institute for Energy for commercial potential, supported in finding commercial sponsorship, and encouraged, where appropriate, to become members of the research consortia currently being funded through UK initiatives in the energy field. Particularly promising opportunities should be considered for initiatives such as the Scottish Funding Council's Strategic Research Development Grant.

Scottish groups are, and should continue to be, major contributors to UK initiatives (SuperGen) designed to enhance energy research, skills and interactions between the research base and industry, to the new Government initiative in carbon capture and storage (HM Treasury Budget 2006) and to European Union and international energy programmes. However, it is also important that the Scottish Executive and its agencies exploit opportunities to increase the power of the research base in those areas where Scotland has distinct advantages, and could exploit them to its economic benefit. These are most likely to be in sectors where the research base is already strong, where we are favoured by geography and where we have innovative engineering companies.

We advocate serious consideration of such initiatives in four areas:

(1) "Clean coal" and carbon sequestration

Scotland still has major coal reserves, which, if they could be exploited in ways that minimise their carbon emissions, could make a major contribution to energy security. The capture of CO_2 at the source of generation and its deep geological disposal in saline aquifers and in oil and gas reservoirs (see Chapter 5) has great potential to create a bridge between the modern fossil fuel energy system and the future non- or low-carbon systems that will take many years to develop. It has the potential to contribute more than 50% to the global reductions in carbon emissions that will be required by 2050 if atmospheric greenhouse gas concentrations are to be held below twice pre-industrial levels.

Scotland is well placed to play a leading role in developing and implementing the necessary technology and applying its skills to developments elsewhere (Scottish Enterprise 2005). The oilfields of the central and northern North Sea (and the gas fields of the southern North Sea) have the potential for sequestration of CO_2 through its re-injection as part of programmes of enhanced oil recovery and its injection into deep saline aquifers or into depleted oil and gas fields. The Miller oilfield east of Orkney is planned to be the world's first site to store CO_2. It will take 1.3Mt of CO_2 per year from the 350MW gas-power generation plant at Peterhead. The Utsira Formation in the same region has the potential to store very large masses of CO_2 in saline aquifers beneath an impermeable cap rock about 1km below the sea bed. These sites are already connected to land by existing pipelines, which could be re-used, or new pipelines built to transport CO_2 from UK fossil fuel power stations. All essential requirements are in place to permit major development of this potential: the infrastructure of the North Sea oil industry, and the engineering, geo-engineering and geological skills, backed by powerful relevant research capacities in the Scottish Universities and the British Geological Survey in Edinburgh.

The House of Commons Select Committee on Science and Technology (2006) has argued that such developments would be timely, safe and cost effective. The industry is keen to respond to the opportunity, and the Chancellor of the Exchequer indicated a support initiative in the 2006 Budget. Full-scale demonstration projects, that could develop into long-term operational capabilities, should be considered for a number of North Sea sites. The possibility of an on-land demonstrator in aquifers in central Scotland, which would readily take emissions from coal-fired stations, should also be considered.

The potential export markets for carbon capture and storage technologies are considerable, particularly for developing economies dependent on coal, not least in China, where the exploitation of massive coal reserves has the capacity to impact heavily on atmospheric greenhouse gas concentrations. Facilitating the next steps that should be undertaken without delay are the creation of appropriate fiscal and regulatory frameworks, government permissions and processes of dialogue to gauge public acceptability. An important further priority is to strengthen an already powerful research effort in Scotland, to ensure that it plays a pivotal role in developing concepts and technologies and is able to capture a major share of national and EU research funding in the field.

> **Recommendation 15:** Scottish Enterprise should engage with Scottish Coal, Scottish Power, Mitsui Babcock, the Scottish Universities and other stakeholders, to determine a significant clean coal research and development programme in Scotland.

(2) The electricity distribution network

The power stations of the current electricity generation system in Britain were largely built in the 1960s/70s. Some have already been de-commissioned and all will be past their useable lifetime by 2030 (see Chapters 3 and 7). Long-term investment is again needed, but against a very different background of supply and demand and at the beginning of a process of change from the current high greenhouse gas emission electricity generation system to a more sustainable one. This is likely to take place through transitional stages to a system whose characteristics cannot be confidently forecast, although it is likely that small scale and distributed generation will become significant components of generating capacity (see Chapter 7). Under these circumstances, a "smart" network able to accept distributed generation and with the flexibility to incorporate new technologies over the next 50 years is likely to be a priority both in Britain and elsewhere. Scotland's geography and population distribution, the need to supply a small number of major conurbations and a very large number of remoter locations, and the potential for major renewable generation far from major population centres, make it an ideal laboratory that could attract power companies to undertake meaningful-scale demonstration projects. This opportunity is complemented by the strength of Scottish research capacity in networks and power electronics.

Research into Future Power Networks

The University of Strathclyde, in collaboration with ITI Energy, Rolls-Royce and Scottish Power, has set up a project to explore the development of new technology to actively manage power distribution networks. This will look into systems that will allow more flexible implementation of distributed generation in the form of smaller-scale localised forms of generation, which could mitigate the need for expensive infrastructure upgrades. The work will also be looking to meet the demands of intermittent renewable sources like wind and new technologies such as fuel cells.

More information can be found at the Institute for Energy and the Environment at Strathclyde University

More information can be found at: http://www.instee.strath.ac.uk/content/

(3) Low- carbon generation of hydrogen in Scotland

One of the barriers to emission reduction is the current lack of a low-carbon alternative to oil as a highly transportable, energetic fuel for transport in particular. If hydrogen could be generated from low-emission energy sources, it has the potential to provide such a source. It could, for example, be generated from renewable resources, nuclear or coal-burning power stations provided that the carbon emissions of these stations are sequestered, as discussed above. Hydrogen has the potential to be a new universal fuel rivalling natural gas but with a higher thermal content and the benefits of producing only water as a waste product. Whilst there is huge potential for the use of hydrogen in transport, there are production, storage and transportation issues that require more development work, as noted in Chapter 5. There are a number of demonstration projects in the UK and Europe, including:

- The Peterhead scheme to extract hydrogen from methane and use it as a clean new source of power.
- The EU PURE project to use wind power to extract hydrogen from sea water and use it as a transport fuel.
- The EU CUTE project supporting hydrogen-powered buses in London.

- The Lothian hydrogen office.

ITI Energy are involved in a project investigating the production of a low-cost, solid nano-material with the potential to store and release hydrogen at room temperature and low pressure. The resulting material could have a range of important energy applications, such as fuel cell and battery systems. Successful development of this material would enable Scotland to establish its position in an important area of clean energy technology, hydrogen storage and a range of industrial processes involving hydrogen. The R&D project and the associated commercial development is based in Scotland. In addition, the Forum for Renewable Energy Development in Scotland (FREDS) has established a hydrogen and fuel cell energy group which is still to report.

There has been development and deployment of fledgling hydrogen technologies from renewables in Scotland. Although this has been on a small scale, such developments could be highly significant for rural communities. An example of such a development is that on the island of Unst which was visited by the RSE's Energy Committee. Although such work is necessarily limited in scale and global impact, it has the potential to create additional diversity of supply that could be of great value in outlying communities.

Hydrogen, electricity, carbon capture and storage

BP, ConocoPhillips, Shell and Scottish and Southern Energy are developing the world's first industrial project to generate electricity using hydrogen manufactured from natural gas, reducing carbon dioxide emissions by around 90%. The unique project combines hydrogen power generation and carbon capture and storage technologies and offers a way of generating significant amounts of clean electricity from existing fossil fuels and making the most of the world's resources.

The project would involve taking natural gas from the North Sea fields and converting it to hydrogen and carbon dioxide. The hydrogen would be used as fuel for a new 350MW combined cycle gas turbine power station close to Peterhead while the carbon dioxide would be transported by an existing pipeline and injected for enhanced oil recovery and long-term geological storage in the Miller Field. This could extend the life of the field by 20 years and enable production of 40 million barrels of oil that are not currently recoverable. It is expected that the power station would provide 'carbon-free' electricity to the equivalent of quarter of a million UK homes. The project is expected to commence operation in 2009.

More information can be found at:
http://www.bp.com/genericarticle.do?categoryId=97&contentId=7006978

Promoting Unst Renewable Energy (PURE) project

In 2002, a local Unst resident conceived a vision of producing energy locally from renewable resources as a method of contributing to the ever-increasing need for green energy production while combating the socio-economic problems faced by the Unst community.

He developed the PURE Project culminating in the establishment of the PURE Energy Centre (PEC) in Unst, dedicated to developing hydrogen technologies, research, testing, training and education. The basic operation of the system uses two 15kW turbines to capture wind energy, and generate power. This power can either be used directly to provide heating to buildings or used to power the electrolyser. Via electrolysis, the electrolyser splits water into oxygen and hydrogen, which can then be stored in high-pressure cylinders. During periods of wind intermittency, hydrogen can be taken from storage and used in conjunction with a fuel cell to produce power. The hydrogen can also be used in a car which has been converted to run on fuel cells.

More information can be found at: http://www.pure.shetland.co.uk/

Widespread applications of hydrogen technology require major investment in infrastructure, equipment, training and public acceptability, such that the development of an effective hydrogen economy may be slow. Its potential, however, is considerable. In the UK, the Government's Chief Scientific Advisor has recommended that centres of excellence should be set up. Several cities have proposals to focus on fuel cell research and development including London, Birmingham, Warwick, Sheffield, Cambridge and Teesside. As part of its response to the report: *A Strategic Framework for Hydrogen in the UK*, in June 2005, the Government announced a £15 million, four-year programme for hydrogen and fuel cell demonstrations. Furthermore, it is committed to establishing a Hydrogen Coordination Unit (HCU) which will provide an important focus and catalyst for hydrogen energy activity in the UK (Department for Transport 2005). It is to be hoped that Scottish groups will be in the forefront in exploiting these opportunities, which could be facilitated by a strategic perspective for hydrogen developments in Scotland.

> **Recommendation 36:** The Scottish Executive should carry out a detailed appraisal of the potential for hydrogen to contribute to Scotland's energy mix.

(4) *Offshore technologies*

Wind

The advantages of offshore wind installations are the greater wind strength and duration found at sea and the absence of visual intrusion in the landscape. The disadvantages lie in the cost of providing secure, storm-resistant foundations at sea and of the power connections to the on-land grid. Development of offshore wind generation in the UK is proving excessively slow, such that the enormous potential of the Scottish west coast in particular, and the potential for associated commercial exploitation, risk not being realised. The gap between capital costs, expected operational costs and revenue for most projects remains too large for substantial industry commitment (British Wind Energy Association; *Offshore Wind: At a Crossroads* 2006) The uncertainty about real future costs is a major problem. Turbine prices are increasing as global demand expands, reliability is uncertain, raw material prices are high and grid connections are uncertain. It is important that discussions take place to establish whether some of the above risks can be mitigated, by a regime of capital grants and adjustments to economic instruments.

Wave and tidal energy

Scotland's west coast, in particular, has a highly energetic wave and tide environment with considerable energy-generating potential. Scotland has companies involved in design and construction of wave-energy devices, research and testing centres (see boxes) and considerable relevant expertise in its universities. The Scottish Executive has given significant support to the development and implementation of these technologies, and should continue to follow their progress and assess their potential as part of a cost effective renewables strategy.

Ocean Power Delivery

Edinburgh-based company Ocean Power Delivery (OPD) has won an €8-million contract from Portuguese consortium Enersis to build Phase One of the world's first commercial wave-farms, 5km off the northern coast of Portugal. The wave-farm, near Póvoa de Varzim, will initially use three Pelamis P-750 machines to generate renewable electricity with a capacity of 2.25MW. Enersis has also signed a letter of intent to order a further 30 Pelamis machines before the end of 2006, subject to the "satisfactory performance" of Phase One of the project.

The Pelamis wave-energy converter is a semi-submerged, articulated structure (140m long and 3.5m in diameter) composed of cylindrical sections linked by hinged joints. The wave-induced motion of the joints is resisted by hydraulic rams, which pump high-pressure oil through hydraulic motors to drive generators and produce electricity. Power from all the joints is fed down a single umbilical cable to a junction on the sea bed, then through a seabed cable to the shore. For optimum performance, the Pelamis is moored in waters 50-60m deep, 5-10km from shore, tapping the power of the larger swell waves as well as reducing the cost of attaching the machines to a longer submarine cable.

The prototype machine for the Enersis project was tested at the European Marine Energy Centre in Orkney.The 12 main tube segments for the three Pelamis machines are fabricated by Camcal Ltd on the Isle of Lewis and assembled in Fife, then delivered to Portugal for final assembly.

More information can be found at: http://www.oceanpd.com/

European Marine Energy Centre

Highlands and Islands Enterprise (HIE) leads a public sector consortium to establish the European Marine Energy Centre (EMEC) on Orkney. It became operational at the end of 2003. The Centre's facilities include four test berths. The Centre currently offers the world's only grid-connected facility designed to test and prove full scale wave and tidal energy devices. This project is an excellent example of cross Government/public sector support for this fledgling industry. The aim of the Centre is to lead the accreditation and independent performance verification of devices, to encourage development in Scotland and to secure the UK's position in leading the development of these technologies. To date, there is one grid connected wave device at the Centre, Ocean Power Delivery's Pelamis, and one off grid device.

More information can be found at: http://www.emec.org.uk/

The extent to which Scotland could reap long-term economic benefit, and some pride in achievement, from these opportunities will depend to a significant degree on its support for the underlying research base. The knowledge and know-how that are increasingly vital contributions to success in exploiting new technological opportunities are to a large extent dependent upon state funding for fundamental research and training of skilled people. The Scottish Executive and its agencies, such as Scottish Enterprise and the Scottish Funding Council (for Universities & Colleges) have shown considerable skill in doing this in the past. It is urgent that they review this in relation to the four opportunities summarised above.

Energy Research in Scottish Universities

There is a wide diversity of energy research in Scottish Universities covering most key energy technologies.

They are heavily involved in **Supergen,** the Engineering and Physical Sciences Research Council's flagship programme for sustainable power generation and supply. The involvement in the various industry/university consortia is as follows:
Marine Energy: Edinburgh (lead), Heriot-Watt, Robert Gordon's, Strathclyde.
Future Network Technologies: Strathclyde, Edinburgh.

Fuel Cells: St. Andrews.
Highly distributed power systems: Strathclyde (lead).
Excitonic solar cells: Edinburgh.
Energy storage: St. Andrews.

Other notable activities include major centres of research supporting the petroleum industry located at Heriot-Watt, Aberdeen and Edinburgh. The Scottish Centre for Carbon Studies involving a partnership between Edinburgh and Heriot Watt Universities and the British Geological Survey in Edinburgh deploys considerable expertise relevant to sequestration. The Institute of Petroleum Engineering (IPE) at Heriot-Watt University links with the International Centre for Island Technology (ICIT) in Orkney to promote a synergistic "petroleum plus renewables" strategy. Researchers in Chemistry at the University of St Andrews have developed a new electrode that is safer, less toxic and 10 times less expensive than lithium cobalt oxide equivalents, capable of storing more charge, and of great potential in the designing of large high capacity battery storage.

The Scottish Science Advisory Committee (SSAC), with support from the Scottish Executive, is currently studying proposals to create a Centre of Scientific Excellence in Energy in Scotland to link and coordinate funding sources and programmes, to exploit cross-disciplinary collaboration, to support skills development and to link with industry in promoting commercial exploitation.

> **Recommendation 17:** The research community, Scottish Executive, ITI Energy and the private sector should work together to provide the financial, intellectual, policy and enterprise stimulus for the development and use of appropriate renewable technologies and the development of cleaner fossil fuel based technologies in Scotland. A Centre of Scientific Excellence in Energy could be an important means of exploiting Scotland's skills and opportunities. The Scottish Scientific Advisory Committee is encouraged to produce a strong proposal for it, which the Executive is encouraged to support.

9. ENERGY DECISIONS NEEDED FOR SCOTLAND

In this chapter, we focus on the decisions we consider are needed on energy for Scotland both at UK and Scottish levels. The points made in earlier chapters have been brought together for the benefit of the reader and, in particular, for the benefit of the decision-making and decision-influencing communities.

We consider that a number of decisions are urgent, especially to set or clarify the strategic framework and policies for the UK as a whole and for Scotland. These are needed to: unlock decisions for investment due to the phasing out of large-scale electricity generating plant, focus action more effectively on fuel substitution and reduction in greenhouse gas emissions, radically improve the effectiveness of energy efficiency programmes, and stimulate the development of different technologies using renewable resources.

We are not convinced of the effectiveness of some of the existing government instruments. We make recommendations for new instruments and the improved definition of others to achieve policy objectives.

We review whether there is a case for new government bodies on energy to be established, especially to promote greater efficiency in the use of energy.

There is also a need for improvements in the way decision support systems are used. In particular, the town and country planning system and the building regulations can be much more effective in relation to efficiency of energy use, fuel substitution, use of waste and stimulating renewables.

Decisions on the strategy and policy framework

(1) Decisions by the UK Government

Decisions are needed by the UK Government as soon as possible, and preferably by the middle of 2007, on the policy framework for energy and on specific instruments and targets for them. We see no merit in changing the policy objectives. However, we have been repeatedly told by the energy industry that the current uncertainty on longer-term carbon emissions targets and the operation of the carbon trading mechanisms are disincentives to investment in energy. The conclusions of the UK Government's Energy Review provides an ideal opportunity for it to set policy and targets for the longer term.

> **Recommendation 1:** It is essential that decisions are taken by the UK Government by the middle of 2007 to provide a more stable and longer-term policy framework to give greater assurance to the consumer on continuity of energy supply and to give confidence to the providers of energy to make investment decisions.
>
> **Recommendation 2:** The UK Government should maintain the energy policy objectives set out in the 2003 White Paper: to ensure an adequate, safe and secure supply of energy, to reduce the emission of greenhouse gases with the setting of unambiguous long-term targets, to promote economic development,

and to protect vulnerable sections of the population from the adverse effect of market forces.

> **Recommendation 3:** The UK Government should periodically review the instruments and targets used for implementing the policy framework to assess their effectiveness in achieving their intended objectives, and to ensure that unintended consequences have not arisen.

We are not convinced that the government's approach to energy efficiency is effective for the reasons set out in Chapter 6.

> **Recommendation 9:** A more comprehensive and integrated package on energy efficiency should be developed at both UK and Scottish levels to reduce the current confusion and increase effectiveness. This should be linked to strengthening the targets and ensuring their achievement under a revised Energy Efficiency Commitment.

We have argued in Chapter 8 that there is a need for electricity to be produced from a variety of energy and fuel sources. Without this diversity the strategic aim we propose of **a secure, competitive, socially equitable, and low carbon emissions supply of energy** will not be achievable.

> **Recommendation 26:** The UK and Scottish Governments should ensure that the framework for energy at both UK and Scottish levels encourages investors to produce electricity from a diversity of supply sources.

(2) Decisions by the Scottish Executive

We recognise that there are many initiatives on energy by the Scottish Executive and others at the UK and EU levels which have a bearing on Scotland. However, we can find no overarching framework for these initiatives or for making decisions on energy policy and action for Scotland. The absence of a framework reduces the ability of the government to place its decisions within a broader goal-orientated structure. Its absence also reduces the ability of the public and all of the components of the energy industry to decide on their contribution and judge the progress being made. We recognise that Scotland has limited authority on energy because energy is predominantly a reserved matter at the UK level. Nevertheless, we consider that a very high priority for the Scottish Executive must be to formulate, consult on and approve a strategy for energy for Scotland. There are specific areas of policy and action which require clarification. And there is also an urgent need for programmes on transport and heating from the energy and emissions perspectives.

The strategic aim should be **a secure, competitive, socially equitable, and low carbon emissions supply of energy for Scotland.**

There should be four supporting objectives to:

(1) encourage energy efficiency to the benefit of economic development;
(2) ensure that energy availability, cost and safety contributes to improvements in social benefits for Scotland;
(3) minimise adverse environmental effects, both locally and globally; and
(4) capitalise on the natural energy resources of Scotland in an economically-viable and environmentally-sensitive way.

> **Recommendation 4:** We strongly recommend that the Scottish Executive develops a comprehensive energy strategy, within the boundaries of its powers and responsibilities and in consultation with the UK Government, by the end of 2007. This should embrace specific strategies on energy efficiency, transport, heating, electricity generation and the use of renewables. This should also include the strategic aim of a secure, competitive, socially equitable, and low carbon emissions supply of energy for Scotland, and the four supporting objectives we propose.

As the generation and supply of energy is wholly in the hands of private companies, which respond to market signals as well as to economic instruments, we do not consider that targets on the proportion of renewable resources of energy which should be achieved for each sector is an effective way to proceed. We propose a broader-based approach which recognises the need for reducing emissions of greenhouse gases and achieves longer-term business, technological and environmental advantages for Scotland.

> **Recommendation 19:** The Scottish Executive, as part of the development of its energy strategy, should develop fuel substitution targets for all of the main energy consumption sectors: transport, heating and electricity.

Clarification is urgently needed by the Scottish Executive of how the target of 40% of electricity production from renewables by 2020 is to be achieved in practice. We propose an alternative definition as follows.

> **Recommendation 27:** The Scottish Executive should redefine the 2020 target for the proportion of electricity generated from renewable resources in terms of reduction in greenhouse gases to meet the UK's 2050 target on emissions reductions, and set out a detailed and comprehensive strategy for meeting it.

The UK and Scottish Governments' strategy and policy should ensure that electricity can be supplied from a variety of energy and fuel sources.

> **Recommendation 26:** The UK and Scottish Governments should ensure that the framework for energy at both UK and Scottish levels encourages investors to produce electricity from a diversity of supply sources.

We welcome the proposals for an energy efficiency programme for Scotland. This needs to be comprehensive and more effective than the current regime.

> **Recommendation 9:** A more comprehensive and integrated package on energy efficiency should be developed at both UK and Scottish levels to reduce the current confusion and increase effectiveness. This should be linked to strengthening the targets and ensuring their achievement under a revised Energy Efficiency Commitment.

We are concerned about the lack of rigour in making assessments about the choice of energy technologies. We identify nine factors to be part of any assessment as follows:

state of technology, infrastructure requirements, security of supply, carbon benefit, effects on water quality, use of waste produced, costs to the consumer, effects on communities, and effects on natural heritage assets.

> **Recommendation 6:** A common methodology could and should be developed to assess the relative merits of energy technologies, using the nine factors identified. It should include full lifetime costs and a carbon audit. Assessments using the methodology should be undertaken independently of specific interests and be open to public scrutiny.

Improved economic instruments to stimulate reduction in emissions, efficiency of energy use and fuel substitution

(1) A carbon levy to replace ROCs

It can be argued that ROCs are a market distortion which has failed in practice. It is a system of subsidies aimed in principle at renewables in general, but in practice they have only generated activity in wind turbines. Largely this is because wind turbines have already developed an acceptable level of technology. So rather than achieving the stated intent of being technology neutral, the ROCs are mainly subsidising one form of technology. A larger concern is that very few wind turbines are economic without the ROC subsidy. This leaves Government with the dilemma on whether to continue the ROCs indefinitely. Continuation of the ROC subsidy is also unlikely to provide much incentive for industry to pursue other technologies to reduce emissions.

We have earlier expressed our support for the policies to reduce CO_2 and other emissions. The market is likely to respond most effectively in support of such policies if they are clearly targeted on greenhouse gas emission reductions and have stability in the longer term. This would require some form of carbon levy. Such a system creates a more level playing field for market investment leaving the generator to choose between the various alternatives of emissions reduction, carbon levy trading or investment in renewables. It provides a direct incentive for the owners of fossil fuel generation to develop technology to reduce their emissions or, if this is prohibitively expensive, to buy certificates in the carbon trading market to reduce their levy obligations. We note that an allocation based system, as used in the EU Emissions Trading Scheme, has just failed. We believe that a carbon levy is far more likely to stimulate this innovation than an indirect instrument, such as the ROCs subsidy.

> **Recommendation 20:** We recommend that the UK Government, supported by the Scottish Executive, replace ROCs as soon as possible with a carbon emission reducing measure, such as a carbon levy applied at the point of carbon production. This should build on the existing EU Emissions Trading Scheme. Existing commitments should be honoured.

(2) Incentives to stimulate research, development and demonstration

We consider that there is a clear case for government financial support towards bringing new technologies to the market where currently there is no incentive, the risk is seen to be great, and faster achievement of government energy policies could result. Grants should be targeted on research, development and demonstration phases of those technologies likely to be of greatest benefit to achieving specific outcomes, especially for transport, heating and electricity generation. These might include: development of electricity generation networks, especially SMART technology; carbon sequestration, including ‘clean coal’ technology; offshore waves and tides; development of hydrogen for transport, fuel and heat; and small community micro-generation units. Incentives should be targeted on those expert groups that are at the research, development and demonstration cutting edge, so that the position of Scottish centres can be maintained and further enhanced, rather than allowing it to be taken by others, as happened previously in wind technology.

> **Recommendation 15:** Scottish Enterprise should engage with Scottish Coal, Scottish Power, Mitsui Babcock, the Scottish Universities and other stakeholders, to determine a significant clean coal research and development programme in Scotland.

> **Recommendation 17:** The research community, government, ITI Energy and the private sector should work together to provide the financial, intellectual, policy and enterprise stimulus for the development and use of appropriate renewable technologies and the development of cleaner fossil fuel-based technologies in Scotland. A Centre of Scientific Excellence in Energy could be an important means of exploiting Scotland’s skills and opportunities. The Scottish Science Advisory Committee is encouraged to produce a strong proposal for it, which the Scottish Executive is encouraged to support.

The potential for hydrogen as an energy vector should be carefully reviewed as a basis for informed financial support measures for the technology.

> **Recommendation 36:** The Scottish Executive should carry out a detailed appraisal of the potential for hydrogen to contribute to Scotland’s energy mix.

There is considerable opportunity for distributed energy systems in many parts of Scotland to create partial self-sufficiency/semi-autonomous networks. This could range from the large-scale district heating or combined heat and power systems in the major settlements to micro-generation facilities using wind, wave or tidal energy sources in the remoter areas of the mainland and on the islands.

> **Recommendation 34:** The various energy use advisory bodies should compile examples of distributed systems and ensure their wide dissemination.

> **Recommendation 35:** Joint initiatives by local enterprise companies, applied research and development groups and private enterprise, especially local community groups, should be encouraged to exploit locally available energy resources for local use.

(3) Incentives for greater use of waste for energy production

We have argued in Chapter 6 the case for greater use of material currently disposed of as waste to be used for energy production. This will not happen without incentives to improve performance and disincentives to halt current wasteful practices.

The regulations determining the exploitation of biomass are inhibiting and are in need of simplification and clarification. For example, a forester growing timber as a fuel crop can access the ROC. However, scrap wood from forests where the timber is primarily grown for other purposes is classified as waste and current definitions of waste hinder its efficient use.

> **Recommendation 25:** The UK and Scottish Governments should introduce a tax disincentive on waste disposal, especially to landfill, and a greater tax incentive for the reuse of waste for space and water heating as part of District Heating and Combined Heat and Power Schemes. They should also introduce a tax credit system to stimulate the use of biomass and waste for the production of heat for all buildings; and should consider an energy efficient dependent stamp duty and Council Tax as incentives for improvements in building design and construction.

> **Recommendation 18:** The Scottish Executive should ensure that the definition of forest waste used by SEPA enables state and private forest owners to utilise forestry thinning and other wood materials in energy production.

(4) Incentives for fuel substitution and energy efficiency in transport

For transport we see the stimulation of hydrogen fuels from low carbon sources and stimulation of biofuels as part of diversification of agriculture as major possibilities.

> **Recommendation 21:** The UK Government should review and improve the incentives to encourage fuel substitution in transport and for the production of biofuels and associated infrastructure.

There is a range of measures which could be effective in improving energy efficiency in both public transport and private vehicles.

> **Recommendation 13:** The UK Government should consider measures, such as the use of lane preference and variable charging systems, to encourage higher occupancy in private vehicles.

> **Recommendation 14:** Bus transport operators should be given greater incentive through the Scottish Executive’s current service support mechanism to operate a wider range of vehicle types to cope with variable passenger loads.

(5) Special incentives for changing behaviour on energy efficiency

The evidence available to us suggests that there are a number of obstacles to the take-up of energy efficiency measures, particularly by domestic households. Our recommendations address these points.

> **Recommendation 12:** As part of encouraging the change of behaviour needed, a comprehensive set of measures including education, information and incentives should be developed by the proposed Energy Efficiency Agency for Scotland (or failing that the Scottish Executive).

In support of this Recommendation we propose the following actions:

> (1) Learning support materials on energy efficiency should be provided to primary and secondary schools through Learning and Teaching Scotland;
>
> (2) an independent assessment should be undertaken to ascertain the causes of failure of energy efficiency schemes as a basis for implementing more cost effective schemes; and
>
> (3) the UK Government should consider financial measures to stimulate changes in behaviour on energy efficiency.

These actions should be taken by the Energy Agency for Scotland.

In addition, we consider that industry can and should do more.

> **Recommendation 7:** Industry should be persuaded, through economic instruments and approval mechanisms in the statutory planning system, to utilise waste energy, especially heat, for beneficial purposes. In particular, we recommend that all future small thermal generating plants, near to population centres, should have specific arrangements for the use of waste heat.

(6) Longer-term stability of instruments and periodic review of their performance

A concern frequently expressed to us was the lack of longer-term stability in the instruments used by government, and the lack of targets set for a sufficiently long period ahead to stimulate investment. We recognise the importance of ensuring that instruments are reviewed periodically to ascertain whether they are achieving the purposes for which they were intended. We consider that these points should be taken much more seriously by government and so recommend.

> **Recommendation 2:** The UK Government should maintain the energy policy objectives set out in the 2003 White Paper: to ensure an adequate, safe and secure supply of energy, to reduce the emission of greenhouse gases with the setting of unambiguous long-term targets, to promote economic development, and to protect vulnerable sections of the population from the adverse effect of market forces.
>
> **Recommendation 3:** The UK Government should periodically review the instruments and targets used for implementing the policy framework to assess their effectiveness in achieving their intended objectives, and to ensure that unintended consequences have not arisen.

Decisions needed to stimulate the development of new electricity generating stations

Given the step-wise decline in electricity generation from current large plants in the next 25 years, and given lead times on approvals and construction of alternatives, then urgent decisions are required in order to stimulate investment on new capacity. We recommend joint activity by the Scottish Executive, energy companies and The National Grid Company to consider the options for new stations, and specifically the decisions needed to be taken by government to stimulate investment decisions by the industry. Such discussions are not to tell each party what to do and not for the government to take decision-making authority away from those formally responsible, but to ensure that there is a sharing of information and clear articulation of obstacles to and opportunities for investment decisions. Without clear government decisions, we are concerned that there might be a second ‘dash for gas’.

A critical decision that the UK government needs to take this year, 2006, is to set emissions targets and costs of carbon through the ETS and ROCs. If the ROCs are to make a real impact on investment on power generation, then Ofgem will have to give some assurance about the long-term market in energy beyond 2015 when the current scheme is set to expire.

We have concluded earlier that the generation of electricity in Scotland should be derived from a multiplicity of sources, to safeguard against over-dependence on one source for reasons of security and continuity of supply, and the opportunity to benefit from improvements in technology as they are brought to the market. We have also noted that the lifetimes of most electricity generating stations in Scotland are limited and that, even on the most optimistic of current assumptions about prolonging their operating lives, they will all be closed by 2030, with significant reductions from 2011 onwards. Given the timescales for the planning, approval and construction of new plants, there is an urgent need for all involved in the decision-making process to play their part in ensuring that Scotland does not have electricity supply shortages.

For the Scottish Executive, this means determining its policy on sources of supply for electricity in Scotland and ensuring that the relevant decision-making systems operate effectively and are applied scrupulously. The traditional manner of making decisions behind closed doors with respect to infrastructure under the various electricity statutes is no longer tenable; a more open and transparent process needs to be put in place. We consider that this can be achieved by administrative decision without recourse to changing the statutory provisions. Significantly, it also means that the coalition partners’ views on the possibility of nuclear electricity generation should be re-visited, if our conclusions that all options for electricity generation technologies should be kept in the frame.

The ideal circumstance that would maximise the prospect of Scotland meeting its overall objectives for energy would be one in which a large variety of generating technologies were available. These could be deployed as conditions dictate. Any decision to exclude particular technologies from consideration might significantly reduce the prospect of Scotland meeting its energy objectives. At present, policies by political parties which remove options are not helpful in this regard.

For this to occur means that the Scottish Executive Ministers have to make decisions on its policy on the options for electricity generation by the middle of 2007, i.e. immediately after the elections to the Scottish Parliament in May 2007. In support of this timescale, we make the following recommendations.

> **Recommendation 29:** Subject to agreement on implementing a satisfactory solution to the very long term treatment of radioactive waste, we encourage both the UK Government and the Scottish Executive to keep open the nuclear

electricity generating option in the interests of diversity and security of supply and suppression of greenhouse gas emissions.

Recommendation 30: Government, industry and political parties should retain options for new build electricity generation from a variety of technologies, specifically renewables, clean coal, gas and nuclear subject to public engagement to decide whether any technologies should be excluded from consideration.

Recommendation 31: The Scottish Executive should discuss with the major generating companies and National Grid Company the decisions required by UK and Scottish Governments and also by generators for the replacement of large-scale electricity generating stations in Scotland. They should take into account the public engagement in Recommendation 30.

Recommendation 32: Government authorities with approval powers, and generating companies should favour the construction of new large-scale electricity generating plant adjacent to existing plant, with easy access to the grid.

Decisions needed on the enhancement of the National Grid

There is an apparent contradiction between the Government policy and the connection policy of the National Grid. The Grid loses power in transmission, and hence generators distant from the centres of power usage are of less value, and the Grid through Ofgem has introduced a connection charge that penalises remote generators. Most wind generation proposals are for remote sites because we have been told repeatedly that these are more profitable as the wind is stronger and more persistent. Thus the Government has introduced the ROCs to make the alternatives more economically attractive, while Ofgem has a transmission charge policy that makes them less competitive. This situation is in urgent need of resolution.

Recommendation 33: The Scottish Executive should carry out a review of the infrastructure implications of its renewables policy, especially in light of National Grid Company's grid-connection charging policy.

Improved use of Local Council decision-support mechanisms

There are a number of important decision-support mechanisms relevant to energy that are the responsibility of Local Councils. Most significant are the Town and Country Planning system and Building Regulations.

(1) Town and Country Planning system

Within the Town and country Planning system particular problems have occurred and are still occurring in decision-making on planning applications for onshore wind turbines where long timescales for decisions are frustrating development and, as a result, achievement of low carbon targets is at risk of not being achieved. The proposed national overview, and the continuation of national strategies for large-scale and widespread development, would help to remove some of the uncertainties for developers and third-party interests and should, in turn, speed up the decision-making process without undermining the well tried and tested procedures. The Local Plans should be used more effectively to develop and guide energy strategies energy action locally.

> **Recommendation 28:** A locational strategy and accompanying planning guidance on onshore wind development should be drawn up immediately by the Scottish Executive to guide Local Councils, investors and third parties, and speed up the process of decision-making.

The statutory planning framework has not been effective in promoting the use of waste for energy, or the development of district heating and combined heat power schemes.

(2) Building Regulations

The Building Regulations are another key decision-support mechanism. They should be used more effectively than at present to set standards for energy efficiency for all new buildings and progressively for other buildings. There is also a need for more effective enforcement of the standards in relation to energy efficiency. A more progressive approach to housing design to achieve higher energy efficiency standards is also needed. An agreement between local authorities and major house builders about designs that are the most energy-efficient should be reflected in ratings in sales literature.

> **Recommendation 11**: The Scottish Executive should require Local Councils to achieve specific and measurable improvements in the efficient use of energy through the town and country planning system and building regulations.

> **Recommendation 24:** Local Councils should undertake the following to improve fuel substitution for heating:
> (1) amend Structure Plans and Local Plans to stimulate the development of combined heat and power and district heating schemes in urban areas;
> (2) do not approve Planning Permission and Building Warrant to developments on brownfield and greenfield sites without these facilities;
> (3) work with the building construction industry to put into effect systems for the delivery of combined heat and power and district heating systems; and
> (4) increase the targets for the reuse of municipal waste for energy production coupled with a reduction on material sent to landfill sites in Local Waste Plans.

> **Recommendation 8:** Local Councils should stimulate more energy-efficient housing designs through the Building Regulations system and should substantially improve the enforcement of Building Regulations in relation to energy efficiency.

New Government body for energy

(1) An Energy Agency for Scotland

At present, energy policy for Scotland and the lead role on energy action within government is the responsibility of the Energy Group of the Scottish Executive Enterprise, Transport and Lifelong Learning Department. Many other parts of the Scottish Executive have responsibilities which impinge on energy, such as the Development Department for Building Standards and the Town and Country Planning system. All Scottish Executive Departments report ultimately to the First Minister. Given this structure, it is vitally important that all of the component parts of the Scottish Executive work to a common set of policy objectives, as we have argued above. It is equally essential that initiatives from various parts of the Executive and the bodies which report to it, are developed and implemented in a coordinated manner.

There is no independent source of advice and no arms-length execution of all government action on energy in Scotland. As we have noted elsewhere in this report, there is a great deal of public interest in and debate about energy for Scotland. Some of it is highly disputaceous and means that the public sends confusing signals to Ministers and their officials. We recognise the role that the Scottish Parliament can play in stimulating debate on energy matters and in scrutinising government policy and action. For example, it can set up specific inquiries, call witnesses and generally stimulate debate before reporting on its findings to the whole Parliament, to the Scottish Executive, and to the public. However, this approach is still part of the political system and we consider that an alterative mechanism is necessary.

Our judgement is that the public is looking for a more open and transparent approach to decision-making. It is worth observing, in this context, that the move towards greater openness and transparency, including the advent of the Freedom of Information (Scotland) Act 2002, has not led to greater openness in giving advice to Ministers on energy. The development of the 40% target for electricity generated from renewable sources is a good case in point. Also the public, industry and commerce frequently have difficulty in finding their way around the plethora of regulations and incentives in the energy field. There appears to be a case for providing government incentives and implementing initiatives in a more integrated manner on all aspects of energy. There is also a great deal of action that could be taken by the public sector in Scotland to improve the efficient use of energy, encourage fuel substitution and stimulate targeted research, development and demonstration. Local Councils and government bodies can do a great deal more than they are doing on these fronts. The establishment of a body to champion action in the public sector, to disseminate best practice, to scrutinise policies and actions, and to press for improvements in performance would be a great advantage in Scotland compared to the present arrangements.

We are not entirely convinced that this can be achieved through the present arrangements whereby all of the decisions on energy are taken within government departments, either in London or in Edinburgh. One of the ways of achieving this is to establish an arms-length agency of government, formally called a Non-Departmental Public Body (a ‘quango’ in common parlance). A body with the specific responsibilities for advising government, parliament and the public on all aspects of energy policy and for taking appropriate action could be more effective, and seen to be so, than the present departmental arrangements.

We consider that a case can be made for a body at arms length from government to undertake a variety of roles on energy in Scotland. These would include: gathering and analysing opinion on policy and practice options, assessing performance of the public sector on all aspects of energy, challenging the public sector to improve performance, providing independent assessments of technologies, scrutinising the relative costs and benefits of energy options, developing and administering energy support schemes especially in relation to technology and energy use efficiency improvements, and sharing best practice on innovation.

In making our recommendation, we recognise that the Scottish Executive is not generally in favour of creating new government agencies.

> **Recommendation 5:** The Scottish Executive should seek Parliament's approval for the establishment of an Energy Agency for Scotland as a Non-Departmental Public Body. Its responsibilities should include the ability to advise the government and all other interests on all aspects of energy, the promotion of energy efficiency, disbursal of all grants and incentives related to energy, independent assessments of technology options and whole lifetime costs, and gathering and disseminating best practice on energy use.

We make a recommendation (10) below for the establishment of an Energy Efficiency Agency for Scotland. If ultimately the Scottish Parliament decides to establish an Energy Agency for Scotland, as we recommend, then the Energy Efficiency Agency for Scotland should be subsumed within it.

(2) The Energy Efficiency Agency for Scotland

We have concluded in Chapter 5 that the approach to energy efficiency is less effective than it could or should be. We have given examples in Chapter 6 where performance on energy efficiency should be improved in relation to transport, heating and electricity. We have already recommended a review of why many of the energy efficiency measures have proved to have limited effectiveness (Recommendation 9). We have argued that a more systematic approach needs to be taken to identifying the factors that would stimulate changes in behaviour on energy efficiency, especially by domestic households. We note that there are many schemes on energy efficiency and consider that, along with human behaviour, these could be part of the problem of low take-up**.** We have noted from our visits and from the evidence given to us that there is a great deal of innovative practice in Scotland, often on a small scale in relatively remote communities. We believe that there is a need to gather information on these innovations and ensure that they are disseminated widely to stimulate others.

We are persuaded therefore of the need for the establishment of a new body which we term the Energy Efficiency Agency for Scotland. This should formally be a Non-Departmental Public Body to ensure that it is at arms length from government but can both act on the government's behalf and advise it on any matters related to improving the efficient use of energy.

> **Recommendation 10:** The Scottish Executive should seek Parliament's approval for the establishment of an Energy Efficiency Agency for Scotland as a Non-Departmental Public Body. It should have both advisory and executive powers with authority to scrutinise and make recommendations on energy

efficiency action in the public sector, disburse incentives for reducing energy use, increasing efficiency and supporting novel initiatives, and for disseminating best practice.

In summary, there are a number of key decisions that need to be taken within the next 18 months. These are listed in Table 17 below.

Table 17: Timescales for key energy decisions

Decision	When	By whom
UK Energy strategy	Mid 2007	UK Government
UK energy targets	Mid 2007	UK Government
Scottish Energy strategy	End 2007	Scottish Executive
Emissions targets for Scotland	End 2007	Scottish Executive
New electricity generating plant	Mid 2007	Scottish Executive/generators/National Grid Company
National Grid upgrade in Scotland	Mid 2007	National Grid Company/Ofgem
National grid upgrade Scotland/England	Mid 2007	National Grid Company/Ofgem

Developing a publicly acceptable energy policy

The need for public engagement

Many governments find it increasingly difficult to implement policies that involve complex issues of science and technology, primarily because of their failure to engage effectively with public concerns. In the UK, public trust in government in such areas has been damaged by its handling of issues such as BSE, genetically modified foods and the disposal of nuclear wastes, which has led to a perennial failure to create acceptable and effective public policy. These difficulties for governments have been compounded by enhanced public expectations of involvement in decision-making on complex technological issues with so far no commensurate procedures for managing the conflicts that often emerge in such situations. This could be the fate of energy policy if it is not well handled.

The spectrum of major energy technologies from which choices must be made does not offer easy options. The redevelopment of coal or nuclear power, the spread of wind turbines, the extension of hydroelectric generation, the large-scale development of biofuels, the development of tidal or wave generation and the use of hydrogen as a compact and energetic vector variously pose problems of health risk, environmental damage, climatic impact, cost or technological uncertainty. Several of the options discussed in this report are also likely to lead to ‘in principle’ objections from some sectors of the public, regardless of risks or other impacts. As a consequence, the complex set of options required to secure Scotland’s future energy supplies will lead to equally complex arrays of public responses, varying from one location to another. Managing the process of public engagement will thus be an important task in itself, requiring a carefully constructed strategy to link it to the policy development process.

In considering questions of public acceptability, it is important to keep in mind that ‘the public’ is an ill-defined concept. We use the term to describe undifferentiated members of the public. Where members of the public come together as a group, with the aim of influencing policy or opposing the plans of private interests, and claiming to act ‘in the public interest’ rather than in their own personal interests, we refer to them as ‘public interest groups’. These would include, for example, consumer or environmental organisations, that are often long term relatively stable organisations likely to campaign on a wide range of issues including, but going well beyond, energy issues. The scene is further complicated by the fact that any member of the public is likely to belong to several of these categories simultaneously. Also, members of the public will include scientists, engineers and others with energy-related expertise, along with policy makers themselves.

The public groups currently involved in energy consultations usually represent separate, coherent public interests, such as consumer, conservation or environmental groups. Their primary aim is to influence the decisions of policy-makers, regulators and those involved in location decisions, so that these conform to the views of their members. Such groups often arrogate to themselves or are given the role of representing the public voice, but although some of them may have very large membership lists and financial resources, none represents more than a very small proportion of the general public. Depending on the issue, the objectives of such groups may vary considerably, and engagement with them may be directed towards reconciling their views to reach a consensus. In some cases, pressure groups come together to create a powerful ‘advocacy coalition’. In such circumstances, a genuinely “public view” can be even more difficult to identify.

Public and stakeholder engagement are, however, essential components of effective governance in relation to such issues in a democratic society. Such engagement can facilitate decision making by reaching a consensus on the desirability, scale, location, etc. of new energy-related developments. However, where there are incipient conflicts and strongly held views, the outcome of an engagement process can be polarisation of opinions and an increase in the level of conflict, making it more difficult to reach a decision based on consensus. Negotiation, compromise and compensation are an accepted part of modern governance in resolving policy-related conflicts. It is important, however, to recognise a fundamental dichotomy between those whose views are based on “interest” and those based on “values” (Table 18). The former feel that their personal or group interests are threatened by a development that may, for example, affect property values, cause a nuisance, a potential health problem or environmental damage. Such situations are usually negotiable through an accommodation between interested parties. For the latter group, the conflict is based primarily on fundamental values or ideology, where the usual means of conflict resolution through stakeholder engagement are likely to be ineffective or counter-productive. Both groups often prefer to use technological or scientific arguments to justify their stance to others. In this regard, it is crucial that, as far as possible, facts where they are available are set out and explained clearly in the context of public debate, which represents one of the justifications for this report.

Table 18: Interest based and value/ideology based engagement[13]

Interest based engagement	Uncommitted members of the public	Value/ideology based engagement
Restricted to specific developments		Spreads across related and sometimes unrelated developments
Location specific, locally organised		Organised nationally or internationally
Can usually be resolved by: - providing information - giving compensation or - negotiation		Very difficult to resolve - information is treated as propaganda - compensation is seen as bribery - negotiation is seen as betrayal
Giving concessions leads to mutual accommodation		Giving concessions leads to escalation of demands

Note that “uncommitted members of the public” are likely to be a large majority, even for highly controversial issues.

Many policy issues are binary, for example about whether or not a road should be built, so that one or another party is likely to be completely satisfied by the outcome. The energy issue is different. Most will agree that something must be done, but it is highly unlikely that any effective strategy will meet the complete approval of any of the stakeholder groups or individuals that have strong views for or against this or that technology.

In the case of energy, the positions of most individuals or groups will be based on a mixture of interests and values. However, some energy issues have the potential to polarise strongly around questions of value, creating a situation where ideology becomes dominant. Those who subscribe to the ideology become intolerant and unwilling to accommodate other viewpoints, and debates and decisions will tend to be dominated by a small proportion of the population who feel very strongly about the issue, with the views of the silent majority being unheard or ignored. Thus it is necessary, not just to understand the interests and values held by different protagonists, but to be aware of the extent to which interests or values are likely to dominate their inputs to a stakeholder consultation. One of the key challenges for government is to elicit a representative public view that is not excessively skewed by sectional interests through a process that is able to demonstrate the democratic legitimacy of that view, and thereby defend itself against the charge of arbitrariness or bias.

Table 19 attempts to summarise the potential public positions on the range of energy-technologies and issues involved in Scotland. It seems likely that fossil-fuel-based

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[13] Tait, J. (2001) More Faust than Frankenstein: the European Debate about Risk Regulation for Genetically Modified Crops. *Journal of Risk Research, 4(2),* 175-189.

options that are not inconsistent with an emissions-reduction policy are likely to lead to public responses based mainly on interests. Public responses to renewable energy sources are likely to have a strong interest-based but also a strong value/ideology-based component, both for and against these technologies, a situation where the public view may be particularly open to rapid shifts from one category to the other. For nuclear-related options, a considerable proportion of public engagement is likely to be firmly ideology-based, and difficult to move across to the other side of the table, although there will be many members of the public who are uncommitted or for whom the issue is one of self-interest. It is also important to be aware that these positions will not be immutable. When an issue or issues become controversial, or when specific decisions are on the agenda, the size of the 'uncommitted' group tends to diminish. It is notable, however, that controversy tends to generate value-based, rather than interest-based, commitment and to harden existing value-based commitments. It is unusual in such circumstances for value-based groups to move to more accommodating views.

Table 19: Different perspectives on energy options

Interest-based engagement	**Value/ideology based engagement**
• Electricity generation from fossil fuels • Fossil fuels for heating • Renewable energy sources – wind, wave, bio-fuels, hydrogen • Nuclear power options	• Renewable energy sources – wind, wave, bio-fuels, hydrogen • Nuclear power options

Processes of public engagement

A recent report of the UK Council for Science and Technology (2005), accepted by the UK government and devolved administrations, recommended that for major issues likely to be of considerable public concern, processes of public dialogue should be used that are deeper than the conventional consultation exercises routinely carried out by Government, and that these should:

- provide a public forum for reflective, considered and informed discussion between people with a range of views and values. Structured conversations between experts, non-experts and policy-makers can permit all to re-evaluate their perspectives and assumptions in the light of those of others, evolve their thinking, and explore areas of mutual and convergent understanding;
- engage a diverse range of people. In particular, to engage with people who have no strong pre-existing interest in the area and so enter the discussion with a fresh perspective that helps to open up debate, and avoids capture by special interest groups; and
- stimulate exploration of the interconnections between scientific, economic, social, ethical and environmental issues, and identify the point at which an issue (for

example on economic priorities or acceptable levels or risk) becomes essentially political.

The tools that are available for the conduct of such dialogue are well-documented (Weldon, S. 2004). The purpose is to establish the broad public acceptability of particular policy options, to improve the quality of decision-making and to avoid policy being excessively determined by any minority group. It is not and should not be an excuse for excessive delay to the overall detriment of the public good. On the other hand, a public engagement process that gives the impression of being rushed and superficial can be counter-productive. In the case of energy, where decisions need to be taken urgently, but will be progressive over several years, we suggest that in the aftermath of the UK Government Energy Review, due to be published shortly, the Scottish Executive should initiate and complete a process of dialogue over the next two years. Although the Executive should be the sponsor of this process, public trust in the process and willingness to participate will depend upon the independence of the body managing the process of dialogue, and the Executive's commitment to explain how the results of the process have influenced policy development. There are two important principles that would need to be observed:

- An engagement process needs to be directed and managed by an independent body, not by the Executive itself.
- Experience shows that there need to be at least two rounds of engagement. A single big bang is unlikely to work. The first stage would allow people to frame the issues in their own way, and the second to engage on substance. People are surprised and delighted when they are approached a second time, and when they are shown that what they initially said has been listened to.

One of the barriers to rapid change could prove to be the system of Public Inquiries under the Town and Country Planning system. In the past, groups challenging proposals put to such enquiries have often created a debate about national policy to delay or prevent a decision about a local initiative. We suggest that a public debate should be a major contribution to the development and adoption of national policy by the Parliament, and that such policy should not be a subject for debate in local public enquiries, which should concentrate on local impacts rather than national need.

It is particularly important that the issues for dialogue are posed appropriately, and that the dialogue process is able to change the way in which issues are framed. Nuclear energy and wind generation are likely to be particularly contentious issues. It would be a mistake to frame the issues as "are you for or against nuclear/wind generation", but rather "what are the energy policies required to meet the challenges of security, climate change and price, and how will they need to evolve in a long term transition to a low-carbon generation system?"

The role of the media is vital. Their influence on the decision-making process and its outcome is likely to be considerable. The energy issue is a tempting target for facile solutions and sensational headlines. Equally, the media could provide a forum for an energy debate that could be a crucial, not uncritical, accompaniment to a process of public engagement and deliberation that would permit Scotland to make informed and possibly difficult choices about its energy future. The media in Scotland should be challenged to play a major, constructive and creative role in a dialogue that is potentially vital for Scotland's future.

With an issue as complex and broad ranging as Scotland's energy policy, it will be important to encourage reasonable expectations of what can be achieved by engagement. The purpose of dialogue is not to determine but to inform policy making and decisions. It does this by challenging the thinking of policymakers and technical experts who contribute to decision making. Government must retain the responsibility for making the decisions.

In the case of energy, we have pointed out the need for a Scottish strategy to be formulated by the end of 2007, and we have recommended that decisions on new electricity generating capacity are made in the same timeframe. We recommend that a process of public engagement begins in the next few months with outcomes reported to government by the summer of next year on the major technologies for electricity generation and later for other aspects of energy. It is preferable that this is undertaken independently of the Scottish Executive. We consider that an existing independent body, such as the Royal Society of Edinburgh, and others of the same type, should jointly undertake this exercise on behalf of the Executive.

> **Recommendation 37:** The Scottish Executive should invite independent bodies, such as the Royal Society of Edinburgh, jointly to design and conduct a process of public dialogue and deliberation. Based on the outcomes of this process, they should make recommendations to the Scottish Executive about the range of technologies that should be acceptable as part of an energy mix in Scotland to ensure security of supply and economic competitiveness and to support the transition to a low-carbon economy. The process should be launched as soon as possible after publication of the UK Government energy review, and completed in the summer of 2007 at the latest.

APPENDICES

A. Committee membership and mode of working
B. Acknowledgement of sponsors and contributors
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APPENDIX A: COMMITTEE MEMBERSHIP AND MODE OF WORKING

The membership of the Committee of Inquiry was as follows:

Professor Maxwell Irvine (Chairman), Professor of Physics, University of Manchester.
Professor Andrew Bain, Former Visiting Professor of Economics, University of Glasgow (until April 2006).
Professor Geoffrey Boulton, Vice-Principal and Regius Professor of Geology and Mineralogy, University of Edinburgh.
Professor Roger Crofts (Secretary), Visiting Professor of Geoscience, University of Edinburgh, and former CEO, Scottish Natural Heritage.
Professor Allan Findlay, Professor of Geography, University of Dundee (until January 2006).
Dr Robert Hawley, Former Chief Executive of British Energy, and Former Chairman, Particle Physics and Astronomy Research Council.
Dr Malcolm Kennedy, Former Chairman of Merz and McLellan, and Chairman of National Energy Action.
Professor Andrew Miller (Vice-Chairman), Biophysicist. Secretary, Carnegie Trust for The Universities of Scotland, General Secretary of the Royal Society of Edinburgh until October 2005.
Professor Jeremy Peat, Former Group Chief Economist, Royal Bank of Scotland (Committee Member: May-August 2005; Special Advisor from September 2005).
Professor Janet Sprent, Biologist, and Member of the Royal Commission on Environmental Pollution.
Professor Joyce Tait, Director, ESRC Innogen Centre, University of Edinburgh (from April 2006).
Dr George Watkins, Former CEO, CONOCO UK, Former Chairman Grampian Enterprise.

The Committee has:

- held two public meetings
- given seven media briefings
- received over 160 written submissions
- heard oral evidence from more than 70 witnesses
- undertaken visits to Inverness, Stornoway, Aberdeen, Orkney, Shetland, Finland, Glasgow and London.

In addition, members of the Committee have attended a wide range of relevant seminars and conferences throughout the UK and abroad.

APPENDIX B: ACKNOWLEDGEMENT OF SUPPORTERS AND CONTRIBUTORS

Resources were sought from a wide range of supporters, balanced so that no sectoral or political bias could be impugned. The RSE gratefully acknowledges the financial support received from the following contributors:

Aberdeenshire Council
The Binks Trust
Buccleuch Estates Ltd
Highlands & Islands Enterprise
Scottish & Southern Energy plc
Scottish Enterprise Energy Team
Total E&P UK plc

APPENDIX C: ABBREVIATIONS, GLOSSARY AND UNITS OF ENERGY MEASUREMENT

Abbreviations

ABWR	Advanced Boiling Water Reactor
ACR	Advanced CANDU Reactor
AECL	Atomic Energy of Canada Ltd
AGR	Advanced Gas Cooled Reactor
AP	Advanced Pressurised Water Reactor
AP1000	Advanced Passive PWR
BETTA	British Electricity Trading and Transmission Arrangements
BNFL	British Nuclear Fuels
BWR	Boiling Water Reactor
CANDU	Canadian-designed, deuterium moderated nuclear reactor
CAT	Carbon Abatement Technology
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CEP	Community Energy Programme
CFB	Circulating Fluidized Bed
CHP	Combined heat and power
CoRWM	Committee on Radioactive Waste Management
CST	Council for Science and Technology
CO_2	Carbon dioxide. One of the major greenhouse gases
DEFRA	Department of the Environment, Food and Rural Affairs
DfT	Department for Transport
DTI	Department of Trade and Industry
DUKES	Digest of UK Energy Statistics
EASAC	European Academies' Science Advisory Committee
EEC	European Economic Community
EEC	Energy Efficiency Commitment
EMEC	European Marine Energy Centre
EOR	Enhanced Oil Recovery
EPR	European Pressurised Reactor
EST	Energy Saving Trust
EU ETS	European Union Emissions Trading Scheme
FBR	Fast Breeder Reactor
FGD	Flue Gas Desulphurisation
FREDS	Forum for Renewable Energy Development in Scotland
G3	Third generation
G4	Fourth generation
GAD	Government Actuary Department
GDP	Gross Domestic Product
GHG	Greenhouse gas
GNP	Gross National Product
GVA	Gross Value Added
GW	GigaWatt (1000 kW)
HCU	Hydrogen Coordination Unit
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ITI	Intermediary Technology Institutes

JET	Joint European Torus
Ktoe	Thousand tonnes of oil equivalent
LAS	Loan Action Scotland
LCPD	Large Combustion Plant Directive
LNG	Liquefied Natural Gas
LPA	Local Planning Authority
LWR	Light Water Reactor
LZCT	Low and Zero Carbon energy generating Technologies↱
Magnox	Nuclear reactor with fuel containers made of magnesium oxide
Mtoe	Million tonnes of oil equivalent
MWh	Megawatt Hours
NAEI	National Atmospheric Emissions Inventory
NGL	Natural gas liquids
NIREX (NII)	Nuclear Industry Radioactive Waste Executive
NOx	Nitrogen oxide emissions from coal combustion
NPF	National Planning Framework
NPPG	National Planning Policy Guidance
OCGT	Open Cycle Gas Turbine
OECD	Organisation for Economic Cooperation and Development
OFGEM	The Office of Gas and Electricity Markets
OPEC	Organisation of the Petroleum Exporting Countries il
OXERA	Oxford Economic Research Associates
PAN	Planning Advice Note
PBMR	Pebble Bed Modular Reactor
PF	Pulverised Fuel
PIU	Performance and Innovation Unit
Ppm	Parts per million
PWR	Pressurised Water Reactor
RAE	Royal Academy of Engineering
RCEP	Royal Commission on Environmental Pollution
ROC	Renewable Obligation Certificate
SAP	Standard Assessment Procedure
SBSA	Scottish Building Standards Agency
SCHRI	Scottish Community and Household Renewables Initiative
SE	Scottish Executive
SEPA	Scottish Environment Protection Agency
SP	Scottish Parliament
SSAC	Scottish Science Advisory Committee
SWR	Special Water Reactor
TCPSA	Town and Country Planning (Scotland) Act 1997
TUoS	Transmission Use-of-System Charging
TWh	Terra watt hour (1,000 million kWh)
UK ETS	United Kingdom Emissions Trading Scheme
UKOOA	United Kingdom Offshore Operators Association
UKCS	UK Continental Shelf
UN	United Nations
USGS	United States Geological Survey
VHTR	Very High Temperature Reactor
WEO	World Energy Outlook

Glossary

Base-load demand	Minimum continuous demand experienced by a generating plant.
Biodiversity	The diversity of plants, animals and other living things in a particular area or region. It encompasses habitat diversity, species diversity and genetic diversity.
Bio-fuel	Fuel such as bio-ethanol and methane, produced from renewable sources, especially plant biomass and treated municipal and industrial wastes.
Biomass	Organic materials, including wood by-products and agricultural wastes, that can be burned to produce energy or converted into a gas and used for fuel.
Carbon sequestration	Carbon sequestration is the uptake and storage of carbon dioxide from the atmosphere, or from power generation.
Clean coal technologies	Technologies designed to enhance the efficiency and the environmental acceptability of coal extraction, preparation and use.
Climate change	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods.
Combined Heat and Power (CHP)	A fuel-efficient energy technology that, unlike conventional forms of power generation, puts to use the by-product heat that is normally wasted to the environment. CHP can increase the overall efficiency of fuel use to more than 75%, compared with around 40% from conventional electricity generation. CHP often supplies electricity locally, therefore transmission and distribution losses can be minimised.
Decommissioning	The process of taking plant off-line and removing it from electricity generating infrastructure. Includes the cost of clean-up of any associated waste material.
Devolved powers	Devolution established the Scottish Parliament with responsibility for devolved matters while the UK Parliament remains responsible for 'reserved matters' in Scotland. By definition, devolved are all those which are not specifically reserved in Schedule 5 to the Scotland Act 1998.
District heating	Delivery of steam or hot water through a network of pipes to heat a number of buildings in a district.
Electricity transmission	Electric power transmission is one process in the delivery of electricity to consumers. The term refers to the bulk transfer of electrical power from place to place. Typically, power transmission is between the power plant and a substation near a populated area. This is distinct from electricity distribution, which is concerned with the delivery from the substation to the consumers. Due to the large amount of power involved, transmission normally takes place at high voltage.
Energy conservation	Reduction or elimination of unnecessary energy use and waste
Energy crop	Crops specifically grown for energy
Energy efficiency	Technologies, measures and behaviours that reduce the amount of electricity and/or fuel required to do the same work, such as powering homes, offices and industries.
Energy markets	A broad term used to describe the market arising when multiple energy buyers and sellers transact, linking wholesale and retail business entities.
Energy Policy	Directives and legislation on energy use, efficiency, supply, and mix as determined by the state acting in the interest of public welfare.
Fossil fuel	Coal, oil (including gasoline) and natural gas
Fuel cell	An energy conversion device that uses an electrochemical process to convert hydrogen into electricity without combustion.
Fuel poverty	A fuel poor household is one which needs to spend more than 10% of its income on fuel for all uses.
Geothermal energy	Heat recovered energy from deep within the earth for power generation, process heating or district heating using a subsurface closed loop working fluid system and surface power generation plant.
Greenhouse gas	A gas, especially carbon dioxide, also ozone, methane, nitrous oxide and chlorofluorocarbons that trap the sun’s heat in the atmosphere.
Grid	Network of electric transmission lines used to move energy which is operated by National Grid Company.
Infrastructure	Fuel supply, fuel storage, physical transportation, electricity transmission and electricity distribution systems including gas pipelines, LNG storage, ships,

	pylons, cables and connectors.
Installed capacity	Is the maximum steady power that an electricity generator can produce.
Interconnector	A cable connection allowing electricity to flow between two countries or markets.
Kyoto Protocol	A Protocol to the UN Framework Convention on Climate Change (UNFCCC) agreed in 1997. Developed nations are required to cut overall greenhouse gas emissions by an average of 5.2 per cent below 1990 levels over the period 2008-2012.
Load factor	Generating time (of electricity generating plant) as a percentage of total available time.
Low carbon fuels	Generation capacity which results in the emission of lower or zero carbon emissions compared with other methods.
Micro-generation	Micro-generation systems typically range in size from a few kilowatts (kW) to 500 kW. They are small generators installed close to the point of use, either in smaller businesses or for household use.
Nuclear fission	A nuclear reaction in which a massive nucleus splits into smaller nuclei with the simultaneous release of energy
Nuclear fusion	A nuclear reaction in which nuclei combine to form more massive nuclei with the simultaneous release of energy
Opencast mining	A method of extracting rock or minerals from the earth by their removal from an open mine or borrow. The term is used to differentiate this form of mining from extractive methods that require tunnelling into the earth.
Peak demand	The highest energy requirement in any given period.
Photovoltaic	The direct conversion of solar radiation into electricity by the interaction of light with the electrons in a semiconductor device or cell.
Plant	The land, buildings, machinery, apparatus, and fixtures employed in carrying on a trade or an industrial business
Primary Energy	Energy sources, such as fossil fuels, nuclear or wind power, which are not used directly for energy but transformed into useful heat, light etc.
Renewable energy	The term used to describe energy flows that occur naturally and continuously in the environment, such as energy from the wind, waves or tides. Such sources are essentially inexhaustible, unlike fossil fuels which are limited in supply.
Reserved powers	See Devolved powers
Solar thermal	Solar thermal uses heat from the sun to warm up a liquid that is pumped through a panel. In the most common kind of system, this liquid then goes through a coil in a hot water cylinder where the heat is transferred to water.
Total Fuel Consumption	Is the sum of the total consumer end use of energy across all sectors for a specified territory. It is also known as “delivered energy.” It is usually recorded by end-use sectors such as agriculture, industry etc.
Total Primary Energy Supply	The amount of energy made available at source for transformation and end use. It is regulated for international trade such that imports are included and exports are excluded, it makes allowance for any change in the fuel stock of a country and, by convention, does not include fuel used for international transportation.
Turbine	A machine which uses the kinetic energy of flowing matter to turn blades on a shaft. The shaft has electromagnets attached, which create an electromagnetic field that can be used to create electricity.

UNITS OF MEASUREMENT OF ENERGY

The international standard unit of energy is the Joule (J). The international standard unit of power is the Watt (W), being the consumption or generation of one Joule per second (1J/s).

Multiples of units are designated by Greek prefixes, thus:

A thousand Watts = a kilowatt = 1kW = 10^3W
A million Watts = a megawatt = 1MW = 10^6W
A billion Watts = a gigawatt = 1GW = 10^9W

(Note that we are using the, now globally-accepted, American definition of a billion as a thousand million. In English a billion was a million million, hence the Greek prefix Giga)
A trillion Watts = a terawatt = 1TW = 10^{12}W

Throughout this report we will refer to an amount of energy, not in Joules, but in the equivalent Watt-seconds. Correspondingly larger amounts of energy are measured in kilowatt-hours, megawatt-years etc.

In the fossil fuel industry an amount of coal is measured in metric tonnes (t), oil in metric tonnes, or barrels (b), and gas in cubic metres (m^3). The precise energy content of the fossil fuels varies with the precise chemical composition. However, it is useful to have average energy content equivalences, and throughout we have used the following:

Coal: 1t = 8,100kW-h
Oil: 1t = 12,000kW-h
1b = 1,700kW-h
Gas: 1m^3 = 11.5kW-h

In energy trading it is common to convert to 'tonnes of oil equivalent' (toe), thus:

1toe = 1.48t coal = 1,043m^3 gas

1kWh = 3,143 Btu or 1Mbtu = 293 kWh

APPENDIX D: ENERGY SUPPLY AND CONSUMPTION IN THE NORDIC COUNTRIES

Energy Supply by Source	**Denmark[1]**	**Norway[1]**	**Sweden[1]**	**Finland[1]**	**UK[1]**	**Scotland[2, 4]**
	2003	2003	2003	2003	2003	2002
Coal	25.49%	3.38%	5.21%	21.92%	16.48%	18.57%
Oil[3]	37.68%	20.89%	30.17%	28.60%	35.10%	25.73%
Gas	20.96%	27.28%	1.72%	10.87%	37.02%	35.79%
Nuclear	0.00%	0.00%	34.09%	15.77%	9.96%	17.76%
Hydro	0.01%	38.86%	8.88%	2.20%	0.12%	1.88%
Geothermal, Solar etc	2.57%	0.11%	0.11%	0.02%	0.06%	-
Combustibles Renewables and waste	9.96%	6.55%	17.06%	19.50%	1.18%	0.27%
Imported Electricity	3.31%	2.90%	2.14%	1.11%	0.08%	-
Heat	0.02%	0.03%	0.61%	0.00%	0.00%	-
Total Primary Energy Supply (ktoe)	22226	23347	51532	37554	231954	(237.501) TWh

Energy Consumption by Sector	**Denmark[1]**	**Norway[1]**	**Sweden[1]**	**Finland[1]**	**UK[1]**	**Scotland[2, 5]**
	2003	2003	2003	2003	2003	2002
Industry	18.91%	41.07%	37.76%	45.70%	25.03%	21.18%
Transport	32.75%	22.83%	23.11%	18.14%	33.29%	28.55%
Agriculture	6.06%	3.87%	1.65%	3.04%	0.53%	1.33%
Commercial and Public Services	12.64%	11.23%	13.66%	6.57%	9.93%	14.95%
Residential	27.87%	17.79%	21.20%	19.80%	27.47%	34.00%
Non-Specified	0.08%	0.08%	0.35%	4.30%	1.07%	-
Non energy Use	1.68%	3.14%	2.27%	2.45%	2.68%	-
Total Final Consumption (ktoe)	15318	20929	35800	26242	160621	14175

Electricity Production from:	**Denmark[1]**	**Norway[1]**	**Sweden[1]**	**Finland[1]**	**UK[1]**	**Scotland[2, 6]**
	2003	2003	2003	2003	2003	2002
Coal	54.69%	0.11%	3.09%	31.78%	35.20%	32.46%
Oil	5.07%	0.02%	2.86%	1.11%	1.76%	0.41%
Gas	21.19%	0.28%	0.37%	16.55%	37.29%	19.44%
Biomass	3.64%	0.25%	3.91%	11.17%	1.30%	0.52%
Waste	3.20%	0.15%	0.31%	0.91%	0.39%	-
Nuclear	0.00%	0.00%	49.71%	26.99%	22.25%	34.85%
Hydro	0.05%	98.91%	39.28%	11.39%	1.50%	9.79%
Wind	12.02%	0.21%	0.47%	0.11%	0.00%	0.89%
Solar PV	0.00%	0.00%	0.00%	0.00%	0.32%	-
Other sources	0.15%	0.08%	0.00%	0.00%	0.00%	1.64%
Total Electricity Production	46.264	107.268	135.615	84.228	398.62	45.517

(TWh)						

1: IEA Energy Statistics (http://www.iea.org/Textbase/stats/index.asp)
2: Scottish Energy Study 2006
3: The figure for ‘Oil’ combines the figures within the IEA 2003 Energy Balances for Crude Oil and Petroleum Products
4: Scottish ‘Energy Supply by Source’ figures are taken from the different ‘bottom-up’ sector totals for the different fuel types in Chapter 3
5: Scottish ‘Energy Consumption by Sector’ figures are taken from the different sectors energy demand totals in Chapter 3 (Energy Demand & Related CO_2 Emissions)
6: Scottish ‘Electricity Production From’ figures are taken from Table 7 in Chapter 3

APPENDIX E: EXISTING INSTRUMENTS

(1) Instruments related to climate change and emissions reduction

The *UK Emissions Trading Scheme* *(UK ETS)* is a voluntary scheme, established in 2002 and initially set to run for four years, covering emissions of greenhouse gases. Thirty-three organisations ('direct participants' in the scheme) have voluntarily undertake to reduce their emissions against 1998-2000 levels.

The *European Union Emissions Trading Scheme* *(EU ETS),* introduced in 2003, has been implemented in the UK through the Greenhouse Gas Emissions Trading Scheme Regulations 2005. Its purpose is to achieve emissions reductions under the Kyoto Protocol through the 'cap and trade' principle. Operators of installations covered by the scheme are given free allowances from the UK's carbon dioxide emission cap. Operators are free to trade in these allowances. Each year the permitted holder has to surrender enough allowances to cover their carbon dioxide emissions for the year; failure to do so results in a fine. An installation that has emitted less than its allocation may sell the surplus to another participant in the emissions trading market. The first phase of the scheme runs from 1 January 2005 to 31 December 2007 and covers only carbon dioxide emissions. The second phase, from 1 January 2008 to 31 December 2012, may be extended to include other greenhouse gases as well as other activities. Limits on the amount of carbon dioxide that permitted installations can emit are set by DEFRA for each phase of the scheme.

The ***Climate Change Levy*** *(CCL)* is a tax on the use of energy in industry, commerce and the public sector, with offsetting cuts in employers' National Insurance Contributions and additional support for energy efficiency schemes and the use of renewable sources of energy. It is intended to promote energy efficiency, encourage employment opportunities and stimulate investment in new technologies. The Levy has been modified to recognise the special needs of the energy intensive industries. It was introduced on 1 April 2001 and is expected to lead to reductions in carbon dioxide emissions of at least 2.5 million tonnes of carbon a year by 2010.

The revised ***Large Combustion Plants Directive*** (LCPD, 2001/80/EC) takes account of advances in combustion and abatement technologies. It will replace the original LCPD (88/609/EEC) and applies to combustion plants with a thermal output of greater than 50 MW. The LCPD aims to reduce acidification, ground level ozone and particles throughout Europe by controlling emissions of sulphur dioxide (SO_2), nitrogen oxides (NOx) and particulate matter from large combustion plants (LCPs). These include plants in power stations, petroleum refineries, steelworks and other industrial processes running on solid, liquid or gaseous fuel.

New combustion plant must meet the emission limit values (ELVs) given in the LCPD. For plants in operation prior to 1987, Member States can choose to meet the obligations by either:

- Complying with ELVs for NOx, SO_2, and particles, or
- Operating within a National Emissions Reduction Plan (NERP). That would set an annual national level of emissions calculated by applying the ELV approach to existing plants, on the basis of those plants' generation over the 5

years to 2000. In order to meet the emission limits, Flue Gas Desulphurisation equipment will need to be fitted.

In April 2005, the UK submitted proposals to the Commission to combine these two implementation approaches. In light of the Commission's flexible interpretation of the "combined approach", the UK will not maintain a firm split between the energy generating industries having ELV and the industry sector having NERP. The Government will offer the opportunity for those companies that want to switch either from the NERP to ELV or vice versa to let Government know by the 3 February 2006, otherwise it will be assumed that they have chosen to stay with their existing option. They do not include nuclear power electricity generation plants.

Article 4(4) of the LCPD provides for operators of existing plants to be exempted from compliance with ELVs or a NERP if they make a written declaration by 30 June 2004 not to operate the plant for more than 20,000 operational hours starting from 1 January 2008 and ending no later than 31 December 2015. Such declarations may be withdrawn with the opt-in deadline being extended to 3 February 2006.

(2) Instruments to encourage the use of renewable sources

Renewable Obligation Certificates (ROCs) are intended to provide encouragement for the greater use of renewable sources of energy. The Obligation requires electricity companies to source an increasing proportion of their supply from renewable technologies, to reach a target of 10% by 2010. The current target is 5.5% for 2005/06 rising to 15.4% by 2015/16. The obligation is expected to extend to 2027 in order to provide long-term security for the renewables market. For each megawatt hour of renewable energy generated, a tradable certificate called a Renewable Obligation Certificate (ROC) is issued to accredited generators of eligible renewable electricity produced within the UK: these include solar energy (including photovoltaics), hydro (excluding hydro plants >20MW), wave power, tidal energy, geothermal energy, biofuels (including energy crops) and onshore and offshore wind.

Suppliers can meet their obligation by purchasing ROCs for £30/MWh; or by a combination of ROCs and paying a buy-out price. The money raised is redistributed to companies that have met their Obligation, in proportion to the number of ROCs they presented that year. Ofgem is responsible for monitoring and enforcing compliance with the Obligation.

The Scottish Executive has announced its intention to consult more widely on introducing a ***Marine ROC*** scheme to provide additional encouragement for the development of wave and tidal sources. If changes are introduced, these will not happen until April 2007 to coincide with the start of the Renewable Obligations year.

A UK review of the effectiveness of ROCs in meeting the Government's objectives is currently underway. This is in tandem with a similar review in Scotland to review the operation of the RO in Scotland and to recommend any changes to ensure its continued effectiveness. The Renewables Obligation (Scotland) Order 2006 came into force on 1 April 2006.

(3) Instruments to encourage Energy Efficiency

The UK Government's strategy on how it intends to deliver its target savings from 2004 to 2010 is laid out in a report, *Energy Efficiency: the Government's Plan for Action*.

The ***Energy Efficiency Commitment*** *(EEC)* sets targets on energy suppliers to achieve improvements in energy efficiency by providing energy efficiency measures, such as cavity wall and loft insulation and energy efficient boilers, appliances and light bulbs, to households across Great Britain. It is primarily a carbon saving programme. At least half the energy savings must be targeted at the 'Priority Group' of households in receipt of benefits or tax credits. Suppliers have flexibility in the types of energy efficiency measures they provide to customers. These measures can also be promoted and delivered with a range of project partners including social housing providers, charities, retailers and manufacturers.

The first phase of the Energy Efficiency Commitment 2002-2005 (EEC 1) is now complete. This target required electricity and gas suppliers to achieve an energy savings target of 62 TWh in domestic households between 1 April 2002 and 31 March 2005. According to a report by the regulator Ofgem, the main measure offered by suppliers was insulation, contributing 56% to the total savings achieved. The distribution of energy efficient light bulbs achieved one quarter of the total savings. Appliances, mainly energy efficient white goods, contributed 11% to the total savings achieved and heating measures achieved 9%. The second phase of EEC 2005-2008 (EEC 2) began on 1 April 2005 with a new target on suppliers to save energy in consumers' homes. The energy saving target for EEC 2 is 130 TWh.

The ***Community Energy Programme*** *(CEP)* supports development and capital expenditure on district heating systems to provide significant energy savings compared to individual heating systems. It is a UK-wide programme, jointly managed by the Energy Saving Trust and the Carbon Trust and funded through DEFRA using Capital Modernisation Fund monies. The Scottish Executive has, through the EST, supplied additional resources to promote the CEP in Scotland.

The ***UK Renewable Transport Fuels Obligation*****,** recently announced, has a target of 5% of fuel sold in the UK to be from renewable sources by 2010.

In December 2004, plans for Scotland's first **energy efficiency strategy** were outlined by the Scottish Executive as part of its action on climate change. The strategy aims to set up a framework, define objectives and create a more joined-up approach for energy efficiency interventions across all sectors of the economy. It has a stated aim to maximise the positive environmental and economic impact of investment in energy efficiency by setting out a total carbon saving target for energy efficiency measures covered by the strategy as a contribution to the overarching Scottish target as set out in *Changing Our Ways: Scotland's Climate Change Programme,* published March 2006. The energy efficiency strategy is due to be published later in 2006.

The Scottish Executive funds the ***Energy Saving Trust*** **(EST)** and the **Carbon Trust's** activities in Scotland. The Carbon Trust is focussed on reducing carbon emissions in business and the public sector in the short and medium term through energy efficiency and carbon management; and in the long term through intervention in low carbon technologies. It does this by providing impartial advice, promoting the Government's Enhanced Capital Allowance Scheme and investing in the development of low carbon technologies in the UK. The EST encourages energy efficiency in homes and vehicles across the UK. It provides expert advice as well as grants. There are eight EST Energy Efficiency Advice Centres throughout Scotland which advise consumers on energy efficiency matters.

(4) Energy efficiency in public buildings and the housing stock

The ***EU Directive on the Energy Performance of Buildings 2002/91/EC*** requires, amongst other aspects, that whenever a building is constructed, sold, or rented out, a certificate detailing its energy performance must be made available. The aim of the Directive is to improve awareness of energy use in buildings, and thereby encourage investment in energy saving. The Directive also requires prominent labelling of 'buildings visited regularly by the public.' The Directive must be in place in Member States by 4 January 2006, although Member States have the option of derogating from the Directive for three years if they believe that there are insufficient qualified or accredited experts (in Europe) to carry out the certification. At the time of writing, the Scottish Executive was due to consult on the implementation of Articles where compliance still had to be achieved; Article 7: Energy performance certificates; Article 8: Inspection of boilers, and Article 9: Inspection of air-conditioning systems.

Energy and the Building Regulation System The Building (Scotland) Act 2003 gives Scottish Ministers the power to make building regulations to:

1. Secure the health, safety, welfare and convenience of persons in and about buildings and others who may be affected by buildings or matters connected with buildings,
2. Further the conservation of fuel and power, and
3. Further the achievement of sustainable development.[14]

The Building (Scotland) Regulations 2004 are the current legal requirements to provide reasonable standards for securing, *inter alia,* the conservation of fuel and power and the achievement of the sustainable development standard for conserving fuel and power. Section 6 of the current Building Standards (Reg 9 (Schedule 5) of the 2004 Regulations) is concerned with energy and the effective means for the conservation of fuel and power and is applicable to both domestic and non-domestic buildings.

The current energy standards for buildings were introduced in March 2002. These standards apply when new buildings are altered and/or extended. A review of the energy standards is underway and has recently gone to public consultation (March 2006). Proposals include introducing a CO_2 emissions standard for new buildings; allowing designers more flexibility with insulation levels in new buildings if they adopt low and zero carbon building integrated energy technologies such as wind turbines or photovoltaics; using condensing boilers for replacement and alteration work in dwellings. Introduction of the revised building regulations will not occur until May 2007.

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[14] Scottish Building Standards Agency http://www.sbsa.gov.uk/

The principal piece of legislation in Scotland relating to energy efficiency in housing is the ***Home Energy Conservation Act 1995*** which came into force in Scotland on 1 December 1996. This requires all local authorities to prepare and publish an energy conservation report identifying practicable, cost-effective energy conservation measures which are likely to result in significant improvement in energy efficiency in respect of all residential accommodation in its area.

The ***Housing (Scotland) Act 2006*** received Royal Assent on 5 January 2006, although at the time of writing (June 2006) the majority of its provisions are not yet in force. Under s.179, Scottish Ministers must prepare a strategy for improving the energy efficiency of living accommodation.

The Warm Deal is a Scottish Executive scheme which provides a grant of up to £500 for those on certain benefits and tax credits to make their home more energy efficient and warmer during winter. Eaga Ltd operate the scheme on behalf of the Scottish Executive.

The ***Scottish Community and Household Renewables Initiative*** *(SCHRI)* was set up in 2002 and aims to produce zero carbon electricity/energy and raise public awareness of the benefits of renewable energy. Grants are available to the end-user to support energy saving devices such as solar panels, heat pumps, wood burners, small scale wind turbines and small hydro plants. Improved heat insulation of buildings, boiler efficiency, and light efficiency are the expected outcomes. The scheme is funded by the Scottish Executive and jointly managed by the Energy Savings Trust and Highlands and Islands Enterprise.

Loan Action Scotland *(LAS)* provides loans form £5000 to £50,000 at 0% fixed interest to support SMEs to reduce their energy bills. LAS loans can be repaid over a period up to 5 years with the aim of being ‘capital neutral’, i.e. the savings from the new energy saving equipment will cover the cost of repayments. The scheme is funded by the Scottish Executive and managed by the Wise Group.

(5) Other instruments

Energy and the Town and Country Planning System

Under Section 36 of the Electricity Act 1989, applications to build electricity generating stations are made to Scottish Ministers if they are in excess of 50 MW for onshore wind farms and power stations that are not wholly or mainly driven by water, and in excess of 1 MW for offshore wind farms and generating stations wholly or mainly driven by water.[15]

When the capacity of a land-based proposed station lies below these thresholds, the application for consent is made to the relevant local planning authority (LPA) and is considered under the Town and Country Planning (Scotland) Act 1997.[16] Local Planning Authorities do not have jurisdiction over offshore developments as applications for these are handled by Scottish Ministers under Section 36 of the Electricity Act 1989 or under the Transport and Works Act 1992.

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[15] Business and Industry; Renewable Energy; Consents Unit; Scottish Executive.

[16] Business and Industry; Renewable Energy; Consents Unit; Scottish Executive.

The Scottish Executive's National Planning Policy Guidance Note NPPG6 (2002) asks planning authorities to provide positively for all forms of renewable energy development in a manner that is compatible with statutory obligations to protect natural and built heritage. The Scottish Executive's Planning Advice Note PAN 45 provides supplementary advice in relation to renewable energy technologies on issues to be taken into consideration.

Significant onshore energy proposals are subject to an Environmental Impact Assessment, under the Environmental Impact Assessment (Scotland) Regulations 1999.

The consent of the Scottish Ministers is required the construction of overhead power lines and applications are made under S.37 of the Electricity Act 1989.

The Planning etc (Scotland) Bill was before the Scottish Parliament at the time of writing our report (June 2006). It has a provision for putting the National Planning Framework on a statutory footing. The Framework must contain a strategy for Scotland's spatial development and a statement of priorities. It is envisaged that energy and waste infrastructure projects, along with major transport, water and drainage, major areas of urban regeneration or expansion, and large strategic business or industrial investments would be included.

APPENDIX F: ASSESSMENT OF ENERGY TECHNOLOGIES

In this appendix we review available fuel technology options. We have not included technologies, such as nuclear fusion, that are unlikely to be significant within the time frame of this report.

Energy can neither be created nor destroyed. Its value lies in its transformation from one form to another. Thus the ***primary source*** of fuel is not directly transferred into the final ***consumption*** of energy. The difference between primary supply and consumption is often in the form of heat, which if not immediately utilised is dispersed into the environment and must be considered as wasted.

Different activity sectors generate ***demand*** for energy.

A major concern is the ***efficiency*** with which primary energy is used. This again is often utilisation-dependent and we have restricted ourselves in this Appendix to the generation of electricity and the presentation of information on the efficiency (energy out) in the form of electricity to primary energy input. The overall efficiency depends on the degree of utilisation of the excess heat.

Not all ***technologies*** are equally mature. We have described the most important current technologies and their state of development. In the case of developing technologies, we have given estimates of the time to fully competitive, commercial exploitation.

Fuel technologies have ***costs***. These costs can be site and utilisation specific. We include data, where relevant, on primary fuel prices and of electricity generation.

All fuel technologies have an ***environmental impact***. There is universal concern about carbon gas emissions and we have included data on such emissions from the direct utilisation of each technology. We have not attempted a whole lifecycle analysis. No universal application of an agreed methodology exists. Often such analysis is highly site dependent and requires assumptions about process that are not universal. Other environmental issues arise; often these are site specific and utilisation dependent. In such cases, we have restricted ourselves to listing the most important matters of environmental concern.

Security of supply can be threatened by physical availability of primary fuel, natural extreme conditions (droughts, hurricanes etc), cost and geopolitical intervention (including terrorism), and the availability and reliability of delivery infrastructure. It is hard to produce universal quantitative data for these, and we restrict ourselves to listing the most important security issues.

We are particularly interested in any special ***Scottish Issues*** including social impact.

For each of the fuel technologies we include entries under each of the ***italicised*** headings. Where relevant, we present global data (IEA: Key World Energy Statistics 2004), UK data (DTI: 2005 UK Energy Statistics) and Scottish data (SE: Scottish Energy Study 2006).

COAL

PRIMARY SOURCE

Coal is by far the World’s most abundant fossil fuel and its distribution is more geographically diverse than any other source of primary energy. Coal currently represents 23.5% (4Bt hard coal and 0.9Bt brown coal, equivalent to 40,000TWh) of total primary energy supply. More than 80% of the World’s hard coal is produced by six countries (Peoples Republic of China, United States of America, India, Australia, Republic of South Africa, Russia), with PRC providing more than a third of the total. Australia is by far the largest exporter of coal with three-quarters of its production going overseas.

In 2003, the UK coal industry produced 27.7Mt of coal, 31.8Mt were imported (the major suppliers being: Australia, Columbia, Poland, RSA and USA) and a further 2.7Mt were drawn from stocks, to yield a total supply of 62.2Mt (503TWh). There are 8 deep mines and 42 open cast sites, each providing roughly half of current domestic production. Coal accounts for 18% of the UK’s primary energy supply.

Scotland has 8 active opencast sites producing approximately 7Mt per annum, representing a quarter of the UK’s mined coal supply.

FINAL CONSUMPTION

In 2002 the World consumed coal with a total energy rating of about 6000TWh. The UK coal consumption was 54.5TWh and the corresponding figure for Scotland was approximately 4.4TWh. The great difference between the primary production of coal and its final consumption reflects the use of coal for electricity generation. 2.3% of coal was consumed by non-energy users.

DEMAND

Globally the demand from industry (excluding agriculture and services) absorbs three quarters of total coal supply (of which 88% is used to generate electricity), 21% is used by the public sector, service industries, agriculture and domestically, 1% is used for transport and 2.3% for non-energy-related activity. Coal generates 39% of the World’s electricity.

In the UK more than 90% of all coal is used to generate 33% of the electricity supply. These figures are mirrored in Scotland with the Longannet and Cockenzie power stations as the principal generators, with an installed capacity of 3.5GW, which yielded 14TWh in 2003.

Discounting the generation of electricity, UK domestic demand for coal absorbs 19% of coal consumption with industry taking 80% and transport and the service sector <1%. The corresponding break down for Scotland is domestic consumption approximately 75% and industry 25%.

EFFICIENCY

Globally, the 30,000TWh of coal used to generate electricity yielded 11,700 TWh of electricity, representing an efficiency of 39%. This represents an averaging over many varieties of coal plant. The figure for the UK and Scotland is 37% reflecting the age of many coal stations.

TECHNOLOGY

The most widely used process for power generation from coal is combustion of pulverised fuel. Current plants operating at subcritical steam conditions (220bar, 540^0C) achieve about 37% efficiency. Most new build plants employ advanced supercritical boilers raising efficiency to around 47% (the industry target is 50%).

Many of the current technical developments are concerned with reducing the adverse environmental impact associated with coal combustion. Available Flue Stack Desulphurisation technology meets the recent European Large Combustion Plant Directive requirements designed to reduce the occurrence of acid rain. The principal development, however, must be an acceptable CO_2 capture and storage technology. The pumping of carbon dioxide into mature oil and gas fields, both to sequester the gas and provide a pressure head for enhanced recovery, is approaching the demonstration stage, but is site dependent. Deep geological storage is under investigation.

Integrated Gasification Combined Cycle (IGCC) plants represent a near market technology. Demonstration units are operating in the USA. This scheme is a virtually closed cycle where oxygen is combined with pulverised coal (or other low value fuel) resulting in the generation of syngas (a hydrogen-carbon monoxide mixture) that can be burnt in a gas turbine to produce power. The heat from the gas turbine and the syngas cooling plant are used to drive a steam turbine. Any carbon dioxide is pumped into the fuel source where it is irreversibly captured with the emission of methane that can be mixed with the syngas in the gas turbine. The by-products are commercially useful nitrogen compounds for fertilisers, sulphur for industrial use, and inert slag for road construction.

The IGCC scheme incorporates a feature essential for the efficient use of all hydrocarbon fuels, namely the heat of flue gasses is captured and used – in this case to drive a steam turbine.

The rate at which these technologies will fully enter the market will depend on investment decisions largely based on costs within a regulatory framework that penalises the producers of carbon gasses. Typically, this is likely to be 5-10 years.

COST

The cost of coal peaked in the1980s. Imported steam coal at this peak cost £50/t; UK-mined coal reached £107/t. Between 1990 and 2004 the cost of imported coal stabilised around £27/t, while the cost of UK-produced coal fell to the same level. Today UK coal is the least expensive in Western Europe (current French and German costs are around £64/t). The last year has seen a sharp rise in imported coal costs in response to international price rises for oil and guest. This has not yet been fully reflected in the price of UK coal.

The costs of generating electricity from coal clearly depend on the price of coal, the efficiency of the generating technology and the costs associated with the regulatory framework. The current situation in the UK is that coal generated electricity costs 2-3p/kWh. Fuel costs are likely to rise and the regulatory framework to become more rigorous thus putting pressure on an increasing cost of electricity generation; increasing efficiency (likely 10-15%) may mitigate this pressure.

Most forms of energy attract some form of public subsidy. In recent years, the UK coal industry has moved from receiving no direct subsidy to one of modest investment aid (£1/t, 12p/MWh). This is much less than the direct subsidy paid in many other European countries (approximately £60/t in Germany).

ENVIRONMENTAL ISSUES

The scale of consumption of coal inevitably impacts on the environment at the point of mining. There are reports of polluted water and gas accumulation in abandoned coal mines. Deep mining has left a legacy of slag heaps of tailings which often dominate the local landscape. Apart from being unsightly, these can become unstable with disastrous consequences, e.g. Aberfan. Opencast mining devastates the landscape during the mining operations leading to widespread opposition to new sites. In wealthier countries, like the UK, remedial work can be undertaken to stabilise slag heaps with suitable plantings, creating new habitats and conversion to recreational areas. Licensing of opencast sites is dependent on a commitment to restore the land suitable for useful functions. This process can take decades to achieve.

The movement of billions of tonnes of coal from mines to the points of utilisation impacts on all the environmental issues associated with transport.

Coal is by far the most environmentally damaging of all fossil fuels in its raw emissions. The most obvious of these are carbon particulates (smoke). In the UK strict control on smoke emissions was introduced in the 1960s. Coal also contains sulphur and nitrogen that can lead to acid rain. Strict sulphur emission standards came into force in the 1970s. The EU has recently introduced its Large Combustion Plant Directive (LCPD) to limit nitrogen oxide emissions (NOx). Under this Directive, Plant have been required to sign commitments agreeing to conform to the new emission standards by the end of 2005 or close by 2015. The current concern is the emission of the carbon gasses and the claims that these may result in global climate change. Many of the UK's aging coal powered stations fail to meet the new emission standards. In Scotland, the decision has been made to close the Cockenzie coal power station and to retrofit supercritical boilers in three of the four units and FSD to the single flue stack at Longannet.

1kWh of coal combustion generates 0.3kg of carbon dioxide.

SECURITY

The World's proven coal reserves will last for around 250 years at the present rate of production. An adequate supply of coal is not a consideration within the horizon of this Report. Adequate reserves of coal exist in the UK to maintain production at the current level throughout the period considered in this Report. Thus there is little threat to the availability of coal. In addition stockpiles of coal are inexpensive to maintain and could be used to mitigate any temporary glitch in supply.

Imported supplies of coal are at risk from attacks on international shipping. However, this is extremely unlikely to be on a significant scale except in time of war. The UK is well served by receiving ports and established rail links.

Imported coal is at threat from political instabilities in the country of origin. For the UK imports, although it is impossible to be certain about political security, we consider that Australia, USA, Poland, and India can be deemed sufficiently stable over the timespan of this Report. The greatest uncertainty must lie with Columbia. However, it is likely that the significance of Columbian exports to Europe will, like Venezuelan exports, dwindle as the USA's appetite for coal continues to grow. The wide geographical distribution of coal reserves is a buttress against geopolitical instability and extreme natural phenomena.

SCOTTISH ISSUES

Scottish Coal is the largest producer of opencast mined coal in the UK and currently employs 1200 people. Scotland is well provided with coal transfer facilities. There is an adequate rail network with six railheads to transport coal to the principal consumers including export to England. The Longannet coal station will now continue operations until around 2020. Together, these factors constitute direct employment for approximately 2000 people. The continued operation of Longannet will require some continued imports of coal. All Scottish coal production is exported to England – the LCPD might impact upon this. All coal consumed in Scotland is imported but will not be required if the Scottish coal stations close.

The closure of the Cockenzie station is likely to result in the loss of 150 jobs.

The necessary replacement of more than 60% of UK electricity generating capacity from large-scale plants over the next 20 years, has the capacity to generate significant employment opportunities within the UK. Firms like Mitsui-Babcock, a UK company with its Manufacturing and Services Division located at Renfrew in Scotland, at the leading edge of supercritical coal fired boilers, should benefit. This company employing around 1000 people in Scotland not only offers a considerable contribution to UK energy needs, the domestically developed technology holds prospects for significant export potential.

The continued operation of the Longannet plant offers an opportunity for a joint industry, government and academic collaboration in clean coal technology to address the pressing environmental concerns locally and develop intellectual property and skills with a strong export potential.

The current Ofgem charging policy for Grid connectivity renders the cost of new generating plant in Scotland uneconomic compared with other parts of the UK, irrespective of fuel source.

There is a significant academic research base in the Scottish Universities. The Scottish Centre for Carbon Studies involving a partnership between Edinburgh and Heriot-Watt Universities and the British Geological Survey in Edinburgh deploys considerable expertise relevant to sequestration. Furthermore, Heriot-Watt is researching the potential of underground coal gasification.

GAS

PRIMARY SOURCE

The World's proven reserves of natural gas (2millionTWh) are predominately in the Middle East (0.8millionTWh) and Russia (0.7millionTWh), followed by Africa (0.16millionTWh), Asia (0.14millionTWh), North America (0.09millionTWh), South America (0.08millionTWh), Europe (0.08millionTWh) and Australasia (0.05millionTWh).

In 2003, the global production of natural gas was 31000TWh. The UK was the World's fourth largest producer at 1240TWh. This is not disaggregated but clearly Scotland is the principal country of entry to the UK for North Sea oil and gas, not only from UK fields but also from Norwegian and Danish fields.

FINAL CONSUMPTION

Final global gas consumption in 2003 was 15318TWh, for the UK (2004) it was 1,120TWh and for Scotland (2002) 84.94TWh.

The difference between the final consumption and primary production figures represents the use of gas to generate electricity and by self use by the gas producers.

DEMAND

Globally the demand for gas comes 44.7% from industry, 5% from transport and 50.3% from the domestic, agriculture and service sectors. Gas is used to generate 19.1% of the World's electricity. The Global demand for gas is growing at over 2% pa mostly for electricity generation.

In the UK, domestic consumption accounts for 60.2% of the total, industry 23.6% and the service sectors 16.1%. The corresponding figures for Scotland are 54.3%, 27.8% and 17.9% respectively. Gas generates 38% of UK electricity and 19.1% in Scotland.

EFFICIENCY

The average efficiency for gas generated electricity in Scotland is 43%. The overall efficiency depends on whether the additional heat is used. At Scotland's principal gas fired power station at Peterhead, it is intended to use the heat to extract hydrogen from methane.

TECHNOLOGY

While there are steady increases in the efficiency of gas-fired boilers and power generating turbines, the principal technical developments in the gas industry are likely to be concentrated in recovery techniques from new fields and more hostile environments. Although gas is the cleanest of the fossil fuels, and has not come under the same pressure to cut carbon gas emissions as coal, it would be able to utilise carbon capture and storage technology. It is clearly also a partner in the development of ICGT technology.

Increasingly, natural gas will be stored and transported in liquid form. The uptake of LNG will depend on the development of liquifaction plants and storage depots.

COST

Since 1999 the price of natural gas has risen steeply, apart from a short dip in 2002, from a low of 0.4p/kWh to the current level of over 2p/kWh**.** In October 2004 the retail cost of gas for domestic consumption was 2p/kWh and for industrial use 1p/kWh. These prices have risen rapidly in the past 18 months, doubling in the month of November 2005 alone. There is no consensus as to whether prices will remain high or fall back 2000 levels, but we note the recent warning from Russia that the era of cheap gas is at an end and that attempts to restrict Russia’s economic aspirations might be reflected in supplies and prices.

In 2004 the Royal Academy of Engineering estimated the cost of electricity generated by a GGGT gas station as 2.2p/kWh. Since fuel costs are the largest component in gas power generation, this figure will have experienced the volatility of the market.

ENVIRONMENTAL ISSUES

It is generally accepted that natural gas is the ‘cleanest’ of the fossil fuels. The only waste products of methane combustion are water vapour and the carbon gases. While concerns about the impact of carbon gases on global climate change remain, the relatively high efficiency of gas as a fuel makes it the least polluting of the fossil fuels.

Concerns exist about the environmental impact associated with oil and gas exploration and exploitation. There are possible interruptions to marine ecosystems, debris on the sea floor and the unresolved issue of decommissioning and removal of hardware. Also there is the affect of pipelines through environmentally sensitive regions.

1kW of natural gas combustion emits 0.19kg of CO_2.

SECURITY

The proven global reserves of gas will last for approximately 70 years at the present rate of consumption. Undoubtedly fresh reserves will be discovered and technical developments will enhance recovery efficiency. This has to be seen against a background where new reserves are likely to come from more physically-challenging and geopolitically less stable regions. The development of new sources of gas will depend on the price that can be obtained in competition with alternative sources.

Dependency on long pipelines requires cooperation between all countries through which they pass. The larger the number of partners the greater the risk of political or economic dispute. The longer the pipeline, the greater is the vulnerability to terrorist disruption. These dangers will be mitigated by a shift to LNG transport and storage.

The global demand for gas is growing at about 2% p.a. To meet this demand, new gas production will require to grow at about 0.03millionTWh per annum. Two thirds of this new production will be required to replace depleted fields. With UK reserves in sharp decline, the UK, which has always been totally self- reliant on gas, began importing gas in 2005 for the first time. In the future the UK will be competing in an ever more competitive global market. In moves to secure gas supplies in the medium term recent agreements have been reached by the UK with Norway to supply up to 20% of requirements for the next 15 years, and with Qatar, to supply up to 20% of requirements in the form of LNG delivered to the new storage facility at Milford Haven.

The 'dash for gas' at the end of the last century and the probable replacement of decommissioned coal and nuclear stations within the next 10years with gas power plant, will mark a sharp decline in the diversity of energy source which is a cornerstone of ensuring security of supply.

SCOTTISH ISSUES

The run down in North Sea gas production will have limited impact on employment in Scotland. The largest social impact, arising from gas usage, is likely to arise from the upward drive in energy costs.

The current Ofgem charging policy for Grid connectivity renders the cost of new generating plant in Scotland uneconomic compared with other parts of the UK.

As the North Sea fields have matured, Scotland has become a centre of expertise in field depletion technology and new opportunities are arising in this area. Already some 30% of the local industries' income is earned abroad.

In the Peterhead hydrogen from methane project, Scotland has an opportunity to take a leading role in what could prove to be a major new source of energy.

The presence of so many global oil companies in Scotland, together with home-grown companies like the Wood Group, constitutes a skill base which, coupled to university based-research capacity at the University of Aberdeen, Robert Gordon University and the Institute of Petroleum Engineering at Heriot-Watt University, is capable of generating intellectual property and skills both for domestic needs and with export potential.

OIL

PRIMARY SOURCE

In 2003 the global oil production was 45000TWh. The leading sources, accounting for two thirds of the total, were: Saudi Arabia, Russia, United States, Iran, Mexico, China, Norway, Venezuela, Canada and the UAR. The absence of Iraq from this list reflects the ongoing political problems in that country.

The UK is self- reliant in oil, producing around 1700TWh in 2000. This figure is currently declining at about 5% p.a. and we may expect to become a net importer of oil by around 2010.

As with gas, oil production from the UK Continental Shelf is not disaggregated.

FINAL CONSUMPTION

Oil has to be refined to produce the final consumption fuels. The break down in refined products varies with the source and composition of the crude oil. Globally, 95% of the crude oil is converted into commercial products with 32% coming as middle distillates, 25% as motor gasoline (petrol), 17% as heavy fuel oils, 8% as LPG, Ethane and Naphtha, 6% as aviation fuel and 12% as other products (non-energy chemicals).

In 2002 global consumption of oil was 37000TWh. The UK consumed 772TWh, of which 60.5TWh was attributed to Scotland.

A UK breakdown of refined product consumption suggests 2.6% butane and LPG, 12.6% aviation fuel (including kerosene), 27.3% petrol, 26%DERV, 8% heating oil, 18.8% other and marine diesel and 4.8% fuel oil.

DEMAND

Globally the demand for oil-based products is 57.2% for transport, 20.1% for industry (excluding agriculture), 16.5% agriculture, domestic and the service sectors with 6.2% consumed in non-energy-related industries. The breakdown of refined products was 32% middle distillates, 24% motor gasoline (petrol), 17% heavy fuel oils, 6% aviation fuels, 9% LPG, ethane and naphtha and 12% for other products.

In the UK 82.3% was used in transport, 9.6% in industry, 5.3% domestically and 2.8% in the service sectors. The corresponding figures for Scotland are: 77.4% for transport, 8.4% for industry, 9.6% domestically and 4.6% in the service sectors.

EFFICIENCY

In Scotland, oil is principally used to provide stand-by electricity generation with an average efficiency of 33%

TECHNOLOGY

The oil industry is mature and technical developments are likely to be most influential in the areas of recovery from existing fields and extraction from unconventional sources and more challenging environments.

In common with other fossil fuels, the oil industry can share advances in carbon sequestration technology. However, its dominant use for transport poses distinct environmental challenges.

COST

The spot price for crude oil is a major global economic indicator. After the politically engineered high prices of the early 1980s, the spot price fluctuated around $20 a barrel with a sharp peak in 1991, associated with the first Gulf war. However, since 2000 the price rose from a low of about $10 a barrel to $35 in mid 2004, and since then it has risen steadily and is currently fluctuating between $60 and over $70 (2-2.5p/kWh).

The rise in crude oil prices is reflected in the cost of refined products, which, in addition, are subject to changes in refining capacity. Thus the 2005 hurricane damage to USA refining capacity saw refined fuels at all times high prices. Typically, the Rotterdam spot price for refined fuels is 10-15% higher than that for crude oil.

There is uncertainty in the future price of oil. Since the current escalation would appear to be driven by increasing demand from developing countries like China and India rather than political engineering as in the past (not withstanding the Iraq war) and the cost of exploiting more geologically challenging fields, it would seem prudent to assume that we are facing a long period of increasing oil prices.

In the UK, the dominant contributor to retail costs of the largest consumer sector (transport) is tax.

ENVIRONMENTAL ISSUES

As with all hydrocarbon combustion there are concerns about the impact of carbon gas emissions on global climate change. The ever present threat of fire at oil storage depots or the deliberate ignition of oil wells in conflict situations has highlighted the problem. While carbon gas sequestration technologies may be developed for major combustion plants, their implementation in millions of independent automobiles presents a formidable technical and societal challenge.

Concerns exist about the environmental impact associated with oil and gas exploration and exploitation relating to interruptions to marine ecosystems, debris on the sea floor and the unresolved issue of decommissioning and removal of hardware. There is also the affect of pipelines through environmentally-sensitive regions.

There are particular concerns about the impact of high altitude emissions from jet aircraft on the ozone layer and potentially carcinogenic particulate emissions from diesel fuel. Fuel oils are constantly being developed to reduce the perceived hazardous emissions, e.g. lead free petrol.

1kg of oil combustion emits 2.5kg of CO_2.

SECURITY

At the current rate of extraction, proven reserves of oil will last about 40 years, but if demand continues to grow at the current rate, then for less than 30 years. However, the US Geological Survey estimates that the amount of ultimately recoverable oil could be as much as three times the current proven reserves and this would allow the expected growth in consumption for about 30 years, provided all these potential reserves can be discovered and brought into production. A lot more oil will need to be 'proved up' if global production is not to peak before 2030 by which time the bulk of oil production will need to come from capacity that has not yet been built. The addition of World proven oil reserves from the discovery of new fields and production has fallen behind the growth in demand for the past twenty years.

The above predictions are based on conventional oil field reserves. It is estimated that unconventional oil stores (shales and sands etc.) could equal conventional reserves. However, the amount of oil that can be extracted from unconventional sources is uncertain, both in volume and cost. It is not expected that unconventional production will change the outlook significantly in the next 25 years.

The development of new sources of oil, whether of a conventional or unconventional form, will depend on the price that can be obtained in competition with alternative sources.

UK oil production from the UK North Sea peaked in 2000 and is steadily declining. The UK will become a net importer within the next five years and within fifteen years will be dependent on imports for most of its oil. As the UK moves from being an exporter of oil to being an importer, it will be entering an increasingly competitive market frequently seeking sources in less politically stable regions, and the UK, including Scotland, will become more vulnerable to the global cost of oil.

As with gas, the principal concern over security of supply relates to the necessary political and economic accord between the producing nation, the consuming nation and all nations through which pipelines run, and the vulnerability to terrorist activity of well heads, pipelines, refineries and storage depots. If the supply of oil falls below the level of demand, the risk associated with these concerns is likely to intensify.

A major concern in the security of oil product supply must be the limited global refining capacity, so recently revealed by the impact of hurricanes on the US Gulf States.

SCOTTISH ISSUES

The run down in North Sea oil production will impact on employment. The greatest social effect, from oil usage, is likely to arise from the upward drive in energy costs.

The high cost of oil in remote regions of Scotland raises the price of transport with consequential social and economic effects.

As the North Sea fields have matured, Scotland has become a centre of expertise in field depletion technology and new opportunities are arising in this area. Already some 30% of the local industries' income is earned abroad.

The presence of so many global oil companies in Scotland, together with home-grown companies like the Wood Group, constitutes a skill base which, coupled to university based-research capacity at the University of Aberdeen, Robert Gordon University and the Institute of Petroleum Engineering at Heriot-Watt University, is capable of generating intellectual property and skills both for domestic needs and with export potential.

HYDROELECTRICITY

PRIMARY SOURCE

In 2002 hydroelectricity accounted for 2.2% of total primary energy supply, 2700TWh in the UK.

The UK has the capacity to generate about 4GW, 2GW in Scotland, of hydropower (including pumped storage) or about 4% of total electricity generating capacity. The theoretical capacity can be reduced in periods of drought. In the exceptionally hot and dry summer of 2003, the UK's hydropower generating capacity fell by over 60% due to the shortage of water.

In Scotland, there are 50 hydroelectric generating stations with only two (Cruachan and Foyers) operational pumped storage facilities. Forty are owned and operated by SSE Generation Ltd and eight by Scottish Power Generation Ltd. None of these plants is expected to have its capacity significantly increased over the next ten years. There is a 30 MW station at Kinlochleven and a 62MW plant at Fort William operated by Alcan, originally in connection with the aluminium smelting plants.

A new plant with a capacity of 100MW is being developed at Glendoe, near Fort Augustus. It will be the second largest conventional hydroelectric station in Scotland. A new development is the Green Power plant at Inverfarigaig, near Foyers that, from 2007/8, will deliver 4MW. Small although this plant is, there is a growing interest in Scotland in micro-generation to which hydroelectricity could be a significant contributor.

FINAL CONSUMPTION

Of all electricity generated globally, 16.2% is produced by hydropower (2676TWh). Production capacity is demand led due to the inability to store electricity in large quantities.

The UK produced approximately 6.6TWh, of which Scotland produced around 3.7TWh, of hydroelectric energy in 2002.

DEMAND

It is impossible to disaggregate demand for hydroelectric power from general demand for electricity. Globally 56.7% of electricity was consumed by agriculture, domestically and the service sector, 41.5% was used by industry and 1.8% for transport.

For the UK 33% of electricity is used domestically, 0.3% for transport, 34% by industry and 31% by the service sectors.

In Scotland 36% of electricity is consumed domestically, 1% by transport, 30% in industry and 33% by the service sectors.

EFFICIENCY

Considered not to be applicable.

TECHNOLOGY

The technology of the generating process is very mature and the scope for significant advances is limited, although there is always scope for advances in turbine design. Because of our inability to store large quantities of electric energy, other means of storing the energy are developed. By far the most common is pumped storage whereby electric power, not required for consumer use, is used to pump water back above the inlet point of the generating station.

There is growing interest in microgeneration of electricity and the need to develop more efficient small scale plant.

COST

It is difficult to make general statements about hydropower costs. The principal cost is the capital cost of the dam and this is very site-specific. Frequently the dam is built to fulfil other objectives, e.g. flood control, as well as generating power. Once constructed costs are limited to the maintenance of the plant and transmission links. The cost then is dominated by the cost of the capital investment. As a result, the discount rate and longevity of the plant become important in the investment decisions.

ENVIRONMENTAL ISSUES

Hydroelectricity is noteworthy for its lack of emissions and waste products. The creation of large dams carries with it the obligation of longer-term maintenance or their careful decommissioning. It can have a dramatic impact on local ecologies with extended damage during the construction phase. Frequently, suitable sites are remote and require the development of service roads. This allows more traffic to enter previously inaccessible regions and the potential for human impact on the local environment is increased.

The hydroelectricity is taken to the Grid by transmission lines strung from tall pylons. This visual evidence of industrial activity can detract from the natural beauty of an area. There is a constant concern about the possible pollution of river water by chemicals as it passes through the generating station and there is a need for constant monitoring. With the construction of dams, it is necessary to develop migration routes for fish.

A counter to this is that many people find the artificial lakes created by dams visually attractive and an asset in encouraging a biodiversity, including fish stocks.

SECURITY

Hydroelectricity generated in the UK is highly secure with the only threats coming from excessively dry periods and water shortages. Frequently, hydroelectric plants are in remote locations and delivery of power can be interrupted, for short times, by severe weather conditions damaging transmission lines.

There are no particular security issues in peacetime. The dams represent a low risk terrorist target. In wartime, dams have become targets of special significance given the importance of energy.

There is always the risk of accidental dam failure. However, vigilant monitoring of dams allows remedial steps that prevent serious danger.

SCOTTISH ISSUES

The concerns that hydroelectric stations would create lakes, displace people, destroy agricultural land and disturb the ecology of rivers and the surroundings with consequences for local flora and fauna, especially fish is largely historical. The Scottish hydroelectric industry has created employment, the road infrastructure has opened access to the local population and enhanced the tourist trade. The lakes have provided increased opportunities for fishing and recreation, and the development of tourist industries.

Approval has been given to Scottish and Southern Energy for a 100MW plant at Glendoe, near Fort Augustus; the largest plant to be built since 1957 and the second largest hydroelectric station. The plans for the pumped storage scheme at Craigroyston to the east of Loch Lomond could possibly be resurrected.

NUCLEAR

PRIMARY SOURCE

Today, nuclear power generates 7% of the total global primary energy supply (8350TWh).

In the UK the total installed power generating capacity in May 2005 was 11.9GW (104TWh)

At present Scotland has two operating nuclear plants with a power generating capacity of 2.3GW (20TWh) in 2005.

FINAL CONSUMPTION

In 2002 nuclear electricity consumption was 2660TWh. The large difference in supply and consumption reflects the large amount of heat that is dissipated.

In the UK, the nuclear contribution to electricity generation has fallen from around 30% in the 1980s to around 23% in 2003 (about 75TWh). The UK also imported 2.5% of its electricity from France, 80% of which is nuclear generated. In Scotland, the nuclear plants delivered around 16TWh in 2002, representing 39% of electricity sold.

DEMAND

It is impossible to disaggregate demand for nuclear generation from the general demand for electricity. Globally 56.7% of electricity was consumed by agriculture, domestically and the service sector, 41.5% was used by industry and 1.8% for transport.

For the UK 33% of electricity is used domestically, 0.3% for transport, 34% by industry and 31% by the service sectors.

In Scotland 36% of electricity is consumed domestically, 1% by transport, 30% in industry and 33% by the service sectors.

EFFICIENCY

Globally the consumption of 8350TWh of nuclear energy to generate 2660TWh of electricity represents an efficiency of 31.8%.

The average efficiency of Scotland's nuclear stations is 37.6%. Because of the tendency to put nuclear generation at remote sites, there is limited scope for using surplus heat. The Finns are planning to use the heat from their new nuclear station for horticultural benefit. The heat could also be used for supplementary steam power generation.

TECHNOLOGY

Nuclear power stations are frequently designated by their fuel, and or cooling/heat transport, and or moderating systems. The first generation of UK reactors were called Magnox because of the composition of their fuel rods. They used graphite moderators and were cooled by water. These stations have now been, or shortly will be, decommissioned. The second generation of Advanced Gas Cooled Reactors (AGRs) were similarly moderated, but carbon dioxide gas was used for cooling and heat transport. The UK has one Pressurised Water Reactor (PWR) at Sizewell. This uses water as both a moderator, cooling and heat transfer medium and represents the most widespread reactor design. All new build reactors are based on developments of this technology. The Canadians have developed a family of CANDU Reactors using heavy water (contain deuterium) as a moderator.

The most recent UK reactor at Sizewell was commissioned in 1995 after more than fifteen years of planning, public enquiry and construction. Consequently it represents a design that is more than thirty years old. Modern reactors are half the size, complexity and cost of these earlier models; they are also inherently safer. Reactors of this form, e.g. the Westinghouse AP1000 reactor, are currently available.

A new generation of reactors, such as the Pebble Bed Reactors, will offer even greater inherent safety and promise a more flexible choice of scale of capacity. No commercial versions of these are likely to be available in less than ten years.

COST

The cost of nuclear generation is dominated by the capital cost and thus closely linked to the amortisation period and the working life of the reactor and its load factor. Fuel and operating costs are relatively small. Decommissioning costs can be high and must be included in the cost of generation over the life of the reactor.

Three independent US university studies (MIT, Chicago and Princeton) arrived at consistent figures of 3-4p/kWh based on a high capital return of 10-15%, a short life of 15-20 years (presumably existing plant) and load factors of 75-85%. Two European studies (Finland and France) reported, for new build, estimates of 1.7-2.2p/kWh. These were based on a capital return of 5-8%, lifetimes of 40-50 years and load factors of 90%. Two OECD studies assuming load factors of 85%, lifetimes of 40 years and capital returns of 5% and 10% reported costs of 1.3-1.9p/kWh and 1.8-3p/kWh respectively. A UK study by the RAE reported figures of 2.2-2.4p/kWh with similar assumptions to the two other European studies.

In 2002 the cost of imported French nuclear electricity was 1.4p/kWh.

Historic costs of nuclear power in the UK reflect the high costs of development, the multiplicity of reactor designs, including the consequent need for a large reprocessing capacity, and a failure to address the waste management issues.

SECURITY

The IAEA estimates that current assured resources of uranium will last for about 25 years assuming a continued global economic growth, ecologically driven energy policies (switch from carbon gas emitting fuels), energy demand growth of about 1% and sustained development of nuclear power world wide, including developing countries. It is estimated that the cumulative uranium requirement 2000-2050, in this scenario, is 5.4Mt.

Unlike other fuels, uranium comes from two sources. The primary source is newly mined and processed uranium and the secondary source is waste repositories and nuclear weapon stockpiles. Between 2000 and 2050 the contribution from secondary sources is projected to decline from around 40% to 10%. However, the UK is a major repository of secondary source material.

The market is in a state of flux having to accommodate falling secondary supplies at a time of increasing demand, led by new plant in China, India, Japan and Korea.

IAEA is confident that uranium reserves will cover all needs for at least 100 years. As with the fossil fuels, the development of these resources will be dictated by the price that they can attract in the global market. However, because fuel costs are a small percentage of nuclear generation costs, the impact on electricity costs is dampened.

More than 50% of the World’s primary supply of uranium comes from Australia and Canada. Both are considered to be geopolitically ‘safe’, although transport to the point of use could be vulnerable.

Nuclear power stations in the UK are designed to withstand a direct hit by a Boeing 747 and hence should be considered secure against a 9/11 type terrorist attack. The threat of theft of nuclear material from an operating power station core is extremely remote.

The acquisition of nuclear technology by any nation not prepared to sign the non-proliferation treaty and fully accept IAEA inspection and monitoring must constitute a global threat. The building of nuclear power stations in established nuclear states does not constitute nuclear proliferation.

Security against human error during operations should be based on failsafe engineering as practiced in all western licensed reactors. Incidents like that at Three Mile Island (caused by inexperienced operators and faulty components) demonstrate the efficacy of such an approach. Incidents like Chernobyl (caused by illegal and unauthorised experimentation) indicate its absolute necessity.

A suitable final waste storage solution must be implemented before the associated risks can be assessed.

ENVIRONMENTAL ISSUES

There are no emissions of carbon gases during the operation of a nuclear power station, but there are in the construction and demolition stages and through the supply of materials by transport during operation of the plants.

No radiation or other emissions have been detected beyond the periphery of a site due to the operation of a nuclear power station in the UK. There have been such incidents associated with temporary waste stores and fuel reprocessing. These emphasise the need for an adequate waste treatment programme.

SCOTTISH ISSUES

Scotland has a long association with nuclear power. The Chapelcross Magnox station was closed in 2004 and decommissioning has begun. The Dounreay Fast Breeder Reactor (FBR) was designed as a research reactor utilising fast neutrons to generate more fuel in its core than it consumed. This essentially experimental station fed the grid but decommissioning began in 2004. Dounreay, along with Sellafield in Cumbria, were designated radioactive waste stores. This storage facility was the source of a number of incidents resulting in radioactivity spreading beyond the site boundaries.

Currently, around 40% of Scotland’s electricity is generated in the Hunterston and Torness nuclear stations. These provide local employment as Torness has approximately 475 full time employees whilst Hunterston B employs approximately 489 and attract skills to their vicinity.

The Hunterston station is due to be decommissioned in 2011 and Torness in 2023. It is possible that an extension of the life of these stations may be sought, however this is unlikely to extend their operations by more than 3-5 years depending on the rate of degradation of the graphite cores.

The loss of Hunterson without an equivalent sized electricity generating station replacement will transform Scotland from an electricity exporting nation to one reliant on imports from England.

The current Ofgem charging policy for Grid connectivity renders the cost of new generating plant in Scotland uneconomic compared with other parts of the UK.

WIND

PRIMARY SOURCE

As an energy source, the supply of wind is universal but the greatest resource lies in regions of steady prevailing winds. The global supply of energy from wind power is virtually limitless.

The north west of Scotland has the greatest intensity and consistency of winds from a predominant direction than anywhere else in Europe.

Typical large commercial wind turbines have ratings of a few MW.

In the UK there was a total 700MW of installed wind capacity by May 2005. Given a typical load factor of 30% this had the capacity to deliver around 3.8TWh.

In Scotland, 222MW capacity was installed by May 2005 capable of delivering approximately 1.2TWh. For the Northern and Western Isles, load factors of 50-60% are reported. The number of planned installations is growing rapidly.

FINAL CONSUMPTION

Globally, wind power provides less than 1% of electricity supply. The largest producer of wind power electricity is Germany and the highest percentage of wind power (about 12%) is in Denmark.

The UK and Scottish figures indicate that about 2% of electricity consumed was generated by wind power.

DEMAND

Wind has been used to power sailing ships and mills for centuries. The current interest in wind rests with the use of modern turbines to generate electricity.

It is impossible to disaggregate the commercial demand for wind generation from the general demand for electricity. Globally 56.7% of electricity was consumed by agriculture, domestically and the service sector, 41.5% was used by industry and 1.8% for transport.

For the UK, there is a Government created demand for wind power through the application of the Renewables Obligation Certificate scheme that sets a target for 2020 that 20% of all electricity should be generated from renewable sources. The ROCS were not meant to favour a particular technology, however, wind power has been the principal beneficiary of the credit scheme.

For the UK 33% of electricity is used domestically, 0.3% for transport, 34% by industry and 31% by the service sectors.

In Scotland 36% of electricity is consumed domestically, 1% by transport, 30% in industry and 33% by the service sectors.

EFFICIENCY

Considered not to be applicable.

TECHNOLOGY

Wind generating technology represents state of the art engineering of a mature industry. We expect to see marginal developments in efficiency and reliability. Offshore developments will be more challenging and expensive.

While the velocity of the wind cannot be controlled in the open, for small-scale generation the wind flow can be channelled, much as water races were used in water mills, to increase the available power. This may make increased microgeneration more attractive.

It is likely that interest in wind generation for local use will grow, especially where grid connections would be impractical or expensive. We are already seeing a widespread use of microgeneration for motorway signs etc. and would expect this to be a growth area. These novel applications are unlikely to represent fuel substitution and more likely to represent new applications.

COST

OXERA has estimated the cost of onshore wind turbine generation at 2.9-3.8p/kWh and for offshore generation, twice this amount. The UKERC has estimated an additional cost of intermittency at 0.5-0.8p. This cost is offset by ROCs, making wind generation economically attractive.

The current cost of microgeneration capacity is £5000/kW with a lifetime of 10-20 years and low maintenance costs.

ENVIRONMENTAL ISSUES

Concerns about noise pollution have led to requirements for the careful siting of wind generation relative to human habitation. There is also concern about the impact of large-scale wind power generation on the diurnal movement and hunting ranges of birds.

Several sites proposed for wind power generation are designated under the EU Birds and Habitats and Species Directives, and/or have special landscape value and natural beauty. The need to construct new power lines from the wind generators to connect with the national grid or to increase the capacity of the existing lines has also led to objections from environmental and community interests. There is thus a body of opposition based on the impact that large-scale generation could have on these sites.

To replace a single conventional power station, typically 1.2GW, with an array of 3MW wind turbines, operating at a typical 30% load factor, would require the construction of approximately 1200 turbines; there are currently less than three hundred throughout the UK.

SECURITY

The principal security of supply issue for wind is its intermittency. This means that the average load factor is reduced to around a third on average, and makes wind unsuitable for base load provision without significant standby conventional capacity.

By the nature of the source, many prime sites for wind generation are extremely exposed creating a greater danger of temporary supply interruptions due to extreme weather conditions.

Concerns have been raised about the stability of the grid, due to intermittency, should wind generation exceed 20% of the total.

SCOTTISH ISSUES

The richest sources of wind power in the UK are available in the Western and Northern Isles of Scotland. Typically, across most of Europe, including the UK, the variability of the wind limits load factors to about 30%. In the Northern and Western Isles the load factor can be up to 60%. However, the Grid connections to the mainland are either totally absent (Shetland) or totally inadequate (Orkney and Western Isles) making the resource currently unavailable to the market. The National Grid Company's charging policy for Grid connectivity means that the cost of connection will render many of the proposed wind generation schemes uneconomic.

Approval was given in May 2006 for the construction of the largest wind power complex in Europe at Whitelee, south of Glasgow, with a capacity 322MW.

Small community-owned wind power projects may have a beneficial impact on remote communities. Where the electricity can be brought to the market it can generate income for what are often marginal economies and reduce energy costs.

Employment opportunities are in large-scale manufacturing of wind generating plant, such as the fabrication plant established at the former military airfield at Machrihanish, near Campbeltown.

The First Minister has set a challenging target for Scotland, that 40% of electricity should be generated by renewables by 2020. At the present time, the bulk of this will have to come from wind generation. Large scale wind power generation would have a considerable visual impact and may conflict with ecotourism.

BIOMASS AND WASTE

PRIMARY SOURCE

Biomass material is any non-fossilised material of either plant or animal origin. It may be generated in its own right or be the by-product of some other activity. Waste is material discarded by humans then processed to be used as biomass. With such a wide definition there is in principle an extremely large source available.

In 2002 biomass and waste (B&W) constituted 11% of global energy supply (13500TWh). The installed capacity for electricity generation by (B&W) in the UK and Scotland was 1.4TWh and 3.2TWh respectively.

FINAL CONSUMPTION

Biomass can be burnt in its original state, e.g. wood, or be highly processed to produce transport fuel. Thus it can be used as an alternative to fossil fuels and consumed as heat, electricity power or transport fuel.

In 2002 the global consumption of biomass was 12000TWh, the balance between source and consumption was used to generate electricity. In the UK 1.4TWh of B&W was used exclusively to generate electricity and a further 3.4TWh (all biomass) was used to co-fire electricity generation. In Scotland 0.24TWh of biomass was used for electricity generation.

DEMAND

There is no specific demand for B&W. It is used as a fossil fuel substitute in response to low carbon emission policies.

EFFICIENCY

The efficiency of B&W combustion depends on the state and composition of the fuel. However the efficiency of heat production or electricity generation cannot exceed that of fossil fuels.

TECHNOLOGY

While biomass represents the prototype of all sources of energy, its modern exploitation is at the cutting edge of technology.

The two most common forms of biofuels are bioethanol and biodiesel. Bioethanol is most efficiently produced from matter with a high sucrose content. Enzymic systems for producing bioethanol from lignin are being studied, particularly in Canada. Biodiesel can be produced from a wide range of waste sources, tallow from meat rendering and used cooking oil, etc. and oil crops, such as rapeseed.

The degree to which co-firing can be expanded requires further technical development.

COST

The costs of transporting, and processing biomass material, adds significantly to the total cost. This makes it attractive to use biomass (particularly timber) close to its source.

OXERA have estimated the cost of B&W electricity generation from energy crops at 4.9-5.5p/kWh, waste at 2.0-2.4p/kWh, landfill gasses at 2.7-3.2p/kWh and co-firing at 0.9-1.1p/kWh.

The table summarizes the range of estimates of potential electricity and heat generation from wood fuel (not including recycled wood) in Scotland, based on the wood fuel volumes presented in the SDC and FREDS reports. For the sake of consistency with the remainder of the feedstocks, these have been adjusted so that they assume a conversion efficiency of 30% for electricity and 85% for heat. It must be stated that these are simple calculations based on the wood volume data from the above-cited reports and should be treated with caution.

Wood fuel energy generation potential to 2020.

Scenario	Total volume (odt yr^{-1})[1]	Heat Output (MW)[2]	Heat Output (GWh)[4]	Electrical Output (MW)[3]	Electrical Output (GWh)[4]
Achievable	800,000 – 1,200,000	400 - 502	3512 - 4392	141 - 177	1240 -1550
Theoretical	3,700,000	1845	16250	650	5735

1) Lower wood fuel volume limits from SDC 2005, higher limits from FREDS 2005 (based on 3 million m^3 volume)
2) Assumes calorific value of 18.6 GJ/odt (DTI 2004), heat conversion efficiency of 85%.
3) Assumes electricity conversion efficiency of 30%.
4) Assumes 24/7/365 operation.

The recently published Scottish Energy Study states that in 2002, Scotland's electricity demand was 34.19 TWh. According to the above estimates, therefore, woodfuel would be able to supply approximately 3.9 – 5.1% of Scotland's current electricity needs. According to the SDC Report, 700,000 to 1,000,000 odt is able to provide between 5 and 11% of Scotland's domestic space and water heating requirements.

ENVIRONMENTAL ISSUES

Provided that the production from biomass sources is at a sustainable level, biomass sources can be considered renewable.

Although B&W emit carbon gases on combustion, they are seen as carbon neutral since during their growing period they were extracting CO_2 from the atmosphere. The processing of biomass fuels may involve carbon gas emissions but these are small compared to emissions during combustion.

Waste incineration for heat or CHP generation reduces the need for landfill disposal.

The growing of large-scale fuel crops may threaten biodiversity and landscape, and requires careful management.

Biomass transport fuels are being widely promoted as supplements to oil based fuels in order to reduce net carbon emissions.

SECURITY

For the poorest people on the planet, who have no source of energy other than B&W, there is clearly a critical availability crisis, especially in areas subject to drought.

Currently the UK imports processed biomass fuel from around the World; this supply is largely from stable geopolitical regions.

In the UK the largest potential biomass resource is in the form of forestry products. The use of timber as a source of energy is in competition with other markets. Estimates by the Sustainable Development Commission 2005 suggest that around 1million tonnes of oven-dried timber per annum might be resourced from within Scotland by 2016. This could provide 4TWh of heat plus 1.4TWh of electricity.

SCOTTISH ISSUES

Forestry and sawmill co-products

Sixty percent of the UK's forestry resources are in Scotland. This equates to an area of 1.3 million ha, which is approximately 17% of the Scottish land area. Furthermore, the growth increment of Scotland's forest is currently increasing and is expected to peak in 15-20 years time (Scottish Industries Forest Cluster 2004).

Of all biomass feedstocks of relevance to Scotland, wood fuel has been the most thoroughly reviewed, but perhaps the most complete review on the availability of wood fuel in Scotland was conducted by the Sustainable Development Commission for Scotland (2005). By adjusting earlier estimates for wood fuel resource in Britain prepared by the Forestry Commission (McKay 2003) with data from timber markets and incorporating several practical constraints, the report demonstrated that there is currently a sizeable volume of wood fuel from forestry operations and the sawmill industry by-products that could be utilized for fuel. The most important of these for Scotland appear to be small roundwood (small diameter wood that feeds the board, pallet and paper market) and sawlog by-products from the timber industry. According to the study report, about 10% of roundwood in Scotland has no market. The authors presented their assessment of wood fuel availability according to three time periods (2005-2006, 2006-2011, and 2011-2016) and three distinct scenarios: immediately available wood not utilized by competing sectors, wood availability under a wood fuel sector growth scenario and theoretical wood availability under the assumption that there were no alternative markets for the product. The results, summarized in the table, indicate that there is presently an immediate volume of around 720,000 oven-dried tonnes (odt), which could increase to over 1,000,000 odt by 2012 under a scenario of growth of the wood fuel sector. The wood sources included in the calculation were arboricultural wood, secondary wood generated by the wood processing industries, harvesting residues, wood from early thinnings and stands of low quality, roundwood (stem wood in 7-14 cm and 14-16 cm diameter classes) and sawlog material (stem wood in 16-18 cm and 18 cm + diameter classes).

Wood fuel availability up to 2016 under three different scenarios.

Time period	**Available Wood Fuel (odt per year)**		
	Immediate	Growth	Theoretical Total
2005-2006	723,036	900,998	2.971,713
2007-2011	758,854	922,548	3.263,591
2012-2016	805,168	1,007,775	3,702,281

Source: SDC Scotland (2005).

The SDC study also provided disaggregated results for different Forestry Commission districts, with lowest immediate wood resource availability in the north east and highest availability in Galloway and the Scottish Borders. Under a scenario of wood fuel sector growth, however, Inverness and Tay would become the regions with greatest availability.

This could result in a future wood harvest of 3 million cubic metres above current production, an amount that will most likely exceed market demand (Sustainable Development Commission 2005). Improved management practice, however, should help to smooth the bulge in supply, an issue that is currently being investigated by the Scottish Forestry Commission and forestry industry (James Pendlebury, in oral evidence to Scottish Biomass Inquiry). This will result in lower peak volumes than those estimated in the Scottish Industries Forest Cluster report (2004).

The estimates from the SDC study were slightly lower than those published in the FREDS Biomass Energy Group (BEG) Report (2005), which suggested there would be 5 million m^3 of wood available for bioenergy use by in the UK by 2020, 60% of which come from Scotland (3 million m^3) although this estimate was based only on resources from forestry. This is equivalent to approximately 1.2 million odt (SDC 2005). The report estimated that this volume of wood could generate 440 MW of electricity, although the FREDS estimates are currently regarded as being optimistic (Gavin McPherson, personal communication) and appears to have been based on the total estimated wood fuel volume for the UK rather than for Scotland.

In addition to the ‘clean’ wood sources included in the SDC study, a large volume of ‘unclean’ wood residues that could potentially be used for bioenergy production is produced from other industries. It has been estimated that over 1.5 million tonnes of waste wood is produced by the construction industry alone in Scotland every year, while the packaging industry could theoretically result in a further 140,000 tonnes, the furniture industry in 33,500 tonnes and 6,000 tonnes per year could come from fencing (Remade Scotland 2004). Unlike wood material arising from forestry and sawmill offshoots, this material is not very homogeneous in nature and often presents heavy contaminant loads, that may lead to complications in some bioenergy technologies. These may also require burning in compliance with the Waste Incineration Directive (WID), which necessitates additional abatement measures that can incur considerable extra costs.

Although they are substantial, Scotland’s forestry resources are highly dispersed, meaning that transport would be problematic if wood resources were to be used in a highly centralised power plant, for example. Addressing this geographical separation of wood supply and heat demand is a crucially important factor in the ongoing debate about how to best develop the biomass sector in Scotland. The small-scale wood fuel market is currently seen as the most promising use of Scotland’s wood fuel resource (Rippengal 2005), but even in this market there are likely to be logistical barriers that need to be overcome.

Specific energy crops are being reviewed, but with only willow under current consideration. There is considerable scope for utilisation of waste.

There is limited scope for transport biofuels. With no sugar beet production in Scotland financially viable, bioethanol production would have to wait the development of commercial enzymic processes. Biodiesel production from rape, linseed and sunflower crops and waste matter is possible in the right economic climate.

An extremely successful demonstration of waste usage is available in Lerwick where waste from Orkney, Shetland and Aberdeen is used to fuel a district-heating scheme. Old-fashioned incinerators have left a bad public image but modern technology has overcome all the old objections and would be most beneficially employed in large urban areas.

B&W fuels have a potentially useful role in integrated microgeneration schemes.

HYDROGEN AND FUEL CELLS

PRIMARY SOURCE

Hydrogen is the lightest element and remains a gas except at extremely low temperatures not experienced on Earth outside cryogenic laboratories. Thus there is no free hydrogen on Earth, it has all escaped into space. Hydrogen is principally present on Earth in the form of hydrocarbons and water.

The removal of hydrogen from water requires as much energy as is released in its burning to form water. Thus water-derived hydrogen consumes more energy than it provides but it is storable and transportable. The removal of hydrogen from hydrocarbons requires much less energy than is released; thus there is a net energy gain.

Globally there is an almost inexhaustible supply of hydrogen, provided there is a sufficient source of energy to extract it.

FINAL CONSUMPTION

No figures exist for the current total consumption of hydrogen.

DEMAND

Much of the current demand is sought for demonstration projects, e.g. in Europe the CUTE (Clean Urban Transport) initiative is supporting nine large European cities (including London) with £13M to operate hydrogen fuel celled buses. In the USA there is a growing use of hydrogen, either directly burnt or with fuel cells to power vehicles. Other applications are limited to niche markets like the space programmes.

Japan has set targets of a Hydrogen Fuel Cell capacity of 10GW and 5 million vehicles by 2020. Iceland has announced a transport policy based on hydrogen-fuelled vehicles.

EFFICIENCY

In combustion, it is expected that hydrogen will be comparable in efficiency of electricity production to natural gas. The overall efficiency will depend on what happens to the surplus heat.

A HFC is not constrained by the Carnot cycle efficiency of a combustion engine because it does not operate within a thermal cycle. Typically, a HFC will convert chemical energy into electricity with an efficiency of 50%. However, this falls off as the current drawn is increased.

TECHNOLOGY

Hydrogen burns violently in air. If free hydrogen is to become widely used, technical advances in safe handling, burner design, and storage will require priority.

The basic input fuels are oxygen (usually in the form of air) and hydrogen. The hydrogen has been traditionally supplied in bottled form under pressure. For transport there is a growing interest in the storage of hydrogen in solid hydrides. These storage cells have a limited capacity and need to be refuelled at regular intervals.

Fuel cells are devices that convert hydrogen and oxygen to electricity. There are more than twenty different forms of HFC, divided into three categories: High Temperature ($>500^0$C), Medium Temperature (500^0C – 100^0C), and Low Temperature ($<100^0$).

The original concept of the fuel cell was developed in 1863 by William Grove as the reverse of electrolysis. The common alkaline fuel cell was developed in the 1960s for use in spacecraft. Like an ordinary battery the cell has an anode and a cathode, but usually in the form of a mesh. Hydrogen enters the cell through the anode and passes through a porous catalytic membrane (usually platinum) into the electrolyte. Oxygen passes through the cathode and a catalytic membrane (usually silver). The electrolyte is often exactly the same as that found in conventional alkaline batteries, e.g. potassium hydroxide. The cell operates most efficiently at 70^0C. The catalytic membranes provide the sites for recombination to take place. This produces water vapour that is condensed out and returned to the KOH header tank to maintain pressure. The process is controlled by maintaining a constant hydrogen pressure and adjusting the air (oxygen) supply.

Modules capable of generating a few kW are constructed from a series of fuel plates. Stacks of modules currently are available for generating up to 100kW and for high power systems up to 500kW stacks can be envisaged.

A variant on the alkaline fuel cell replaces the electrolyte with fluorocarbon ion exchange and a polymeric membrane. This appears the best prospect for light duty vehicles and small-scale applications.

Solid oxide fuel cells contain a thin layer of zirconium oxide as a solid as an electrolyte with a lanthanum manganate cathode and a nickel-zirconium anode. They show promise for high power applications.

The Direct-Methanol fuel cells are similar to the proton exchange membrane cells but draw their hydrogen from liquid methanol.

Molten Carbonate fuel cells employ a molten carbon salt electrolyte and have the potential to be fuelled by natural or carbon derived gas.

COST

At present the cost of HFCs is such that positive support is necessary for their commercial application except in niche areas.

ENVIRONMENTAL ISSUES

Hydrogen is seen as the perfect fuel in that it releases more energy when burnt with oxygen than any other fuel and the only emission product is water vapour. However, there could be leakage of methane to the atmosphere and into the soil.

Unless the temperature of hydrogen combustion can be lowered, there is a danger of NOx production.

The production of hydrogen requires energy, and, unless this is generated in an environmentally acceptable manner, the potential benefits may not be fully realised. However, it is probably still beneficial to produce hydrogen even in a fossil fuelled plant where carbon-capture and storage is implemented rather than deal with the emissions from a large number of independent vehicles.

The large-scale disposal of obsolete or damaged HFCs could produce a significant environmental hazard.

Hydrogen produced by non-carbon emitting means could become a clean fuel for space and water heating, transport and power generation.

SECURITY

Given sufficient energy, there is a virtually inexhaustible supply of hydrogen at a price.

There are no obvious security issues arising from the use of HFCs except for the supply of critical elements for their manufacture, e.g. platinum and silver.

SCOTTISH ISSUES

The gas-fired power station at Peterhead is developing a hydrogen extraction plant using the waste heat from the gas turbines to remove hydrogen from natural gas and pumping the resultant carbon dioxide back into the offshore gas field to generate a pressure head for additional extraction.

The PURE project, in the small community of Unst, Shetland, is using wind power to generate hydrogen by electrolysis from water to power cars. There are also plans to develop a marine engine.

Plans are at an advanced stage to build a hydrogen-powered office in Lothian.

If hydrogen becomes a widely used fuel to replace fossil fuels, whether by burning hydrogen directly as a gas alone, or mixed with natural gas, or in fuel cells, there will be a premium on non-carbon gas emitting means of producing hydrogen. Scotland’s large resource of wind and marine energy that cannot be fully exploited without an enormous expenditure on grid infrastructure, could prove of great value. Intermittent sources, like wind, could be used to generate hydrogen that is storable and transportable. Thus offering the combined advantages of harnessing an enormous, relatively inexpensive source of energy while reducing to near zero the hazardous emissions associated with fossil fuels.

The use of hydroelectricity, wind power, marine power and nuclear power to generate hydrogen during periods of reduced demand would allow the electric energy to be stored and smooth the demand curve, thus leading to an approximately 30% efficiency gain in the use of capital plant

The development of a hydrogen economy offers the possibility of employment, particularly in the economically marginal regions of the North and West of Scotland, including the Islands. It is also an opportunity to develop a skills base with export potential.

There is considerable research expertise in hydrogen technology in the Scottish universities, particularly the University of St Andrews, University of Strathclyde and Robert Gordon University.

MARINE (TIDES AND WAVES)

PRIMARY SOURCE

All the oceans of the World are potential sources of enormous quantities of energy and, unlike wind power, there is a greater degree of predictability in the motions of tides and currents.

The UK, and particularly Scotland, is extremely rich in marine energy sources.

There are a few tidal barrages across estuaries, designed to extract power from this source; notable amongst these is the plant at Rance in Brittany constructed in 1967. Eight sites have been identified in the UK as suitable for barrages.

FINAL CONSUMPTION

Apart from barrages, there are no fully commercial, large scale marine power stations yet. Small amounts of wave power are used to power remote buoys.

EFFICIENCY

Considered not to be applicable.

TECHNOLOGY

Both wave and tidal generation are at the development stage. It is estimated that it will be about 10 years before there are commercial stations for either technology. Pelamis is a large-scale, highly-subsidised demonstration and the first plant is currently being installed off the Portuguese coast. The project is subject to a guaranteed price for its electricity for 15 years.

COST

Barrages have so far proved uneconomic. The current marine energy programmes are heavily subsidised. But, if traditional sources of energy continue to become more expensive and as the marine technology improves, the hope is that this resource will become competitive. A concern must be the cost of gathering power from a distribution of marine power generators and transmitting this to the Grid links.

ENVIRONMENTAL ISSUES

The barrage at Rance has had a detrimental impact on the local ecology. Disturbing the estuarial tidal flow has affected plant and animal life, and silting has reduced the generating plant’s efficiency. There are also more stringent wildlife regulations, under the EU Birds and Habitats and Species Directives. These concerns coupled to cost have deterred development of such plants in the UK and mean that it is unlikely that any plants will be constructed on any major estuaries in the UK, given the cases taken to the European Court which have all resulted in development in estuaries protected by the Directives being prohibited.

There are concerns about the impact of ocean tide generators on nutrient flow and hence seabed ecology, and concerns about wave generation devices on ecological and landscapes of coastal areas.

SECURITY

There is a virtually unlimited supply of marine energy.

The reliability of the performance of large-scale marine power generating plants has still to be tested but there are concerns about the ability of ocean wave and tide generators to operate reliably in the extremely high energy environments in which they will operate. The gathering of the electricity and its transmission to shore also present challenges.

SCOTTISH ISSUES

Given its wealth of marine energy sources and resident scientific, technological and commercial expertise, Scotland stands to benefit from this technology.

The European Marine Energy Centre is based in Orkney. The World's first large-scale wave power generator was designed in Orkney and constructed in Lewis and in Fife. It is currently being sited off the Atlantic coast of Portugal.

Continuing development of this technology provides an opportunity for growth of a skills base to tackle Scottish needs and with an export potential. FREDS has highlighted the potential of marine energy. However, the potential will not be realised until the technology becomes competitive.

There is already considerable expertise in the Scottish universities, particularly the Institute for Energy Systems at the University of Edinburgh, Universities of Strathclyde and Glasgow and the Centre for Research in Energy and the Environment at Robert Gordon University.

SOLAR HEAT AND PHOTOVOLTAICS

PRIMARY SOURCE

Solar energy is a ubiquitous source on Earth. Radiation across the complete electromagnetic spectrum constantly strikes our atmosphere with a power density of about 1,400 W/m^2. The solar spectrum is peaked in the range of visible light with most of the remainder in the lower energy infrared. Nearly a third of all this radiation is reflected by the atmosphere directly back into space. While 20% is absorbed directly in the atmosphere, including most of the potentially damaging short wavelength ultraviolet, x- and gamma rays. The 47% that reaches the Planet's surface provides us with warmth and light and photosynthesis for plant growth.

In the UK the available solar energy is about 300W/m^2.

There are two modern attempts to tap this source, first by direct heating and second by the direct conversion of sunlight to electricity (photovoltaics).

FINAL CONSUMPTION

The final use of solar power is either as low-grade heat or low power electricity. Solar heating panels deliver 50-100W/m^2 and modern photovoltaic panels can reach achieve 100-200W/m^2.

DEMAND

For many years the principal UK demand for solar heating has been for swimming pools, but more recently it has been growing for a wider range of domestic and commercial heating needs. Photovoltaics have a niche market for remote sites, e.g. for space programmes (i.e. widely used in space craft where grid connections are difficult) and more recently motorway signs. By far the largest user of solar energy is the agriculture industry, which relies on photosynthesis for plant growth.

The non agricultural use of solar power accounts for about 0.2% of global energy consumption and less in the UK.

EFFICIENCY

Typical solar cell efficiencies are about 20% at the present time.

TECHNOLOGY

Solar heating is a mature technology and dramatic improvements in efficiency and cost are not expected. Photovoltaics is still a technology under development and we may expect to see new materials at lower costs entering the market in the relatively near future.

It is possible that the future of solar power in the UK may be as a component in integrated microgeneration programmes.

COST

The current cost of photovoltaic power is approximately £7000/kW of installed capacity in the UK.

ENVIRONMENTAL ISSUES

There are no environmental issues other than the disposal of exhausted photovoltaic panels if they become widely used.

SECURITY

There are no security issues.

SCOTTISH ISSUES

There is some potential for the use of photovoltaic cells in Scotland, particularly for background water and space heating in buildings. However, the capital costs are high in relation to the length of the pay-back period. Napier University is undertaking research and has installed a wall of photovoltaic cells on one of its buildings.

GEOTHERMAL

PRIMARY SOURCE

The source of geothermal energy lies in the natural radioactivity of rocks. At great depths the rate at which heat is generated by this process exceeds the rate at which it is conducted towards the surface. The result is that the planet has a high temperature molten core. Due to irregularities in the surface layers of the Earth, this internal heat source is manifest in the volcanic regions. In less active regions, it yields hot water springs. But whether from natural springs or the result of bore holes geothermal energy is usually in the form of relatively low-grade heat.

The most extensive use of geothermal power is in Iceland where almost 80% of space and water heating is drawn from this source. Despite the existence of a few warm water spas in the south of England and test sites in Hampshire, there is no significant use of geothermal energy in the UK.

FINAL CONSUMPTION

Most geothermal energy is consumed close to site in the form of space or water heating. To obtain temperature differentials of a sufficiency for power production requires multiple deep bore hole extraction currently not considered economically viable.

DEMAND

There is no overt demand for geothermal energy in the UK apart from the general search for alternative sources of non-carbon emitting energy.

EFFICIENCY

Not considered to be applicable

TECHNOLOGY

Boreholes several kilometres deep are possible but costly. The diameters of these holes, however is limited to a few centimetres, thus restricting the rate of energy extraction.

COST

There is no universal measure of cost. This is determined by the local geology. In Iceland it is clearly competitive with other forms of heating. In the UK it is not.

ENVIRONMENTAL ISSUES

Despite small gas emissions from some boreholes, there are no significant environmental issues.

SECURITY

There are no significant security issues.

SCOTTISH ISSUES

Scotland’s distinct geological history, and the lack of hot spots beneath the country, makes it an unattractive site for sourcing geothermal energy.

APPENDIX G: LIST OF EVIDENCE RECEIVED

Written Responses to Inquiry Consultation

Organisations

Aberdeenshire Council
Aberdeen Renewable Energy Group
Bond Pearce LLP
British Energy Group Plc
British Hydropower Association
Buccleuch Estates Ltd
The Business Environment Partnership
British Nuclear Fuels Plc
BP Plc
British Wind Energy Association
CBI Scotland
Centrica Plc
The Coal Authority
Communities Scotland
Comhairle Nan Eilean Siar
Confederation of Passenger Transport UK
Confederation of UK Coal Producers
J S Cruickshank & Associates
Depletion Scotland
Dumfries and Galloway Council
East Ayrshire Council
East Renfrewshire Council
Energy Academy, Heriot-Watt University
Energy Action Scotland
Energy Institute
Energy Saving Trust
Forward Scotland
Friends of the Earth Scotland
Friends of Stallashaw Moss
Genersys Plc
Greenheat Systems Ltd
Highlands Before Pylons
Highlands and Islands Enterprise
Institution of Chemical Engineers
Institution of Mechanical Engineers
Industrial and Power Association
Institution of Electrical Engineers
Institute of Physics
James Jones and Sons Ltd
Mitsui Babcock Energy Ltd
Mountaineering Council of Scotland

National Grid Transco
Natural Environment Research Council
Nuclear Decommissioning Authority
Nirex
North Ayrshire Council
North Lanarkshire Council
Nuclear Free Local Authorities
Nuclear Industry Association
Ofgem
Orkney Islands Council
Orkney Renewable Energy Forum
Ramblers' Association Scotland
Renewable Energy Foundation
Road Haulage Association
RSPB Scotland
Royal Yachting Association
Rural Development Initiatives Ltd
Rural Scotland
RWE Npower Plc
Save Our Borders Scenery
Scottish Borders Council
Scottish and Southern Energy Plc
Scottish Coal Company Ltd
Scottish Conservatives
Scottish Council for Development and Industry
Scottish Countryside Alliance
Scottish Enterprise
Scottish Environment Protection Agency
Scottish Green Liberal Democrats
Scottish Green Party
Scottish National Party
Scottish Natural Heritage
Scottish Power Plc
Scottish Renewables Forum
Scottish Solar Energy Group
Scottish Wildlife Trust
Sea Mammal Research Unit, University of St Andrews
Shawater Ltd
Shetland Heat, Energy and Power Ltd
siGen Ltd
Stirling Before Pylons
South Ayrshire Council
Southern Uplands Alliance
Sustainable Development Commission Scotland
Trees Not Turbines
Westray Development Trust
WWF-Scotland

Individuals

Mr J R Atkinson FRSE
Dr J Balfour FRSE
Mrs K Barber
Professor J Bialek
Mr D Birkett
Mr R Bowie
Mr J Burchell
Mr S Burchell
Mr C R Buxton
Mr J Cherrie
Mr T Douglas
Mr C S Cunningham
Mr D Davidson MSP
Ms E A O Fagrell
Mr I Fairbairn
Professor A Fallick FRSE
Professor P B Fellgett FRS FRSE
Professor I Fells FRSE
Mr R Fordham
Mr P Gallie MSP
Mr R Gibson MSP
Professor F P Glasser FRSE
Mr J R Hall
Mr J H R Hampson
Mr A C Henderson
Mr N Hollow
Professor J Irvine FRSE
Mr I Jenkins
Mr I Keillar
Mr J Kelly
Professor A Kemp FRSE
Mr F Kiernan
Sir David King FRS
Ms S Kitchin
Mr B Lawrence
Mr I Lindley
Dr U Loening
Mr P MacFarlane
Mr D MacLeod
Mr H Maguire
Professor A Manning FRSE
Mr A Mansfield
Mrs J Martin
Ms C May MSP
Mr M McIlwrick
Professor J McManus FRSE
Sir Donald Miller FRSE
Professor G Morgan FRSE
Mr W Nicholson
Mr A Pallister

Professor J Paul FRSE
Mr P Phare
Emeritus Professor C I Phillips
Mr R Quartermaine
Ms N Radcliffe MSP
Mr P Roche
Dr G Russell
Mr A Shaw
Mr T Simchak
Professor M Slesser
Mr P Spare
Mr D Speirs
Mr S Stevenson MEP
Mr A Stewart
Mr A Stobart
Mr J Thorogood
Dr P Tothill FRSE
Mrs S L Tremlett
Mr C Wallace
Professor A Wardlaw FRSE
Mr S Watson
Emeritus Professor F Willett FRSE
Mr B Wilson
Mr D L Young

Oral Evidence

1 Aberdeen City Council: Ms Janice Lyon and Mr Roddy Matheson
2 Aberdeen Renewable Energy Group: Mr Iain Todd, Professor Ian Bryden and Professor Paul Mitchell
3 AMEC Group Limited: Mr Alastair Rennie
4 Aquatera: Mr Gareth Davies
5 BP plc: Mr Ray Hall
6 British Energy plc: Mr Robert Armour and Dr Chris Anastasi
7 Burgar Hill wind farm test site: Mr Richard Gauld
8 Comhairle nan Eilean Siar: Cllr Archie Campbell, Mr Angus Campbell, Mr Bill Howat and Mr Derek McKim
9 Conoco Philips European Power Ltd: Mr George Armistead
10 Culham Science Centre (UKAEA): Dr David Ward
11 Department for Environment, Food and Rural Affairs: Mr Bill Stow, Director General for Environment
12 Department of Trade & Industry: Ms Vicky Pryce, and Mr Stephen Green
13 Department of Transport: Professor Frank Kelly, Chief Scientific Advisor
14 European Marine Energy Centre: Mr Andrew Mill and Mr Dave Cousins
15 Findhorn Foundation: Mr Alec Walker
16 Finnish Ministry of the Environment: Mr Markku Nurmi
17 Finnish Ministry of Trade and Industry: Mr Riku Huttunen and Mr Jorma Aurela
18 Finnish Parliament: MP Martin Saarikangas, Professor Martti Tiuri and Dr Paula Tiihonen

19 Forestry Commission: Dr James Pendlebury
20 Foundation for Science and Technology: Dr Dougal Goodman
21 Fraser of Allender Institute: Professor Peter McGregor
22 General Register Office for Scotland: Celia Macintyre, Head of Demography Branch
23 Glasgow City Council: Mr Sandy Gillon, Mr Bill Brown & Ms Fiona Roche
24 Highland Council: Mr Mike Greaves,
25 Highlands and Islands Enterprise: Ms Elaine Hanton
26 Horizon Scotland: Mr David Williams
27 Institute of Energy and the Environment, University of Strathclyde: Professor Jim McDonald, Dr Graeme Burt, Dr Steve Finney, Dr Keith Bell, Mr Colin Foote, Dr Bob Currie, Dr Graham Ault, Dr Andy Cruden, Mr Cameron Johnstone, Dr Gary Connor, Dr Andy Grant, Dr Stephen McArthur and Dr Pawel Niewczas
28 International Centre for Island Technology: Professor Jon Side
29 Lerwick Power Station: Mr Bob Kelman
30 Lewis Wind Power: Mr John Price
31 Macaulay Land Use Research Institute: Mr Steven Radford
32 Mitsui Babcock Energy Ltd: Dr Mike Farley and Dr Glen Little
33 Moorland Without Turbines: Mr Justin Busbridge
34 Mott MacDonald: Mr John Cherrie and Mr Tom Douglas
35 New and Renewable Energy Centre: Professor Ian Fells FRSE
36 Norwegian Academy of Science and Letters: Professor Ole Didrik Laerum, Professor Olav Edholm, Professor Knut Faegri and Professor Magne Espedal
37 OFGEM: Mr Charles Gallagher, Mr David Gray and Mr Colin Sausman
38 Orkney Island Council: Mr James Stockan, Mr Jim Foubister and Mr Jackie Thomson
39 Orkney Renewable Energy Forum: Mr Mike Holdgate and Mr Colin Risbridger
40 Peterhead Power Station: Mr Dave Tweed
41 Pipistrelle Ltd consultancy: Mr Dick Winchester
42 Promoting Unst Renewable Energy: Mr Sandy Macaulay
43 Royal Society for the Protection of Birds: Mr Peter Ellis (Shetland) and Mr Martin Scott (Lewis)
44 Save Cash And Reduce Fuel: Ms Jean Morrison
45 Science and Technology Policy Research Unit, University of Sussex: Professor Gordon MacKerron
46 Scottish and Southern Energy plc: Mr Ian Marchant, Dr Keith Maclean and Mr Iwan Morgan
47 Scottish Coal Company Ltd: Mr Dacre Purchase and Mr William Wishart
48 Scottish Enterprise: Mr Brian Nixon and Mr Simon Puttock
49 Scottish Executive Enterprise and Industrial Affairs Group: Mr Graeme Dickson, Mr Wilson Malone and Mr Richard Bellingham
50 Scottish Executive Environment and Rural Affairs Department: Mr Mike Foulis, Head of Environment Group
51 Scottish Executive Transport Agency: Dr Malcolm Reed
52 Scottish Natural Heritage: Mr John Uttley (Shetland)
53 Scottish Power plc: Mr Ian Russell, Mr Keith Anderson and Ms Angela Love
54 Scottish Renewables Forum: Mr Maf Smith and Mr Grant Thoms
55 Shell: Lord Oxburgh
56 Shetland Development Trust: Mr Neil Grant

57 Shetland Enterprise: Mr David Watson
58 Shetland Heat, Energy and Power Ltd: Mr Neville Martin
59 Shetland Island Council: Mr Aaron Priest, Mr Alistair Cooper and Mr Jim Grant
60 Shetland Renewable Energy Forum: Mr David Thomson
61 Statoil: Hans Konrad Johnsen
62 Stornoway Trust: Mr Iain MacIver
63 Sustainable Development Research Centre: Dr Stephen Tinsley
64 Talisman Energy UK (Ltd): Mr Allan MacAskill
65 Total E&P UK PLC: Mr Martin Tiffen
66 Tyndall Centre for Climate Change Research: Dr Kevin Anderson
67 UK Energy Research Centre: Professor Jim Skea
68 UK Offshore Operators Association: Mr David Odling
69 University of Aberdeen: Professor Alex Kemp
70 University of Oxford: Dr Dieter Helm
71 University of Stirling: Professor Nick Hanley
72 Wavegen: Mr David Gibb
73 Western Isles Development Trust: Cllr Peter Carlin
74 Western Isles Enterprise: Mr Donnie Macaulay

APPENDIX H: REFERENCES AND FURTHER READING

AEA Technology; January 2006; *Scottish Energy Study: Volume 1; Energy in Scotland: Supply & Demand;* Scottish Executive

AEA Technology; January 2006; *Scottish Energy Study: Volume 2; A Changing Picture;* Scottish Executive

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BRE; February 2003; *The UK Potential for Community Heating with Combined Heat and Power;* The Carbon Trust

British Wind Energy Association; April 2006; *Offshore Wind: At a Crossroads*

British Wind Energy Association; March 2006; *Onshore Wind: Powering ahead*

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