WWW.IPPR.ORG

Energy Security in the UK

An ippr FactFile

By Jenny Bird

August 2007

Institute for Public Policy Research
Challenging ideas – Changing policy

Contents

About ippr 3
Acknowledgements 3
About the author 3
About this paper 3
Glossary 4
Executive summary 5

1. Introduction 6

2. Use of fossil fuels in the UK 6
   Oil – keeping the UK moving 6
   Gas – jack of all trades 7
   Coal – keeping the lights on 8
   Summary 10

3. Global context 10
   Oil 10
   Gas 12
   Coal 12
   Summary 12

4. Threats to UK energy security 13
   Import dependency and supply disruption 13
   Power station closures 13
   Price volatility 14
   Peak oil and gas 14
   Transportation and infrastructure 14
   The global context 15
   Summary 15

5. Possible solutions and barriers 15
   Ensure security of supply of fossil fuels with climate change in mind 15
   Alternatives to fossil fuels 17
   Demand reduction 19
   Summary 20

6. Conclusion 20

References 21

Annex I Cumulative global investment in energy infrastructure in the IEA's reference scenario (business as usual) by fuel and activity, 2005–2030 (2005 prices 24
Annex II Approximate conversion factors for weight, volume and calorific content for crude oil, natural gas, liquid natural gas and coal 24

About ippr

The Institute for Public Policy Research (ippr) is the UK's leading progressive think tank, producing cutting-edge research and innovative policy ideas for a just, democratic and sustainable world.

Since 1988, we have been at the forefront of progressive debate and policymaking in the UK. Through our independent research and analysis we define new agendas for change and provide practical solutions to challenges across the full range of public policy issues.

With offices in both London and Newcastle, we ensure our outlook is as broad-based as possible, while our international and migration teams and climate change programme extend our partnerships and influence beyond the UK, giving us a truly world-class reputation for high quality research.

ippr
30-32 Southampton Street, Covent Garden, London WC2E 7RA
Tel: +44 (0)20 7470 6100
info@ippr.org
www.ippr.org
Registered Charity No. 800065

This paper was first published in July 2007.

Acknowledgements

The Institute for Public Policy Research (ippr) is very grateful for the financial support provided to its Low Carbon Britain Post-2010 project by the Greenpeace Environmental Trust, Johnson Matthey Fuel Cells and the Royal Society for the Protection of Birds, and the core funders of the two-year Low Carbon Programme: the Esmee Fairbairn Foundation, Shell International, CE Electric, the Ashden Trust, WWF-UK and E.ON UK. Without their willingness to contribute to our research, this project could not have been undertaken.

The findings of this research are, however, the responsibility of the author alone and do not necessarily represent the views of our funding partners or any other individual or organisation involved in the project.

The author would like to thank Bridget Woodman, Warwick University; Nick Mabey, E3G; John Mitchell and Beverley Darkin, Chatham House; Sonia Brown, Ofgem; Kirsty Hamilton, UKBCSE; Matthew Lockwood, Ian Kearns, Simon Retallack, Georgina Kyriacou and Raquel Alvarez, ippr for their helpful comments, advice and support. Any omissions and errors remain the author's own.

About the author

Jenny Bird is a researcher with the sustainability team at ippr. She is the co-author of ippr's reports on attitudes towards road pricing, *Steering Through Change* (2006) and *Charging Forward* (2006) and is working on the Low-Carbon Britain Post-2010 project.

Prior to joining ippr, Jenny worked for the Environment Agency. She has a Masters degree in Sustainable Development from Forum for the Future.

About this paper

This FactFile comes from ippr's Low Carbon Britain Post-2010 project. It aims solely to review the existing literature on energy security. Our policy recommendations will be published in a separate report later this year.

Glossary

APEC	Asia-Pacific Economic Cooperation
bcm	Billion cubic metres
CCL	Climate Change Levy
CCS	Carbon capture and storage
CHP	Combined heat and power
CNG	Compressed natural gas
CO_2	Carbon dioxide
CTL	Coal to liquid
Developing Asia	Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, China, Chinese Taipei, Fiji, French Polynesia, India, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macau, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Tonga, Vietnam, Vanuatu
EIA	Energy Information Administration
EU ETS	European Union Emissions Trading Scheme
GWh	Giga Watt Hour
IEA	International Energy Agency
LCPD	Large Combustion Plant Directive
LNG	Liquid natural gas
LPG	Liquid petroleum gas
m^3	Cubic metre
mcm	Million cubic metres
NOx	Nitrogen oxide
OECD	Organization for Economic Co-operation and Development
OECD Europe	Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom
OLADE	Organizacion Latinoamericana de Energia
OPEC	Organization of the Petroleum Exporting Countries
Pa	Pascal
RTFO	Renewable Transport Fuel Obligation
SO_2	Sulphur dioxide
UKCS	UK Continental Shelf
UNSD	United Nations Statistics Division

Tables showing the factors for converting the weight, volume and calorific content for oil, gas and coal are contained in Annex II.

Executive summary

The Energy White Paper, published in May 2007, highlighted energy security and mitigating climate change as the two major challenges facing the energy sector in the UK. This FactFile assesses the energy security challenges facing the UK's electricity, transport and heating sectors. It goes on to outline potential solutions, the barriers to their implementation, and their impact on efforts to reduce greenhouse gas emissions.

The issue of energy security is currently receiving a lot of attention in the UK. Dwindling oil and gas reserves in the North Sea and the impending closure of a number of power stations have focused attention on the problem of ensuring the lights do not go out. But energy security is not just about electricity. Transport accounts for almost all of our oil use and a greater proportion of natural gas is used in the domestic and commercial sectors (mainly for heating) than is used to generate electricity. This means that disruption of gas and oil supplies could leave us cold and stationary, as well as in the dark.

The UK is rapidly moving from a position of relative self-sufficiency to one of import-dependence for oil, gas and coal. At present, most of our oil and gas imports are from Norway. In the future Russia, the Caspian region, West and North Africa and the Middle East are likely to become more important sources of imports. Coal is imported from a more diverse range of countries; among these, South Africa and Russia provide the largest amounts.

Although the UK's transition to dependency is perhaps occurring more quickly than in some other countries, the situation is similar across Europer. The story is one of increasing dependence on imported energy. Globally, demand for energy is rising – particularly from India and China – and this leads to questions about whether supply will be able to meet demand in the future. This uncertainty is founded on concerns about achieving the required level of investment, geo-political tensions, and, more fundamentally, on doubts about the accuracy of reporting on the size of reserves.

The UK faces both short-term and longer-term threats to its energy security, which are quite different from one another in nature. The greatest short-term threat is the risk of disruption to gas supplies from mainland Europe. Exposure to Russian gas in particular is viewed as a problem. Oil price volatility may also pose a short-term risk, although the UK's oil use appears to be fairly unresponsive to higher prices at the moment.

In the medium term, the planned closure of a number of coal-fired and nuclear power stations has lead to concerns about how this generating capacity will be replaced. The Government has estimated that this will amount to a 'gap' equivalent to around 30 per cent of today's existing capacity (DTI 2006a). In practice it is likely that new capacity that gets built before 2015 will consist mostly of gas- and coal-fired stations as well as some wind farms, but longer-term plans are less clear.

In the long term the fundamental concerns are about whether supply will be able to meet demand, for the reasons mentioned above. However, proponents of the 'peak oil' analysis suggest that we might reach this point sooner than has previously been expected. This could have particularly serious consequences for climate change. Pressure on oil supplies resulting in high oil prices would make non-conventional sources of oil (such as oil sands, extra-heavy oil, oil shale and coal-to-oil) more economic to produce. Extraction and combustion of all of these non-conventional sources is highly carbon-intensive and so would result in an increased rate of climate change.

Clearly there is no one-size-fits-all solution to these challenges and undoubtedly a mix of policy measures will be required. However, for convenience, it is useful to talk about the potential solutions in terms of three main categories: ensuring security of supply of fossil fuels (but keeping climate change in mind), finding alternative sources of energy and reducing demand for energy.

In the first category, options for the UK are relatively limited but include increasing investment in the UK Continental Shelf to maximise oil and gas production and continuing to push for market liberalisation in Europe. Turning to coal as a cheaper and more secure fuel for electricity generation could increase energy security but would come at the cost of increasing carbon dioxide (CO_2) emissions. Carbon capture and storage may present one way round this problem.

Alternative sources of energy already exist for electricity generation, transport and heating although the technologies are at different stages of development and market penetration. Options for electricity generation include renewables, such as wind, solar, wave and nuclear power. For transport the main alternative in the near term is biofuels, with hydrogen presenting an option in the longer term. For heating, biomass can be used in dedicated heat or combined heat and power plants. Solar heating, geothermal heating and heat pumps are other options.

Measures for energy reduction are also already available. In the electricity sector, one important idea is that of a decentralised system of combined heat and power plants. This would have the dual benefits of more efficient use of fuel (since it is used to produce both electricity and heat) and reduced losses during transmission and distribution. For transport, using more fuel-efficient vehicles, changing our driving habits and reducing the overall amount of transport would all help to cut oil use. Finally, in the heating sector, better insulation and draught-proofing in buildings would help to reduce our use of oil. Clearly, reduced use of fossil fuels through efficiencies and the use of alternatives will also reduce emissions of CO_2.

Whatever the precise mix of measures taken, it is clear that a radical shift is necessary in our energy supply and use. The policy decisions made by government in the coming months and years will set the course for our energy use for decades to come. Investments in new infrastructure will tie us to particular fuels and technologies. The challenge is to set a course that has the vision to meet our long-term objectives and that can achieve both security of supply and security of the climate.

1. Introduction

Energy security is a topic that features frequently in the British headlines. The issue is often portrayed as being about the need to ensure there is enough electricity to 'keep the lights on', but energy security encompasses a much wider set of concerns. A balanced policy response to the challenges of energy security today needs to reflect four strands of debate:

- Security of supply
- Energy and climate security
- Infrastructure protection and system resilience
- Implications of energy choices for foreign policy and defence strategy.

This FactFile has been produced as part of ippr's Low Carbon Britain Post-2010 project and as such focuses mainly on the first two of these strands, but further work on the other two areas will be carried out by ippr's Commission on National Security in the 21st Century[1].

Almost every aspect of our lives depends on fossil fuels: from running electrical appliances, to heating our buildings, to the transport we use to get around. It is clear that the UK is becoming more dependent on imports of fossil fuels as our own reserves in the North Sea decline and this, combined with high gas and oil prices and the looming closure of many power stations, has led commentators to express concern about how we can ensure 'the lights do not go out'. We also face the risk of increasing levels of fuel poverty, which is linked to increased gas prices, and severe disruption to our transport systems, which, at present, are almost entirely dependent on oil.

These are important concerns but they must not be addressed at the expense of global climate security. The use of fossil fuels is under heavy scrutiny amid efforts to mitigate climate change, and the UK Government has set a target of reducing emissions by 60 per cent on 1990 levels by 2050. If this is to be achieved, major cuts in emissions will be required across the power generation, domestic and transport sectors.

This FactFile aims to investigate whether there could be synergies between these two agendas. It analyses just how 'energy-secure' the UK is, and explores how efforts to increase levels of energy security could also contribute to efforts to reduce carbon dioxide emissions and conversely, how increased energy security could lead to increased emissions.

Fossil fuels are at the root of concerns about both energy security and climate change and so in section 2 we begin by looking at how they are currently used in the UK – where they come from, how much is left and what they are used for. In section 3 this is put in the context of what is happening globally, in terms of energy use and production. Section 4 highlights the key energy security concerns for the UK and the final section provides an account of the possible solutions and barriers to increased security and what these might mean for carbon dioxide emissions.

In drawing together the evidence we hope to provide a useful overview of the key issues in the energy security and climate change debates.

2. Use of fossil fuels in the UK

Around 90 per cent of the UK's demand for energy is met from fossil fuels and they are expected to remain the principal source of energy for the foreseeable future (DTI 2006a). Different fuels are used for different purposes. Gas and coal fuel most of our electricity production; heating needs are met mostly by gas, and transportation is run on oil. This section looks at the supply and demand for each fuel in turn, as well as current infrastructure and projections of future use.

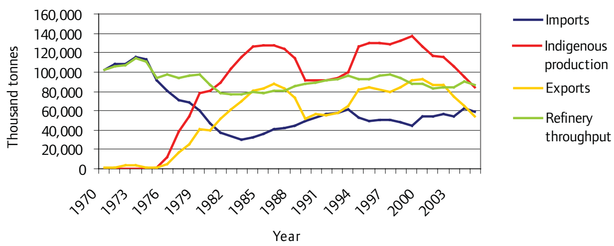
Oil – keeping the UK moving

Oil production and use

Before the 1970s, the UK was dependent on imported oil to meet its needs. In the 1970s however, indigenous production in the North Sea began and by the 1980s the UK was a net exporter of oil. This has – more or less – remained the situation up until the present day, but production from the UK Continental Shelf (UKCS) is now in decline. These trends are depicted in Figure 1.

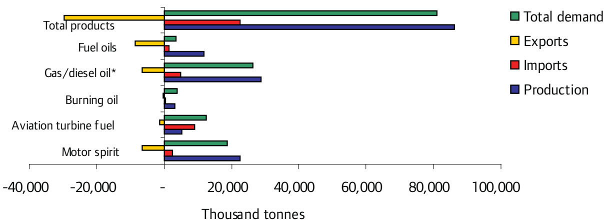
Although the UK is still a net exporter of oil, there is nevertheless a need to import a certain amount of crude oil, one reason being that

Figure 1: UK crude oil trends, 1970-2005



Source: DTI 2007a

Figure 2: Supply and demand of selected petroleum products in the UK, 2005



Source: DTI 2007a

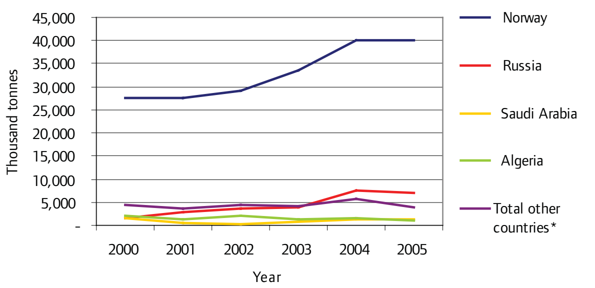
* includes marine diesel oil

1. ippr's Commission on National Security in the 21st Century was launched on 23 May 2007. For more information see www.ippr.org/events/index.asp?id=2718

other crude oils contain a greater proportion of heavier hydrocarbons than North Sea oil, which are needed to manufacture certain petroleum products (DTI 2006b). The UK also has a significant refining capacity, although again some petroleum products must be imported where domestic production is unable to meet demand. The most important example of this is aviation turbine fuel, as depicted in Figure 2 (DTI 2007a). In 2005, imports accounted for 62 per cent of UK consumption of this product (JESS 2006).

Norway is the biggest supplier of oil imports to the UK and accounted for 75 per cent of imports in 2005 (DTI 2006b). Russia, Saudi Arabia and Algeria are also important producers for the UK (See Figure 3). Imports of petroleum products (aviation turbine fuel, motor spirit and gas oil/diesel) came from France, Germany, Kuwait, the Netherlands, Saudi Arabia and the United Arab Emirates in 2004. The UK exported oil products to the USA, Belgium, France, Ireland, the Netherlands and Spain. Of these, most (17 per cent) went to the USA (DTI 2006b).

Figure 3: UK imports of oil by country of origin, 2000-2005



Source: DTI 2006

* Angola, Latvia, Libya, Lithuania, Mexico, Netherlands, Nigeria, Venezuela and other

The vast majority of oil use in the UK is for transport. In 2004, 74 per cent of petroleum products were used for this purpose (DTI 2006b). This reflects the fact that transport in the UK is almost entirely dependent on oil. In 2005, petroleum accounted for 98.8 per cent of energy consumption used for transportation (DfT 2006). This means that this sector is particularly vulnerable to oil supply disruption.

Other uses include domestic (especially for those living in remote areas who are not connected to a gas network or who require back-up generators), industrial and the energy sector. Use of oil to generate electricity has declined over the last few decades as gas has become the fuel of choice for electricity generators. However, there was an increase in oil use in this sector in the winter of 2004, owing to high gas prices (DTI 2006b).

Oil infrastructure

The UK has nine major and three minor oil refineries with a total distillation capacity of 92 million tonnes (DTI 2006b). The refineries supply approximately 50 major oil terminals by pipeline, rail and sea. There is a network of around 3,000 miles of oil pipelines in the UK, around 1,500 miles of which is privately owned. The remainder is used by the Government to supply oil to airfields (UKPIA 2006).

Under EU law, the UK must hold at least 67.5 days' worth of oil stocks in case of emergency. This figure will increase as domestic production falls. In order to comply with this, the Government places an obligation on oil companies to maintain oil stocks (JESS 2006, DTI 2006a).

Future oil production and use

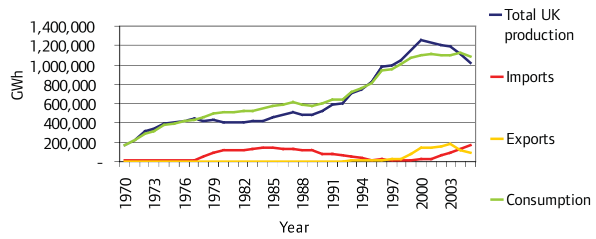
Because of the decline in the production of oil from the UK Continental Shelf since its peak in 1999, the UK will not remain a net exporter of oil for much longer. It is predicted that it will become a net importer by around 2010. Norway is already a key supplier of imported oil to the UK and is likely to remain so in the future, but it is likely that Russia, the Caspian region, West Africa, North Africa and the Middle East will also increase supplies as the UK comes to rely more and more on imports (JESS 2006).

Gas – jack of all trades

Gas production and use

Gas has become a much more important component of the UK's energy mix since the 'dash for gas' in the 1980s and 90s (see Figure 4). Much of this consumption was due to fuel switching in electricity production away from coal and oil. However, gas production from UK North Sea sites peaked in 1999 and is now declining. In 2004, the UK became a net importer of gas (DTI 2005).

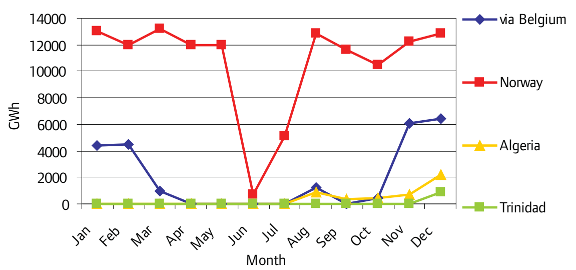
Figure 4: UK production and consumption of natural gas, 1970-2005



Source: DTI 2007a

Figure 5 shows that in 2005, most of the UK's gas imports were from Norwegian North Sea gas fields. A significant proportion was also piped through the UK-Belgium interconnector between Zeebrugge in Belgium and Bacton in Norfolk . This source of gas is particularly important for meeting peak demand during the colder winter months. Smaller amounts came from Algeria and Trinidad and

Figure 5: UK imports of gas by country/inter connector, 2005

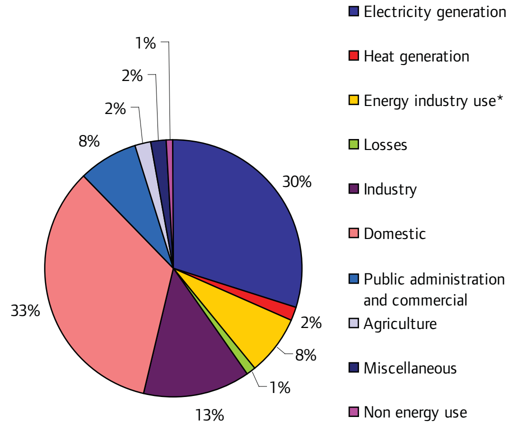


Source: DTI 2007b

Tobago, shipped as liquid natural gas (LNG).

A total of 39 per cent of the UK's electricity is produced in gas-fired stations, but as Figure 6 demonstrates, this only accounts for 30 per cent of the total gas demand (DTI 2007a). The greatest demand is actually from the domestic sector, where gas is used primarily for space and water heating. The fact that the majority of our gas use is for heating has important implications for the debate on security of gas supplies and potential alternatives as this often focuses on electricity generation only. It is estimated that approximately 75 per cent of the UK's heat needs are met by gas delivered through the national grid. Disruption to gas supplies that results in increased gas prices could have important implications, particularly with regard to fuel poverty, where higher costs could increase the number of people who are unable to afford to heat their homes adequately (DTI 2006a).[2]

Figure 6: UK use of natural gas, 2005



Source: DTI 2006c
*excluding electricity generation

Gas infrastructure

There are three major pipelines to import foreign gas into the UK: the Belgian interconnector and new pipelines from the Netherlands and the Norwegian Ormen Lange gas field. This new import capacity could potentially supply 35 per cent of annual UK gas consumption (DTI 2006d). There is currently only one LNG terminal, on the Isle of Grain, north Kent, which has the potential to deliver up to 17 mcm per day (approximately 4 per cent of the averaged national supply) (DTI 2006d). However, three more are under construction, two in Milford Haven, South Wales and one on Teeside; several others have been proposed and are awaiting planning decisions (Ofgem 2006a, JESS 2006).

The UK currently has about 4300 mcm of gas storage capacity (DTI 2006d). A new gas storage facility was recently completed in Hampshire, which has a capacity of 315 mcm. Two more are under development and at least four more are proposed, subject to planning (Ofgem 2006a, JESS 2006).

Future gas production and use

The UK will become more dependent on imports to meet its gas demand in the future. In its Energy Review, the Department of Trade and Industry (DTI) projected that up to 80-90 per cent of the UK's gas would be imported by 2020. Most of this is expected to continue to come from Norway along with LNG from Algeria and Qatar. In the long term, Russia, the Caspian Sea region and Nigeria are also likely to become important providers of gas to the UK (DTI 2006a).

Reliance on Norway

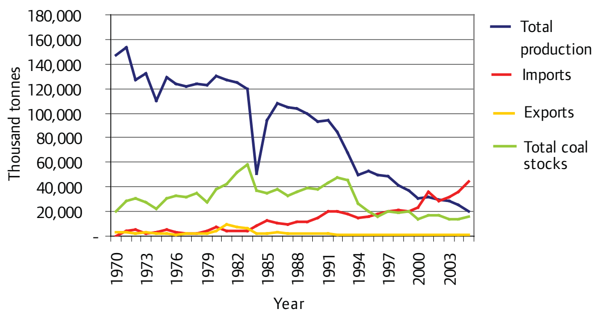
As we have seen, most of the UK's oil and gas imports come from Norway. It is expected that Norwegian gas and oil will continue to meet the UK's fossil fuel needs in the immediate future, as UK production decreases. Projections from the Norwegian Petroleum Directorate anticipate a total of 4.7 billion m^3 oil equivalent to be produced from Norwegian fields over the next 20 years. Oil production is expected to peak in 2008, but gas sales are predicted to rise to around 120 billion m^3 per year in 2011 (Norwegian Petroleum Directorate 2005).

Coal – keeping the lights on

The amount of coal mined in the UK has steadily declined since the 1970s (with a sharp drop in production in 1984 due to industrial action). Figure 7 (below) shows the trends in production and consumption of coal over the last few decades.

Despite having relatively large reserves of coal, the UK is a net importer; more than 70 per cent of demand was met by imports in 2005 (JESS 2006). The reasons for this are primarily economic; most UK reserves are either low-quality or occur in narrow seams that are expensive to produce. Estimations of UK coal reserves for existing mines show 70 million tonnes remaining in deep mines by 2020 and reserves in surface mines being depleted between 2010 and 2020. Around another 400 million tonnes of recoverable coal is thought to exist in the UK, but this would require new mines to be built or significant investment in existing mines (DTI 2006a). To put these figures in context, total inland coal consumption of coal in the UK in 2005 was 61.9 thousand tonnes (DTI 2007a). However, it is worth reiterating that the figures for the estimated remaining coal reserves are price-dependent.

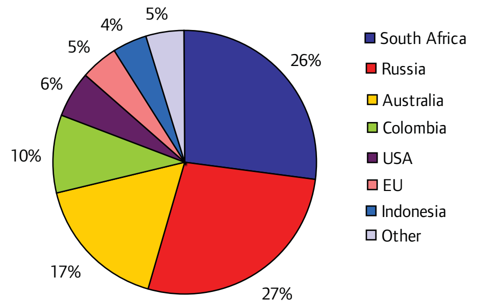
Figure 7: UK production and consumption of coal



Source: DTI 2007a

2. According to the UK Government's definition, a household is said to be in fuel poverty if it needs to spend more than 10 per cent of its income on fuel to maintain a satisfactory heating regime (usually 21 degrees for the main living area, and 18 degrees for other occupied rooms) (DTI 2007c).

Figure 8: UK imports of coal and other solid fuel by country of origin, 2004

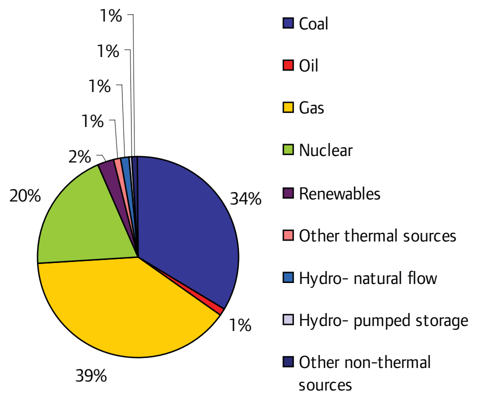


Source: DTI 2005

In 2004, coal was imported from a diverse mix of countries, with the largest proportions coming from Russia and South Africa (depicted in Figure 8).

Most of the coal used in the UK is for electricity generation. In 2004, 83 per cent of coal consumption was for this purpose (DTI 2005). Around a third of the UK's electricity generation is fuelled by coal and only gas contributes a greater proportion (Figure 9). However, coal is significant as a reserve option – during the winter of 2005-06 when gas prices were high, coal's contribution to electricity generation rose to 42 per cent of the national total (JESS 2006).

Figure 9: Fuel used in electricity generation, on an output basis, 2005



Source: DTI 2006e

Note: electricity supplied (gross) figures used. Gas is turned into electricity more efficiently than coal and therefore contributes to a greater proportion of electricity output even though in absolute terms the amount of coal used is greater than that of gas.

Coal infrastructure

There are currently six major deep mines in production and 35 open cast mines. Two deep mines have recently been mothballed.

The UK has 18 coal-fired power plants, including Drax, Yorkshire, the biggest coal-fired station in Europe. Six of these power stations have 'opted out' under the EU's Large Combustion Plant Directive (LCPD), which means they must close either by the end of 2015 or after 20,000 hours of operation, whichever is sooner (JESS 2006).

Coal-fired replacements are being considered for three of the stations due for closure. These would use clean-coal technology to meet sulphur dioxide (SO_2) and Nitrogen oxide (NOx) emission requirements, and two would have 'carbon capture and storage' (CCS) capability (JESS 2006). The third station, at Kingsnorth in Kent, will have the option of adding a 'bolt on' CCS unit at a later date. Whether this occurs or not will be greatly influenced by the price of carbon under the European Union Emissions Trading Scheme (EU ETS) (Ofgem 2007).

Future coal production and use

Projections suggest that coal production could be between 21 and 29 million tonnes in 2010 and 15 and 21 million tonnes in 2016 (Mott MacDonald 2004). The main constraint on UK production is obtaining planning permission for new sites, particularly for open cast mines.

UK production at these rates will not be sufficient to meet predicted use. Projected demand from electricity generators lies between 30 and 56 million tonnes in 2012 and 12 and 50 million tonnes in 2016. The large ranges reflect significant uncertainties around the price of carbon, gas prices, decisions around the retirement of nuclear power stations and the rate of expansion of renewable energy sources. The main drivers for reducing the use of coal in power stations are the price of coal under the EU ETS, the levels of contribution from nuclear and renewable electricity sources and the implementation of pollution control directives (Mott MacDonald 2004).

Energy prices

Wholesale energy prices are influenced heavily by international events. For example, the 1970s oil shocks (driven by action taken by OPEC to increase oil prices following the Yom Kippur war in 1973 and in the wake of the Iranian revolution in 1979), the first Gulf War and most recently, Hurricane Katrina, have all resulted in peaks in the price of crude oil. Global oil prices have been rising over the last few years and recently broke the US$70 per barrel threshold (BBC 2007). Analysts attribute this to continuing tensions between the US and Iran, lower than average stockpiles in the US and tensions in Nigeria. Gas prices are often linked to oil prices (since many long-term gas contracts are fixed to the price of oil) and so follow similar trends. This has been the case in Europe and the resulting increases in gas prices since late 2000 have translated into rising wholesale gas prices in the UK.

The sharp rise in wholesale gas prices in the UK in the winter of 2005/06 was due to a number of factors, including a shortage of supply and cold weather. The result was a 10.8 per cent increase in the use of coal to generate electricity (DTI 2007d).

Wholesale prices are an important influence on domestic energy prices in the UK although other factors have also played a role in the trends seen over the last few decades. Gas prices fell during the late 1990s as competition in domestic electricity and gas supply was introduced. However, prices have been rising since 2001, as wholesale prices have increased. Electricity prices have followed a similar trend, falling during the 1990s and early 2000s as competition was introduced, Ofgem set price controls, VAT was reduced and the New Electricity Trading Arrangements were introduced. Electricity prices have risen again since 2003, driven by wholesale prices (DTI 2007d).

Domestic gas prices rose by 18 per cent between 2003 and 2005 and electricity prices increased by 13 per cent. Industrial gas prices rose by 57 per cent and electricity prices by 36 per cent over the same period (DTI 2006f). While many consumers have been able to afford these price increases, the number of people living in 'fuel poverty' has risen. Estimations for England show an additional one million people living in fuel poverty in 2006 compared to 2004 (Fuel Poverty Advisory Group 2007).

Heating oil prices have tended to follow crude oil prices. This has also been true in the past for diesel and petrol prices – for example, the price peaks seen as a result of the oil shocks in the 1970s and the first Gulf War in 1991 – but during the 1990s the gradual increases in diesel and petrol prices in the UK were mainly attributable to increasing levels of duty. In 2001 prices fell in real terms, before beginning to rise again in 2003.

Summary

- Fossil fuel uses vary according to type. Oil is used mainly for transport, coal for electricity generation and gas for a mixture of heating and electricity production.
- The UK is a net importer of coal and gas and is likely to become a net importer of oil by around 2010.
- Norway provides most of the UK's gas and oil imports and is likely to remain a key supplier in the future. Coal is imported from a more varied range of countries but Russia and South Africa together account for over half of the UK's imports.
- Gas and oil use remain sensitive to price increases. Coal prices have risen less sharply than oil and gas and its future use is more likely to be constrained by restrictions on emissions on CO_2 such as a high carbon price under the EU ETS.

3. Global context

As the UK becomes increasingly dependent on imports of fossil fuels, it is important to consider the global context in which this is occurring. This section looks at trends of energy use and production around the world and describes where demand for and supply of different fuels is likely to come from in the future.

Oil

Demand

Global primary consumption of oil in 2005 was approximately 84 million barrels per day (IEA 2006). The greatest demand (of 20.6 million barrels per day) was from the USA, followed by Developing Asia and OECD Europe who used 14.6 and 14.4 million barrels per day respectively (IEA 2006).

Forecasts expect demand to continue to grow; the International Energy Agency (IEA)'s 2006 World Energy Outlook projects that under a business-as-usual scenario we will require 116 million barrels per day globally in 2030 (although others have produced lower estimates than this; see, for example, Drollas 2006). Demand in all regions will increase, but the greatest rise will be from developing countries and in particular from China (IEA 2006).

Uses of oil are mixed. Unlike the UK and Europe, where most of the oil consumed is in fuel transportation, uses of oil across the world are much more varied and include residential, commercial and industrial uses as well as power generation (Mitchell 2006).

Oil reserves are concentrated in only a few locations around the world which means that most countries are dependent on imports for their oil supply. In absolute terms, the USA imports the most oil (Table 1). However, since that country also produces a substantial amount of oil, it is not the most dependent on oil imports. Table 1 shows the world's top 10 oil-importing countries and the extent to which they are dependent on these imports to meet their needs. As a region, OECD Europe is the second most dependent in the world with imports accounting for over half of the oil consumed in 2004. This dependency is predicted to increase sharply to 80 per cent by 2030 (IEA 2006)

Supply

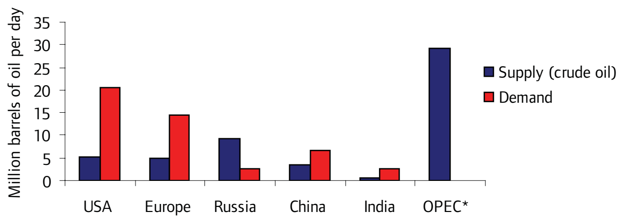
Countries that belong to OPEC (Organization of the Petroleum Exporting Countries) produce just under half of the world's crude oil. Of member countries, the largest producer is Saudi Arabia, which in 2005 produced more than double the amount of crude oil than the next largest producer, Iran (OPEC 2006, IEA 2006). Outside OPEC, Russia is the largest producer and in 2005 supplied roughly the same amount of crude oil as Saudi Arabia. Global production of crude oil in 2005 was approximately 71–72 million barrels per day (IEA 2006, OPEC 2006). If natural gas liquids and non-conventional

Table 1: Top 10 oil importing countries in 2005

	2005 oil imports (million bbl/day)	2005 oil consumption (million bbl/day)	Import dependency as percentage of consumption
USA	13.5	20.7	65%
Japan	5.2	5.4	97%
PR China	3.4	7.3	47%
Germany	2.6	2.6	100%
South Korea	2.3	2.3	100%
France	1.9	2.0	97%
Italy	1.8	1.8	100%
India	1.7	2.5	68%
Spain	1.6	1.6	99%
The Netherlands	1.1	1.1	100%

Sources: World Coal Institute 2006, BP 2006

Figure 10: Primary oil demand and crude oil supply, 2005



Source: IEA 2006

*Figures for demand not available

sources of oil are also included, the total oil supply in 2005 was around 84 million barrels per day (IEA 2006).

Some of the major producers are also major consumers of oil which means they do not necessarily export as much oil as they produce (Figure 10). In absolute volumes, the Middle East is the region with the greatest exports of crude oil – around 17 million barrels per day in 2005. In contrast, North America had one of the lowest export rates at just 1.7 million barrels per day.

In the same way that some countries are heavily dependent on oil imports to meet their demand, many exporting countries are also dependent on the oil trade. For example, in 2003, 98 per cent of Algeria's imports and services were paid for by petroleum exports. Export dependence is much higher for OPEC countries than non-OPEC countries (Mitchell 2005).

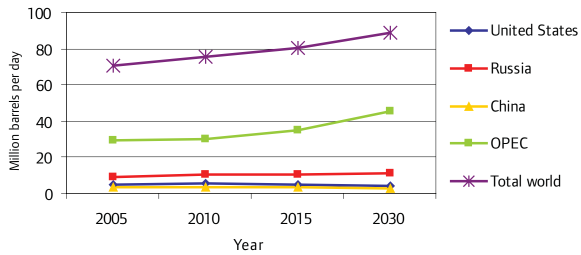
As we have seen, current rates of production are sufficient to meet demand. However, an important question is whether there is capacity to increase production of oil to meet the increase in demand that is expected to occur over the coming decades. This depends on two factors: how much remaining oil there is underground and the capacity of oil companies to increase the rate of extraction.

The IEA estimates that $4.3 trillion (2005 prices) will need to be invested by the oil industry between 2005 and 2030 in order to meet demand. It is not clear whether this level of investment will be achieved, particularly because of restrictions on foreign investments made by countries that exercise state control over oil reserves. Tensions in the Middle East may also discourage investment by private companies (IEA 2006). A more detailed breakdown of projected investment costs across all sectors is given in Annex I.

Uncertainties also exist over the extent of global reserves. Most publicly available sources of information on oil reserves describe a healthy level of supplies remaining to be exploited. OPEC, the IEA and the Energy Information Administration (EIA) report between 1082 and 1293 billion barrels worth of oil reserves remaining in 2005 (OPEC 2006, IEA 2006, EIA 2006). According to the IEA, this is enough to last for 42 years at current consumption levels (IEA 2006). This had led these organisations to predict that oil supply will continue to grow over the next few decades, as depicted in Figure 11.

However, some critics claim that these estimates of reserves are

Figure 11: Conventional crude oil supply, 2005-2030*, business as usual scenario



Source: IEA 2006

*These projections are broadly commensurate with IEA proven reserves

not reliable. This is because there has been a tendency for national oil companies to overestimate, largely because of the decision by OPEC to award quotas according to the size of national reserves (EREC and Greenpeace 2007, Leggett 2005).

Some commentators argue that a more reliable way to predict reserves is to take historical data on oil field discoveries as a basis. Generally speaking, the production of oil from any field follows a roughly bell-shaped distribution. This is because although the initial rate of production is high, it becomes progressively more difficult and expensive to extract oil the more depleted a field becomes. M. King Hubbert was the first person to predict that the oil production of entire countries would follow a similar bell-shaped curve and based on his knowledge of oil field discoveries, was able to accurately predict in 1956 that the USA's oil production would peak in 1971; it actually peaked in 1970 (Leggett 2005).

The 'peak oil' analysis applies this technique to global oil reserves. Data on global discoveries of new oil fields shows that a peak occurred in 1965. Since then, the number of new fields being discovered and the size of new oil field discoveries have been steadily decreasing. Projecting the size of new discoveries based on this historic trend leads advocates of the peak oil argument to conclude that oil production will not continue to increase indefinitely, as predicted by organisations such as the IEA (Figure 11, above), but that it is likely that global oil production will peak some time within the next 10 years (Leggett 2007). Based on this analysis, the Association for the Study of Peak Oil (ASPO) has calculated the global ultimate recoverable reserves to be 1,850 billion barrels. For comparison, The US Geological Survey calculated global ultimate recoverable reserves of between 2,248 and 3,896 billion barrels (Leggett 2005).

This raises an important question about whether supply will be able to meet demand, as we shall see in section 4.

Gas

Demand

In 2004, total global consumption of natural gas was 2,784 billion cubic metres, with the greatest demand coming from the USA and OECD Europe, which consumed 626 and 534 billion cubic metres respectively.

In the IEA reference (business-as-usual) scenario, natural gas demand grows to 4,663 billion cubic metres per year by 2030. Demand for gas grows fastest in Africa, the Middle East and developing Asia, especially China (IEA 2006).

Although OECD Europe's gas consumption is not predicted to grow as quickly as other regions, falling levels of production within the region mean that to sustain levels of consumption, it will become more dependent on imports. Imports are predicted to rise from 40 per cent of inland consumption in 2004 to 63 per cent in 2030 (IEA 2006).

Europe currently receives most of its gas supplies from Russia (127 bcm in 2004). However, it is uncertain whether Russia has the capacity to meet Europe's increasing levels of demand and whether it will be able to raise production levels sufficiently. The IEA predicts that the biggest supplier of gas to Europe in 2030 will be Africa, followed by Russia and the Middle East, with additional LNG supplies from Latin America (IEA 2006).

Supply

The region that exported the most gas in 2005 was the Middle East (exporting around 17 million barrels per day). Eastern Europe, Africa and Latin America were also significant suppliers, exporting 7.5, 6.5 and 5.6 million barrels per day respectively (OPEC 2006). Gas markets are currently constrained to a great extent by the ability to transport gas from producer to customer. For this reason, they have tended to operate on a regional basis via gas pipelines in the past. This picture is changing slowly as more gas is shipped in the form of LNG. Imports of LNG to the USA are expected to grow the most in the next few years (IEA 2006).

Over half of the world's gas reserves are located in just three countries: Russia, Iran and Qatar (IEA 2006). The IEA states that proven reserves at the end of 2005 were around 180 trillion cubic metres, enough to last for 40 years under the IEA's 'business-as-usual' growth scenario (IEA 2006, OPEC 2006).

The IEA forecasts that investment of $3.9 trillion will be needed between 2005 and 2030 in order for gas demand to be met. It is not at all clear whether this will be achieved, particularly because of the situation in the Middle East. There are also questions over whether the Russian state-controlled energy company Gazprom will invest sufficient money in Russian gas infrastructure (IEA 2006).

Coal

Coal consumption

In 2004, the two major consumers of coal were China (1,881 million tonnes) and the USA (1,006). Total global consumption was 5,558 million tonnes.

The IEA projects that coal demand will increase to 8,858 million tonnes in 2030. Forecasts have been revised upwards in recent years because of the increase in gas prices, making coal more competitive, particularly for power generation (IEA 2006). Most of the increase in demand will come from China and India, both of which have abundant supplies of coal. Demand is predicted to fall in Europe, the price of carbon established through the EU ETS playing a role in its demise.

The USA has large reserves but is still heavily reliant on imports because much of its own coal is more expensive to extract. For this reason, the USA is expected to become a net importer of coal between 2015 and 2030. OECD Europe is already a net importer of coal and will be the largest global importer of hard coal[3] in 2030. This is in spite of the prediction that coal use in Europe is set to decline and production rates are set to fall even faster (IEA 2006).

Unlike oil and gas, where a country's status as an importer or exporter is mostly determined by its endowment of reserves, the coal market is driven much more by economic factors. The costs of producing coal depend on a number of factors such as geology, technology, infrastructure and labour costs (IEA 2006).

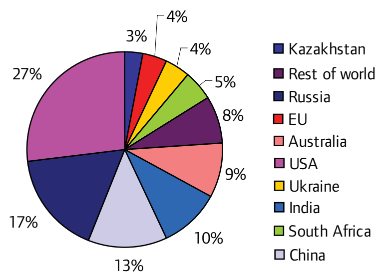
Coal production

Total global production of coal in 2004 was equivalent to 5,559 million tonnes. This is expected to rise to 8,858 million tonnes by 2030 (IEA 2006).

Proven reserves of coal are estimated to be 909 billion tonnes, which is equivalent to 164 years at the current production rate (BP Statistical review of world energy 2006 cited in IEA 2006).

Coal reserves are more evenly distributed globally than oil and gas fields, but China, the USA, India, Russia, Australia and South Africa between them account for over 80 per cent of the reserves; see Figure 12 (IEA 2006).

Figure 12: Global coal reserves by country, 2005



Source: IEA 2006

The IEA estimates that a total of $563 billion of investment will be needed by 2030 under a business-as-usual scenario.

Summary

- Under a business-as-usual scenario, Europe will become increasingly dependent on energy imports. By 2030, Europe will be the world's biggest importer of coal and will rely on imports to meet 80 per cent of its oil needs and 63 per cent of gas demand.
- OPEC countries account for around half of the world's oil and gas exports. OPEC members' economies are generally more dependent on these exports than those of non-OPEC exporters.

3. Hard coal is a primary coal from which other fuels, such as coking coal and steam coal, are derived.

- Challenges for future oil supplies include a lack of investment opportunities for private oil companies, geopolitical tensions in the Middle East and uncertainty about the size of remaining reserves, with some commentators warning that global oil production will peak in the next decade.

4. Threats to UK energy security

The issue of energy security has become much more prominent in the UK over the past two years. This has been driven by a number of factors including high oil and gas prices, international events involving Russia and the Ukraine and pressing decisions about power stations that are coming to the end of their lifetimes.

Despite this, energy security is difficult to define; there is no single metric to measure the level of security of the UK's energy supply or the level of public good it delivers. This makes it difficult to compare with other policy objectives (Mabey 2006). The Government's Joint Energy Security of Supply Working Group uses a set of indicators of security of supply based on supply and demand forecasts and market signals (forward prices). The indicators do not include factors such as diversity of supply, import dependency as a proportion of consumption or likelihood of interruption of supply of imported fuels (JESS 2006). Woodman and Mitchell (2006: 2) set out five elements that contribute to energy security:

- A secure fuel supply from diverse sources
- Sufficient generation to compensate for unforeseen plant closures
- Diverse means of generation
- Reliable energy infrastructures
- Flexibility in use (to reduce demand if necessary or use an alternative form of energy)

This section outlines the most widely-perceived threats to domestic energy supply. However, it should be noted that the risks are rooted in different causes and are therefore difficult to compare in terms of the likelihood of occurring.

Import dependency and supply disruption

It is clear that the UK is becoming increasingly dependent on imports of fossil fuels to meet its energy needs. It is already a net importer of coal and gas and will become a net importer of oil within the next few years. This shift away from a position of relative self-sufficiency towards one of import-dependency has focused attention on the issue of energy security for the UK.

The UK receives most of its gas imports from Norway and disruption to this supply is unlikely. As Figure 5 showed, however, a significant proportion of the UK's gas comes via the Belgium interconnector. The UK relies on this route to import gas from mainland Europe to meet demand at peak times such as during particularly cold weather in winter. This means there is a risk of short-term supply disruption if this gas is not received.

The situation was highlighted in the winter of 2005/06 when gas supply from Europe was not sufficient to meet peak demand. This scarcity pushed up gas prices and the result was that electricity-generating companies switched to the cheaper option of coal to prevent power cuts (DTI 2006d). Domestic gas customers also felt the squeeze; the high prices are estimated to have led to an additional one million people living in fuel poverty in 2006 compared to 2004 (DTI 2006f, Fuel Poverty Advisory Group 2007).

There are a number of theories as to why the supply did not arrive, ranging from a shortage of gas owing to a cold winter in mainland Europe and problems arising from the current network of interconnectors, which meant it was difficult to move the gas around the grid from areas where it was plentiful to make up scarce supplies in the UK. Another explanation points to the role of public service obligations in some European countries, which prevented the release of gas from storage facilities that could have made up the shortfall. Most extreme of all, some commentators suggest that market abuse could have taken place. The failure of gas to be supplied to the UK despite gas prices being higher than in the rest of Europe highlights the fact that gas markets in Europe are not responding to price signals as they would if they were fully liberalised.

Elsewhere in Europe, energy security was hitting the headlines as, during a dispute over gas prices, Russia temporarily turned off its supply of gas to the Ukraine and to Belarus a year later. Recognising that the UK is at the end of the pipeline, this led some commentators to claim that the UK's exposure to Russia as a gas supplier remains the greatest short-term threat to gas supplies.

Oil supplies are similarly subject to the same kinds of geopolitical pressures. Once again, the UK is most dependent on Norway for its imports, hence is unlikely to face any unexpected shortage of physical supply. In terms of global oil supplies, potential confrontation and sanctions in Iran over its continued use of uranium enrichment facilities and the 2007 elections in Nigeria could slow production in these countries. Equally, the renationalisation of Venezuela's oil companies could mean less access for foreign investment and therefore reduced production rates (Mitchell 2006). Threats to pipelines in the Middle East could also disrupt supply. While this would not affect the physical supply of oil to the UK – since very little oil is imported from these countries – it could affect the UK's oil supply indirectly, through increased oil prices. This is discussed in more depth below.

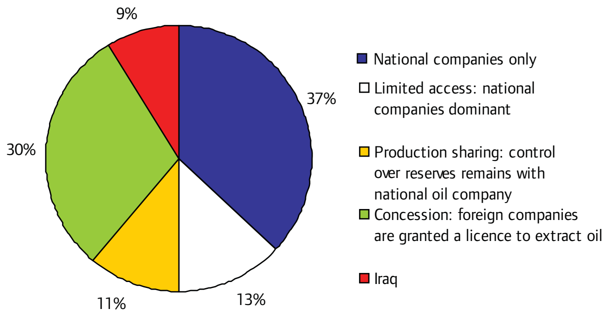
It is difficult to predict where the UK's future oil supplies will come from as this will depend on the market. However, it is likely that imports from Russia, the Caspian Sea region, West Africa, North Africa and the Middle East will increase (JESS 2006). Oil production in Norway is forecast to peak in 2008 (Norwegian Petroleum Directorate 2005).

Opportunities for UK companies to invest in new projects are limited because access to most of the world's oil reserves is restricted to state-owned oil companies, as shown in Figure 13 (IEA 2006).

Power station closures

Several UK electricity power plants are scheduled for closure during the next few years. A total of eight nuclear power stations will come to the end of their lifetimes during the next 10 years. Of the remaining stations, the last – Sizewell B – is due for closure in 2035

Figure 13: Access to world proven oil reserves, end of 2005



Source: IEA 2006

(JESS 2006). Six coal-fired power stations, which between them have a capacity of 8GW, will also close under the Large Combustion Plant Directive by 2015 at the latest.

Much of the energy security debate in the UK has focused on how to fill the resulting gap in electricity generation created by these closures. The Environmental Audit Committee reports that between 15 and 20GW of electricity generation capacity will be closed by 2016 and the Government's Energy Review in 2006 estimated that the UK is likely to need around 25GW of new electricity generation capacity by 2025, around 30 per cent of today's existing capacity (DTI 2006a). Others have argued that the gap could be closed by employing greater energy efficiency measures in order to reduce demand (ippr 2006).

In practice the short-term gap (that is, up to 2015) is very likely to be filled by a combination of new gas and coal stations as well as some renewable energy, mainly wind (JESS 2006). The nature of generating plant in the longer term, however, is much less clear.

Price volatility

As demand for oil has grown the surplus capacity (oil that is ready for market but not extracted due to lack of demand) in OPEC countries has fallen. Historically, this surplus has buffered oil prices from changes in demand for oil, but without it, oil prices are now subject to much greater uncertainty. Developed importing countries such as the UK are able to absorb a certain amount of volatility without a great deal of impact to government revenue or expenditure. However, large shocks could be potentially damaging. The impact of price volatility tends to be felt most by governments of major exporting countries, whose economies are heavily affected by changes in oil prices (Mitchell 2006).

In the short term, the UK's oil use is fairly inelastic. There has not been a reduction in oil consumption in recent years, despite higher prices.

Gas prices are often tied to oil prices because many medium- and long-term purchase contracts for gas are linked to oil prices. However, there is some room for flexibility in the use of gas. For example, during the winter of 2005/06, higher gas prices resulted in reduced demand for gas from the power generation sector. This was achieved through fuel switching, mostly to coal. Some energy-intensive companies also reduced production (DTI 2006d).

Peak oil and gas

The UK is becoming increasingly dependent on imports of fossil fuels, at a time when global demand continues to rise, largely as a result of new and rapidly growing demand from countries such as China and India.

It is difficult to predict precisely where future energy supplies will come from as this will be dependent to a large extent on the market. It is likely that oil supplies will continue to be imported mainly from Norway. However, imports from Russia, the Caspian Sea region, West Africa, North Africa and the Middle East are also likely to increase. Gas supplies will be reliant on the same countries, including LNG imports from Algeria and Qatar (DTI 2006b). As part of the drive to diversify gas supplies to the UK, there has been recent investment in LNG terminals in Teesside and Milford Haven (ICE 2006). Some commentators argue that the UK is likely to face intense international competition – in particular from the USA – for LNG resources (RES 2006:2).

As we saw in section 2, international oil companies as well as organisations such as the IEA predict that fossil fuel reserves are sufficient to meet projected growth in demand. However, some commentators argue that the information on global oil and gas reserves is not reliable and that total recoverable resources are likely to be much less than conventional reporting shows.

Proponents of the 'peak oil' analysis claim that the result could be a sharp spike in the price of oil, which could have drastic consequences if economies that are heavily dependent on oil are unable to adjust quickly enough. In particular for the UK, there is concern about what this would mean for transport as nearly all forms of transport are currently dependent on petroleum products. Others claim that a more likely outcome is a price 'plateau', as demand drops in response to high prices and other sources of oil, previously considered too expensive, become economic to extract. This raises an important concern about climate change because, as we shall see in the next section, production of non-conventional sources of oil (such as oil sands, extra-heavy oil and oil shale and coal-to-oil) tends to result in much greater emissions of CO_2 than crude oil.

Transport and infrastructure

Potential damage to the fuel transport network, generating capacity and distribution network could disrupt the UK energy supply. Threats include: the risk of accidental damage, such as the fire at Buncefield oil, petrol and kerosene storage depot in 2005; severe weather incidents, such as the disruption to oil production and refining caused in New Orleans by Hurricane Katrina in 2005 and the resulting increases in oil prices; and sabotage and terrorist attacks, for example sabotage of Iraqi oil fields and protests in Nigeria (FCO nd).

Little information is available on the level of risk associated with each of these types of damage. Once again, as most UK oil and gas imports come from Norway, one might assume that the probability of such an event directly disrupting the UK's imports would seem low. However, the Government argues that the UK does have a strategic interest in protecting global resources, for example protecting the interests of British oil companies or the protection of oil infrastructure in Iraq.

The global context

This section has focused on threats to the UK's energy supply but it would be wrong not to acknowledge the wider global context. Energy security is clearly not a concern that stops at the shores of the UK and our growing dependency on imported fuels highlights this fact. However, the issue of energy security goes beyond direct threats to our own energy supply. As a part of the global economy, the UK is also susceptible to disruptions to global energy markets as they could have a major impact on the global economy and therefore be felt indirectly by the UK.

Although this aspect of the energy security debate is an extremely important one, it is beyond the scope of this paper to go into more detail here.

Summary

- The UK is becoming more dependent on imports of fossil fuels. Already a net importer of coal and gas, the UK will soon also be a net importer of oil.
- In the short term, imports of gas from mainland Europe present a risk of supply disruption. Exposure to Russian gas in particular is considered a problem.
- In the longer term, there are concerns that Europe might be over-reliant on Russian gas and that a lack of investment could mean that Russia is not able to meet future demand.
- Planned closure of nuclear and coal electricity-generating plant over the next decade has heightened concerns about 'keeping the lights on' and raised questions about how this capacity will be replaced.
- Loss of surplus oil production capacity worldwide has resulted in a much greater uncertainty for oil prices. In most cases, gas prices are tied to oil prices through long-term contracts.
- An early 'peak' in global production of oil could jeopardise climate security if production of non-conventional oils becomes an economically feasible option.

5. Possible solutions and barriers

This section outlines some of the ways in which energy security could be improved and highlights barriers to change. It begins by identifying ways to secure supply of fossil fuels, before looking at options to reduce their use, through alternative fuels and demand reduction.

Ensure security of supply of fossil fuels with climate change in mind

Transparency

The Government has identified data transparency as a key barrier to effective energy markets. It will continue to support the Joint Oil Data Initiative in an effort to improve this (DTI 2006a). The Joint Oil Data Initiative is a collaboration between six international organisations (Asia-Pacific Economic Cooperation [APEC], EUROSTAT, IEA/OECD, Organizacion Latinoamericana de Energia [OLADE], OPEC and the United Nationals Statistics Division [UNSD]) to improve the transparency of oil data.

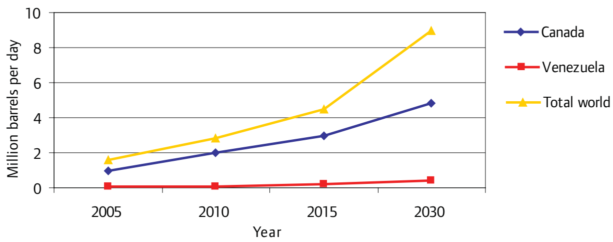
Oil

As we have seen, future production of crude oil is likely to depend on a number of factors: physical capacity to extract and refine oil, geopolitical tensions and the absolute volume of remaining oil reserves.

According to the International Energy Agency (IEA), most oil companies currently make investment decisions based on an assumed price of crude oil of $25–$35 per barrel (IEA 2006) despite prices rising to over $50 a barrel in recent years.

Rising oil prices will mean that new sources of oil, which have previously been considered too expensive to exploit, become economic. This includes sources in arctic regions and ultra-deep water. Non-conventional sources of oil, including oil sands, extra-heavy oil and oil shale, would also become more attractive. In its reference (business-as-usual) scenario, the IEA predicts that global production of non-conventional oil will grow by 7.2 per cent between 2005 and 2030, with the majority of production coming from Canadian oil-sands (Figure 14). For comparison, total oil supply is forecast to grow by 1.3 per cent over the same period to 116.3 million barrels per day. However, this projection is based on the assumption that 'no financial penalty for carbon dioxide emissions is introduced' (IEA 2006: 99). This assumption is key because production of oil from oil sands is highly carbon intensive – extracting one barrel of bitumen in Canada uses on average about 30 m^3 of natural gas (0.19 barrels oil equivalent) (IEA 2006).

Figure 14: Supply of non-conventional oil, 2005-2030, business as usual scenario



Source: IEA 2006

Another alternative to crude oil is to produce liquid fuels from coal and gas. Gas supply is subject to many of the same restrictions that apply to oil supply, namely that reserves are concentrated in just a small number of locations around the world, and transporting them is not straightforward. However, coal is much more abundant and widely distributed and therefore could present an attractive alternative to imported oil.

The capital costs of coal to liquid (CTL) plants are very high and plants need to be situated near to a reliable supply of low-cost coal; they are therefore most attractive to countries with large coal reserves and high oil demand. However, like non-conventional oils, the use of CTL to produce petroleum products has a significant impact in terms of CO_2 emissions. Compared with conventional oil refineries, CTL processes without carbon capture and storage can result in seven to ten times more CO_2 emissions (IEA 2006).

Economic factors remain a major barrier to the growth of CTL. These include volatility of and uncertainty about oil prices as well as the high capital costs of building CTL plants. However, some countries have already established a CTL industry. One example is South Africa, which established CTL plants as a result of sanctions in the 1970s and 80s; around 30 per cent of domestic petrol and diesel demand is produced from indigenous coal. A number of other CTL projects are underway around the world. China, the USA and Australia are currently leading in this regard (World Coal Institute 2006). Estimates show that a long-term oil price of around $50 per barrel would make oil from coal competitive. Without carbon pricing, higher oil prices would lead to a significant increase in the use of these fuels (Anderson 2007).

Gas

While oil price volatility remains the biggest risk in terms of oil security for the UK, for gas supplies, the greatest risk is associated with short-term disruptions to supply of imported gas, as discussed in section 4.

The UK has liberalised its energy markets and, compared to the rest of Europe, has enjoyed cheaper electricity and gas prices on average as a result. The UK was in a position to do this because of its relative self-sufficiency in energy supplies. Liberalisation has not occurred to the same extent in mainland Europe. The following of a 'national champion model' has led to the rise of three 'super companies' (EDF, E.ON and RWE), which means that achieving genuine competition is difficult particularly as such vertically integrated companies present a barrier to new entrants in the market (DTI 2006a).

The UK continues to push for greater liberalisation as a method of achieving increased energy security. The problem with this approach is that while the UK was able to liberalise while prices were low, liberalisation for some EU members where energy prices are being held artificially low could result in price increases and therefore represents a politically difficult option.

There is no doubt that the UK needs to work with the rest of Europe to secure its gas supplies. The EU has a greater 'clout' when it comes to dialogue with potential suppliers, such as Russia, and competitors, such as China. It is also cheaper to address gas security issues on a European level than on a nation by nation basis when considering the physical infrastructure through which competition takes place.

Of particular interest is the desire to reduce Europe's dependence on Russia as an energy supplier. This desire is mutually held as it is also in Russia's interest not to be overly dependent on exporting to European gas markets. There are questions over the extent to which this is likely to be achieved (Mitchell 2006). Commentators are sceptical about the chances of Russia signing the Energy Charter Treaty – an international agreement that aims to establish a legal framework for international cooperation between European countries and other industrialised countries in the energy sector.

Coal

As we saw in section 2, there are abundant coal reserves worldwide. Prices are less volatile than gas and oil; in fact, coal is becoming an increasingly attractive option as oil and gas prices remain high. The major problem is the additional emissions of air pollutants and CO_2 that go along with increased coal use. Compared to oil and gas, coal-fired electricity generation produces the most CO_2 per unit of energy delivered. CTL processes also generate large quantities of CO_2.

Various technologies are available to clean flue gasses of air pollutants such as SO_2, NOx and particulates, although there are costs associated with all of these. Carbon Capture and Storage (CCS) has been proposed as one solution for reducing CO_2 emissions. CCS involves capturing the CO_2 emitted from burning coal and preventing its release into the atmosphere by pumping it into a secure depository. There are a number of ways that this could be done – by pumping into appropriate geological formations, injection into the sea or by converting it into a solid mineral through a chemical reaction. The different capture and storage technologies are at different stages of development, the most advanced are post-combustion and pre-combustion capture methods and geological storage (IPCC 2005).

Studies have shown that around 20–40 per cent of global emissions (mainly from point sources such as fossil fuel-fired power stations and heavy industrial emitters of CO_2) could be suitable for capture by 2050 although these installations may not necessarily be near to a suitable storage site (IPCC 2005). A power station with a functioning CCS facility still remains to be demonstrated on a commercial scale (DTI 2006a). However, initial steps are being taken towards achieving this goal. For example, in September 2005, the EU and China signed an agreement to develop technology options for CCS with the potential to establish a demonstration project in China between 2010 and 2015 (Defra 2007). The European Commission's Zero Emissions Fossil Fuel Technology Platform (ZEP) also recommends a network of 10 to 12 integrated, large-scale demonstration projects across Europe (European Technology Platform for Zero Emission Fossil Fuel Power Plants 2007).

Economics remain a barrier to the development and deployment of CCS. The Intergovernmental Panel on Climate Change (IPCC) estimates that for CCS to reach its economic potential, several hundreds to thousands of plants will have to be installed around the world over the next century (IPCC 2005). If oil and gas prices remain high, coal-fired power stations will become a more favourable option. However, whether or not these are fitted with CCS facilities will depend to a large extent on the price of carbon under the EU ETS. Some commentators remain sceptical that prices will rise sufficiently to incentivise investment in CCS.

Adopting CCS would also require changes to current legal and regulatory frameworks. Issues such as property rights, liability in the case of leakage, international agreements in the case of injection into the sea and accounting of greenhouse gas emissions, where CO_2 is stored in a different country to the one in which is was produced, will need to be addressed (IPCC 2005).

UK supply-side options

For the UK, supply-side options are fairly limited. Investment in the UK Continental Shelf (UKCS) could increase the total amount of oil and gas that is recoverable from North Sea reserves (since extracting oil and gas grows more expensive as fields become depleted) and therefore slow the decline in production. To some extent, investment will be driven by oil prices. However, the UK Government aims to maximise investment, using its regulatory powers if necessary, irrespective of oil prices (DTI 2006a).

There are considerable economic and environmental barriers to increasing coal production, although the Government has convened a 'Coal Forum' to secure a 'long-term future of coal-fired generation and UK coal production' (DTI 2006a: 91). Coal currently receives subsidies and a lower carbon price via the climate change levy (CCL). Some have argued that the implementation of the EU ETS has actually encouraged the use of coal-fired power stations (despite their higher CO_2 emissions). By allocating a greater number of free carbon allocations to plant fitted with Flue Gas Desulphurisation (FGD), the allocation plan has effectively incentivised the retrofitting of FGD to coal plant with the result that they will run longer than would otherwise be expected (IPA Energy & Water Consulting 2006).

A new coal-fired power station is being planned by E.ON, partly as a result of high gas prices. The plant will not be built with CCS capacity, although there will be an option to 'bolt on' a CCS plant at a later date if economic conditions prove favourable. There are two other potential projects to build new power stations with CCS capability: at Ferrybridge, in West Yorkshire and at Tilbury in Essex, although these are still at the stage of feasibility studies (JESS 2006). CCS can also be used on gas-fired plants, although the capture process is more expensive than for coal.

Depleted oil and gas fields in the North Sea could act as potential storage sites for CO_2 and so CCS could potentially be an important way for the UK to reduce its emissions to the atmosphere. The development of CCS will depend on whether it is economically viable, environmentally sound and on changes to the regulatory framework, in particular to the London and OSPAR conventions on the marine environment and reporting of CO_2 emissions under the Kyoto Protocol (since emissions captured in CCS facilities are not currently reflected in reporting).

CCS could provide an economic opportunity for the UK, taking advantage of existing skills from the oil and gas industry. There would also be opportunities to use such expertise in projects in developing countries (DTI 2006a, Foresight 2001).

The Government has called for demonstration projects on key components of carbon abatement technologies and has established a CCS Regulatory Task Force (DTI 2006a). If CCS can make the grade in terms of environmental integrity and economic viability, then coal may be an important component of maintaining a secure electricity supply for the UK.

Alternatives to fossil fuels

Turning to alternative sources of energy would obviously reduce dependency on fossil fuels and therefore could contribute to greater energy security. Here they are discussed according to use.

Electricity

As section 3 described, much of the concern over security of electricity supply has been driven by the impending closure of generating plant over the next decade as nuclear power stations come to the end of their working lives and coal-fired power stations are closed under the LCPD.

As we have seen, the resulting 'generation gap' is expected to be around 15–20GW by 2016 (House of Commons Environmental Audit Committee 2006) and the Government estimates that a total of 25GW of new capacity will be needed by 2025 (DTI 2006a).

The potential 'gap' in generation capacity coupled with concerns about the security of gas supplies has prompted interest in alternatives sources of fuel for electricity generation to ensure the 'lights do not go out'.

There are essentially two alternative non-fossil sources of electricity: renewables (encompassing a whole range of different technologies; for convenience, energy from waste, landfill gas and sewage sludge digestion are included here) and nuclear power. Each of these will be addressed in turn.

Renewables

The UK is endowed with significant renewable resources. Indeed, within the UK the available wind resources alone could provide the country's electricity demand several times over (Anderson 2006). However, many other factors play a role in determining the extent to which technologies are taken up. These include technological capability to harness resources, the accessibility of resources, integration with current energy distribution networks, public acceptability and costs, which in turn depend in part on world prices of oil, gas, coal and carbon, as well as the proportion of each technology in the energy mix (Boyle 2004, Anderson 2006).

In 2005, 4.6 per cent of the UK's electricity production was from renewables, equivalent to 16,919 GWh of electricity (DTI 2006b). This is still some way short of the Government's target for 10 per cent of electricity to be generated from renewable sources by 2010.

A number of studies have been carried out into the potential for renewables in the UK. Based on an assessment of the existing data, the Sustainable Development Commission concluded that the total practicable resource is at least 334TWh/year, which is around 87 per cent of current electricity production. If price restrictions are taken into account, the practicable resource reduces to around 258TWh/year (approximately 59 per cent of current production) (SDC 2006a).

It is not clear when this level of renewable electricity is likely to become available. Different technologies are at different stages of development – on-shore and off-shore wind farms are already in operation, but other technologies, such as photovoltaics and wave power are not likely to be a significant part of the UK's energy mix until around 2025 (Watson *et al* 2002).

The main barriers to renewable energy sources are economic rather than technical. Obtaining planning permission and public acceptability also present problems. In terms of microgeneration, market rules and network regulation also present barriers to uptake (Ofgem 2006b). There are also concerns about intermittency of supply from renewable sources of electricity. For example, if electricity generation was more dependent on wind turbines and the winds were to drop at a peak time of use, it might not be possible to meet demand. Investigations are being carried out into exactly how much of a problem this might present and possible ways to alleviate the problem (Ofgem 2007). One potential solution is the use of demand-side responses, such as incentivising large energy-users not to use electricity at times when demand is especially high, or by incorporating 'dynamic demand' devices into household electrical goods (Dynamic Demand 2007).

The Government's Renewables Obligation (RO) has created an incentive for investment in renewable sources. Onshore wind and landfill gas have been the main beneficiaries of the policy to date but it is recognised that more could be done to drive innovation and foster emerging technologies (DTI 2006a). At the time of writing, a consultation on reforming the RO is being carried out. Proposals include the introduction of a system of banding which would encourage less well established technologies such as offshore wind and photovoltaic solar panels (DTI 2007e).

Nuclear

Following the Government's Energy Review in 2006, interest in the idea of building new nuclear power stations in the UK has enjoyed a resurgence. The 2007 Energy White Paper suggests that a new fleet of nuclear power stations would contribute to the twin goals of improving energy security and reducing CO_2 emissions (DTI 2007f). The rationale for improved energy security is based on four factors:

- Reducing reliance on imports of fossil fuels
- Providing a diverse mix of technologies used to generate electricity, reducing reliance on any one technology
- Sourcing fuel from a greater geographical spread of countries (in contrast to gas and oil, which tend to be concentrated in a few countries)
- Providing greater resistance to fuel price fluctuations than for fossil-fuel-based power stations.

Beyond these security of supply issues is a set of wider security concerns related to the use of nuclear power. The Government concludes that the risk of a serious accident is low and that the existing security regime is robust and effective enough to protect against a terrorist attack on nuclear power stations. It is also argued that the risk posed by diverting nuclear materials from power stations is low (DTI 2007f).

However, critics claim that this view of energy security is too narrow and should take wider security concerns into account. In its 2006 review of nuclear power, the Sustainable Development Commission (SDC) argued that if nuclear power proves part of the solution to reducing CO_2 emissions in the UK, then it will be considered a viable solution for all countries (SDC 2006b). If nuclear technologies become more widespread globally, it could become more difficult to monitor compliance with international treaties and control the spread of nuclear weapons. It could also increase opportunities for nuclear terrorism (both attacks on nuclear installations and the use of stolen fissile material for the manufacture of nuclear explosives) (SDC 2006b, Barnaby and Kemp 2007). These wider security concerns will be considered in greater detail as part of the work of ippr's Commission on Security in the 21st Century (for more information, see ippr 2007).

Closer to home, concerns have been raised recently about the vulnerability of nuclear power stations – which must be built with good access to cooling water – to sea level rise and increased storm surge as a result of climate change. Greenpeace carried out an assessment of four proposed new-build sites and concluded that at least three of them faced such a threat over the next 200 years (Greenpeace 2007).

The second reason for adopting nuclear power – that it will help reduce CO_2 emissions – is also subject to some criticisms. Although nuclear is a low-carbon technology, it will not deliver CO_2 reductions in the short to medium term, since planning, development and construction of any new station is likely to take many years. The Government acknowledges that new nuclear will not bring any benefits in terms of emission reductions until 2020 (DTI 2007f). Several commentators have expressed concerns that new nuclear build will lock the UK into a centralised energy system, reducing the opportunities for developing more efficient decentralised energy systems (SDC 2006b, Greenpeace 2006). There are also concerns that political attention will be diverted away from increasing the use of renewable energy and improving energy efficiency measures (SDC 2006b).

The Government's 2006 Energy Review concluded that the market should deliver new nuclear stations, but that government should remove regulatory barriers, particularly planning regulations, which can significantly lengthen the amount of time taken to construct a new station (DTI 2006a). The 2007 Energy White Paper asserts that new nuclear power stations would bring economic benefits to the UK, in the context of reducing CO_2 emissions and increasing energy security. The full costs of the construction, operation, decommissioning and waste management would be bourne by private sector companies. However, some commentators maintain that the nuclear power industry still benefits from indirect subsidies in the form of caps on insurance liability.

In May 2007, the Government launched a consultation on nuclear power and whether the private sector should be allowed to build new nuclear power stations. The consultation closes in October 2007 with the intention that a decision will be taken later in the year on whether to allow new nuclear build.

Transport

There are four main alternative fuels for road transport. These are:

- electricity
- mineral gases such as Liquid Petroleum Gas (LPG) and Compressed Natural Gas (CNG)
- hydrogen
- biofuels.

Electricity is restricted to battery-driven or hybrid vehicles. Mineral gases require engine modifications in order to run and are subject to the same security of supply concerns that apply to gas supplied for heat and electricity generation. Hydrogen used for fuel cell vehicles is not a viable short-term solution, although it could play an important part in the future (Fergusson *et al* 2006).

Biofuels can be blended with conventional petroleum products and used in conventional combustion engines. Under the Renewable Transport Fuel Obligation, the Government has set a target that 5 per cent of transport fuel supplied must be from renewable sources by 2010/11. However, there is still a vigorous debate around the use of biofuels. From an environmental point of view, there are questions about the actual level of greenhouse gas reductions once the total lifecycle emissions of growing and transporting the crops are taken into account. There are also important questions about the protection of biodiversity, which have yet to be fully addressed (for example, see UN-Energy 2007).

There are no real alternatives to kerosene for aviation fuel in the short or medium term. Electricity and biofuels can be used for rail transport and biofuels and wind can be used for shipping: a number of projects are developing high-tech aerofoil sails and kites to propel ships and tankers (Fergusson *et al* 2006, Hamer 2005).

Heat

As discussed in section 2, most of the UK's heating requirements are met by gas supplied through the national grid. Currently, the main alternative source of heat is electric heaters, which account for around 8 per cent of heat needs nationally (DTI 2006a). Clearly the way in which the electricity is generated will determine the security of supply for this alternative, as has been discussed previously.

Aside from electricity, the other main alternative fuel for heat generation is biomass – this can be used to fuel dedicated heat or combined heat and power (CHP) plants. It is also used in 'distributed' heat generation, for example in wood-fired stoves and boilers. Other alternatives to fossil fuels for heat generation include solar water heating, geothermal heating and heat pumps – ground source heat pumps in particular are gaining prominence at the moment (DTI 2006a).

Barriers to increasing use of renewable sources of heat include high capital costs and uncertainties about long-term demand, which in turn deter investment. The Biomass Task Force, in its 2005 report to Government, recommended that the best way to overcome such investment uncertainties would be to introduce streamlined capital grant support rather than using market-based incentives such as a Renewable Heat Obligation (Biomass Task Force 2005).

Barriers to the use of CHP are discussed further below.

Demand reduction

Reducing demand is an obvious way to improve energy security. However, it is difficult to point to countries that have successfully reduced energy demand while simultaneously maintaining economic growth (DTI 2006a). This can make demand reduction seem like an unappealing option. Nevertheless, some studies have argued that it would be possible to halve the UK's total energy use by 2050 (Cooperative Bank *et al* 2006).

Looking first at electricity: energy efficiency measures can be taken at a number of points along the supply chain, by ensuring the most efficient use of fuel, minimising transmission and distribution losses and taking measures to reduce consumption by the end user.

A decentralised energy system of gas-fired CHP plants could reduce overall demand for gas because both the electricity and heat generated by the plants are used (as opposed to centralised gas plants, where the heat is generally lost to the atmosphere) thereby reducing the total amount of gas used. Losses from transmission and distribution are also reduced because the electricity is generated close to the point of use (Greenpeace 2006). Woodman and Mitchell (2006) argue that a more decentralised energy system will bring a number of other benefits to energy security, including increased system flexibility and greater reliability (owing to reduced reliance on long-distance transmissions lines and because faults in smaller plants affect fewer people).

The barriers to distributed energy include:

- A lack of awareness among developers and planning authorities
- Difficulties obtaining planning permissions
- Problems around selling electricity back to the grid (both in terms of process and the price offered by electricity companies)
- The higher costs of these technologies compared to conventional technologies (DTI 2006a).

In terms of consumption by the end user, two areas where energy efficiency could be particularly important are domestic heating and transport. As described in section 1, the biggest consumer of gas in the UK is the domestic sector. The vast majority of this is used for heating space and water. Likewise, transport accounts for around 80 per cent of UK consumption of petroleum products.

It is interesting that, in the UK at least, much of the information available on the impact of energy efficiency measures tends to focus on the reduction in carbon emissions rather than the energy saved. For example, the Energy Saving Trust reported that the absolute cost-effective carbon abatement opportunity for space and water heating in the domestic sector would reduce carbon emissions by 20 per cent (EST 2005). Fergusson *et al* (2006) report that if all UK drivers switched to the most fuel-efficient model in their class, greenhouse gas emissions would be reduced by 32 per cent. These figures give some indication of the size of demand reduction that could be made through efficiency measures. The Government's Plan for Action on Energy Efficiency calculated that total energy use could be reduced by around 30 per cent over the next two decades through energy efficiency measures (ippr 2006).

There are three main ways in which energy use could be reduced in the transport sector: using more fuel-efficient vehicles, using fuel more efficiently through changing driving habits or switching to public transport, and by reducing the overall amount of transport (Fergusson *et al* 2006). In terms of heat efficiency in our homes, energy can be saved through better insulation and draught-proofing.

Even though installing energy efficiency measures may be the most cost-effective option, there are other reasons why people do not take these measures. These are:

- 'Hidden' costs, such as the time spent researching options or taken to install measures and the hassle and inconvenience of installing measures
- Lack of access to relevant information
- Lack of capital to pay upfront costs
- Difficulty in breaking habitual behaviours or going against social and institutional norms and the 'invisibility' of many efficiency measures
- The misperception that people cannot reduce their energy use from current levels

- Split incentives between landlords and tenants in the private rented sector. (Stern 2006, Retallack *et al* 2007)

Summary

- The UK continues to push market liberalisation within Europe as the way to secure energy supplies.
- Coal security is tied to environmental objectives since tough policies on carbon dioxide emissions would penalise the use of coal. CCS could offer one solution.
- The short-term gap in electricity created through plant closures will most likely be met through new coal- and gas-fired stations.
- Renewable sources of energy could provide a large proportion of the UK's electricity needs. Without price restrictions, the total practicable resource is at least 334TWh/year, which is around 87 per cent of current electricity production.
- Nuclear power could increase energy security through diversifying the mix of fuels used for electricity generation, but there are concerns that its use might lead to increased security risks associated with nuclear proliferation and nuclear terrorism.
- Alternatives to oil include biofuels in the short term and hydrogen in the long term.
- Demand reduction could be particularly important for reducing reliance on gas (through better insulation) and oil (particularly from improved vehicle efficiency).

6. Conclusion

Oil

Without oil, the UK's transport system would rapidly grind to a halt. Clearly, this would have a huge impact on almost every aspect of life. The UK's own oil reserves are in decline and so we are rapidly becoming dependent on other countries to meet our needs. There is also uncertainty around the future price of oil, both as a result of the loss of surplus capacity in OPEC countries and as a potential consequence of peak oil (see section 4 above). Demand is relatively inelastic in the short term, as we have seen in recent years as rising oil prices have not resulted in fewer cars on the road, but there is the possibility that peak oil could cause significant disruption through sharp price increases.

The main near-term options available are to increase the use of alternative fuels (which the Government is already beginning to do through the Renewable Transport Fuel Obligation) and to encourage the use of more efficient and alternatively-fuelled vehicles that are already on the market. Medium-term options include improving the energy efficiency of the UK car fleet (efforts targeted at the supply side will probably require cooperation at a European level) and increasing the use of alternative fuels (this will involve changes to the fuel distribution network). In the long term, hydrogen may become a viable fuel source and this would require significant changes to fuel distribution. Demand reduction through reducing the need to travel or through switching from private cars to public transport becomes more viable through improvements in planning and interventions such as road pricing.

Gas

In the short term, gas supplies face a threat of shortages and price disruptions, as a result of an increasing reliance on gas imports. A shortage of gas supplies in recent winters has led to electricity-generating companies switching from gas- to coal-fired electricity generation. Further threats to gas supplies are likely to lead to greater use of coal for electricity production. Without CCS, this will lead to an increase in CO_2 emissions from this sector.

It is also important to remember, however, that most of the UK's gas supply is used for heating. In the short term, energy efficiency measures to improve insulation for space and water heating could contribute significantly to reducing reliance on imported gas.

In the medium to long term, there is a risk of supply not being able to meet demand. Alternative sources of energy could help to reduce dependence on gas, for example, CHP and electric heating combined with alternative sources of electricity generation. Investment in efficiency measures would help to tackle both energy security and climate change objectives.

Coal

Security of supply is less of a problem for coal, although it should be recognised that the UK is likely to remain dependent on imports to meet its projected demand levels. Attempts to limit the environmental impact of burning coal are likely to pose a bigger restraint to the use of coal.

Coal is used mainly to generate electricity. In the 'merit order' of generators, coal stations are used to respond to peaks in electricity demand throughout the day, while nuclear and gas stations provide a constant 'base-load'. The reasons behind this are principally economic – when gas prices were high during the winter of 2005/06, the roles of gas- and coal-fired stations essentially switched and coal stations provided more of the base load. A short- to medium- term solution could therefore be to work with heavy users of electricity (for example heavy industry) to even out electricity demand throughout the day. Long-term options include replacing coal-fired generation plant with alternatively-fuelled generators (nuclear or renewables) or to develop carbon capture and storage capacity.

It will not be possible to reduce the UK's dependency on fossil fuels overnight and so it is important to secure supplies to provide for short- and medium-term energy needs. This will be achieved most effectively by working with the EU in negotiations with large global energy players, such as Russia and China. However, a responsible energy policy must ensure that energy security for the UK or even the EU must not come at the expense of other countries' own energy security or the security of the climate.

There are many ways in which energy security and climate objectives align: switching to alternative (low-carbon) fuels and implementing energy efficiency measures will clearly also reduce CO_2 emissions. Risks to the climate arise, however, from turning to coal as a more secure source of energy than gas or oil without the use of CCS. Similarly, using non-conventional sources of oil would have a serious impact on greenhouse gas emissions.

This is a critical time for determining the future energy security of the UK as decisions about new infrastructure made in the next few years will determine the course of energy use for the next two or three decades. The Government's own Foresight programme concluded that a radical shift was needed towards, 'an economy that uses much less energy and towards energy sources not based on carbon, or to novel ways of capturing and using carbon', and highlighted the fact that this could not be delivered by incremental change (Foresight 2001:28). For a government committed to a market-based approach to deliver energy goals, the most important question will be whether the policy and regulatory framework is sufficient to deliver such a radical shift.

References

Note: web references correct June 2007

Anderson D (2006) *Costs and finance of abating carbon emissions in the energy sector* London: Imperial College London, available at: www.hm-treasury.gov.uk/media/8A3/32/stern_review_ supporting_technical_material_dennis_anderson_231006.pdf

Anderson D (2007) *Energy Industry Markets and Climate Change paper for the Commission on Environmental Markets and Economic Performance* (forthcoming)

Barnaby F and Kemp J (Eds) (2007) *Secure energy? Civil nuclear power, security and global warming* London: Oxford Research Group, available at: www.oxfordresearchgroup.org.uk/publications/ briefing_papers/pdf/secureenergy.pdf

BBC (2007) *Global worries push oil above $70*, Online article, published 23 May, available at: http://news.bbc.co.uk/1/hi/business/6684745.stm

Biomass Task Force (2005) *Report to Government Biomass Task Force*, available at: www.defra.gov.uk/farm/crops/ industrial/energy/biomass-taskforce/pdf/btf-finalreport.pdf

Boyle G (2004) *Renewable energy Power for a sustainable future, second edition* Oxford: Oxford University Press

BP (2006) *BP Statistical review of world energy* June 2006, available at: www.bp.com/productlanding.do?categoryId =6848&contentId=7033471

BP (2007) *BP Statistical Review of World Energy 2007*, Conversion Factors webpage, available at: www.bp.com/extendedsectiongenericarticle.do?categoryId=901794 4&contentId=7033505

Cooperative Bank, Friends of the Earth, The Big Ask (2006) *The future starts here: the route to a low-carbon economy*, available at: www.foe.co.uk/resource/reports/low_carbon_economy.pdf

Department for Business, Enterprise and Regulatory Reform (DBERR) (2007) Energy Statistics: explanatory notes webpage, available at: www.dti.gov.uk/energy/statistics/source/notes/page18916.html

Department for the Environment, Food and Rural Affairs (Defra) (2007) Working with developing countries – China webpage, available at: www.defra.gov.uk/environment/climatechange/ internat/devcountry/china.htm

Department for Transport (DfT) (2006) *Transport statistics Great Britain 2006 edition* London: The Stationery Office, available at: www.dft.gov.uk/pgr/statistics/datatablespublications/tsgb/

Department of Trade and Industry (DTI) (2005) *Digest of United Kingdom energy statistics 2005* London: DTI, available at www.dti.gov.uk/files/file10737.pdf

Department of Trade and Industry (2006a) *The Energy Challenge. Energy Review Report* 2006 London: TSO

Department of Trade and Industry (2006b) *Digest of UK Energy Statistics* available at: www.dti.gov.uk/energy/statistics/ source/gas/page18525.html

Department of Trade and Industry (2006c) Energy Statistics online resource, DUKES table 4.1 available at: www.dtistats.net/energystats/dukes4_1.xls

Department of Trade and Industry (2006d) *Understanding gas supply this winter*, London: DTI, available at: www.dti.gov.uk/files/file27821.pdf

Department of Trade and Industry (2006e) Energy Statistics online resource, DUKES table 5.6, available at: www.dtistats.net/energystats/dukes5_6.xls

Department of Trade and Industry (2006f) *Energy: its impact on the environment and society 2006* London: DTI, available at: www.dti.gov.uk/energy/environment/energy-impact/page29982.html

Department of Trade and Industry (2007a) Energy statistics website www.dti.gov.uk/energy/statistics/index.html

Department of Trade and Industry (2007b) Personal communication with Clive Evans, 19 January

Department of Trade and Industry (2007c) Web page on fuel poverty, available at www.dti.gov.uk/energy/fuel-poverty/index.html

Department of Trade and Industry (2007d) *Quarterly energy prices March 2007* London: DTI, available at: www.dti.gov.uk/files/file38655.pdf

Department of Trade and Industry (2007e) *Reform of the renewables obligation* London: DTI, available at: www.dti.gov.uk/files/file39497.pdf

Department of Trade and Industry (2007f) *Meeting the Energy Challenge a White Paper on Energy* Norwich: TSO, available at: www.dti.gov.uk/files/file39387.pdf

Drollas L (2006) 'The oil market – key questions', presentation given to Cantor Index Forum, 29 June, available at: www.cges.co.uk/pub/LDrollasCantor290606.pdf

Dynamic Demand (2006) Dynamic Demand website: www.dynamicdemand.co.uk/the_technology.htm

Energy Saving Trust (EST) (2005) 'Household Sector Final report, report for the Energy Efficiency Innovation Review', presentation available at: www.est.org.uk/uploads/documents/aboutest /EEIR_Household_summary_Dec_05.pdf

Energy Information Administration (EIA) (2006) *Annual energy review 2005*, available at: www.eia.doe.gov/emeu/aer/contents.html

European Technology Platform for Zero Emission Fossil Fuel Power Plants (2007) *European technology Platform for Zero Emission fossil Fuel Power plants (ZEP) Strategic Overview* Report prepared on behalf of the Advisory Council of the European Technology Platform for Zero Emission fossil Fuel Power Plants, available at: www.zero-emissionplatform.eu/website/docs/ETP%20ZEP/ZEP%20Concepts %20Final%20V2.pdf

European Renewable Energy Council and Greenpeace (2007) *Energy [r]evolution* available at: www.energyblueprint.info/fileadmin/ media/documents/energy_revolution.pdf

Fergusson M, Mackay E and Skinner I (2006) *Over a barrel: reducing the UK and Europe's oil dependency*. Report by the Institute for European Environmental Policy for Greenpeace UK. London: Greenpeace, available at: www.greenpeace.org.uk/ contentlookup.cfm?ucidparam=20061207111604

Foreign and Commonwealth Office (FCO) (nd) *UK international priorities the energy strategy* London: FCO, available at: www.fco.gov.uk/Files/kfile/Energy_Report_281004.pdf

Foresight (2001) *Energy for Tomorrow Powering the 21st Century* London: DTI, available at: http://vizyon2023.tubitak.gov.tr/ teknolojiongorusu/paneller/enerjivedogalkaynaklar/kaynaklar/FC4tomorrow.pdf

Fuel Poverty Advisory Group (For England) (2007) *Fifth annual report* London: DTI, available at: www.dti.gov.uk/files/file38873.pdf

Greenpeace (2006) *Decentralising UK energy: cleaner, cheaper, more secure energy for the 21st century* London: Greenpeace

Greenpeace (2007) *The impacts of climate change on nuclear power stations sites* London: Greenpeace, available at: www.greenpeace.org.uk/files/pdfs/nuclear/8179.pdf

Hamer M (2005) 'The new age of the sail' *New Scientist*, 26 February

House of Commons Environmental Audit Committee (2006) *Keeping the lights on: nuclear, renewables and climate change. Sixth report of session 2005–06, volume 1*, London: The Stationery Office

ILEX (2006) The balance of power Reducing CO2 emissions from the UK power sector A report for WWF-UK by ILEX Energy Consulting, Surrey: WWF, available at www.wwf.org.uk/filelibrary/pdf/ilex_report.pdf

Intergovernmental Panel on Climate Change (IPCC) (2005) *IPCC Special Report Carbon Dioxide Capture and Storage, Summary for Policymakers* available at: www.mnp.nl/ipcc/pages_media/SRCCS-final/ccsspm.pdf

International Energy Agency (IEA) (2006) *World Energy Outlook 2006* Paris: IEA

Institute of Civil Engineers (2006) *The state of the nation 2006* London: ICE

Institute for Public Policy Research (ippr) (2006) 'Energy efficiency could solve 'security of supply' anxiety' Press release, 8 July, available at www.ippr.org/pressreleases/?id=2207

Institute for Public Policy Research (2007) Commission on National Security in the 21st Century webpage, available at: www.ippr.org/security

IPA Energy & Water Consulting (2006) *UK power sector emissions – targets or reality? Report to WWF-UK* Edinburgh: IPA Energy & Water Consulting, available at: www.wwf.org.uk/filelibrary/pdf/ipareport.pdf

Joint Energy Security of Supply (JESS) working group (2006) *JESS Long-term security of energy supply December 2006 report*, available at: www.dti.gov.uk/files/file35989.pdf

Leggett J (2005) *Half gone: Oil, gas, hot air and the global energy* *crisis*, London: Portobello Books Ltd

Mabey N (2006) 'Beyond zero sum politics: frameworks for delivering energy and climate security in the Asia Pacific region.' Presentation at 'Energy security in the Asia-Pacific region: conflict potential and possible solutions', East-West Institute and Madariaga European Foundation, Brussels, September 27

Mitchell J (2005) *Producer – consumer dialogue: what can energy ministers say to one other?* London: Chatham House, available at: www.chathamhouse.org.uk/pdf/research/sdp/Nov05energy.pdf

Mitchell J (2006i) (2006) *A new era for oil prices* London: Chatham House, available at: www.chathamhouse.org.uk/pdf/research/sdp/Oilprices0806.pdf

Mott MacDonald (2004) *UK coal production outlook: 2004-16 Final report for the Department of Trade and Industry*. Brighton: Mott MacDonald, available at: www.dti.gov.uk/files/file14151.pdf

Norwegian Petroleum Directorate (2005) *The petroleum resources on the Norwegian continental shelf* Stavanger: Norwegian Petroleum Directorate, available at: www.npd.no/English/Emner/Ressursforvaltning/Ressursregnskap_og_-analyse/Ressursrapport_2005/ressrapp05.htm

Ofgem (2006a) *Securing Britain's gas supply*. Ofgem factsheet 32, available at: www.ofgem.gov.uk/Media/FactSheets/Documents1/15916-sosgasupdatenov06.pdf

Ofgem (2006b) *Ofgem's commitment to sustainable development*. Ofgem factsheet 65. available at: www.ofgem.gov.uk/Media/FactSheets/Documents1/15911-susdevfactsheet.pdf

Ofgem (2007) Personal communication with Sonia Brown, Director of Wholesale Markets, Ofgem, 28 February

OPEC (2006) *Annual Statistical Bulletin 2005* Vienna: OPEC, available at www.opec.org/library/Annual%20Statistical%20Bulletin/pdf/ASB2005.pdf

Renewable Energy Systems (2006) *Plugging the gap: a survey of the world fuel resources and their impact on the development of wind energy* Kings Langley: RES, available at: www.gwec.net/uploads/media/RESGWEC-Plugging_the_Gap_report_01.09.06.pdf

Retallack S, Lawrence T with Lockwood M (2007) *Positive Energy: Harnessing people power to prevent climate change* London: ippr

Stern N (2006) *Stern review on the economics of climate change* London: HM Treasury

Sustainable Development Commission (SDC) (2006a) *Reducing CO_2 emissions – nuclear and the alternatives.* Paper 2 of the SDC nuclear evidence base London: SDC

Sustainable Development Commission (2006b) *The role of nuclear power in a low carbon economy* London: SDC, available at: www.sd-commission.org.uk/publications/downloads/SDC-NuclearPosition-2006.pdf

UN-Energy (2007) *Sustainable Bioenergy: A Framework for Decision Makers UN-Energy*, available at: http://esa.un.org/un-energy/pdf/susdev.Biofuels.FAO.pdf

UK Petroleum Industry Association Limited (2006) *Statistical review 2006* London: UKPIA

Watson J, Hertin J, Randall T and Gough C (2002) *Renewable energy and combined heat and power resources in the UK* Manchester: Tyndall Centre for Climate Change Research, available at: www.tyndall.ac.uk/publications/working_papers/wp22.pdf

World Coal Institute (2006) *Coal: liquid fuels* London: World Coal Institute, available at: www.worldcoal.org/assets_cm/files/PDF/wci_coal_liquid_fuels.pdf

Woodman B and Mitchell C (2006) *Real energy security and the transition to a decentralised energy system* Warwick: Centre for Management Under Regulation, Warwick Business School. Available at: www.carolinelucasmep.org.uk/publications/pdfs_and_word/EnergySecurityBridget_Jun06.pdf

Annex I

Cumulative global investment in energy infrastructure in the IEA's reference scenario (business as usual) by fuel and activity, 2005–2030 (2005 prices)

Fuel	Activity	Investment (US$)
Electricity	Power generation	5.2
	Transmission and distribution	6.1
Coal	Mining	0.5
	Shipping and ports	0.1
Gas	Exploration and development	2.2
	LNG chain	0.3
	Transmission and distribution	1.4
Biofuels		0.1
Oil	Exploration and development	3.1
	Refining	0.8
	Other	0.4
Total		20.2

Source: IEA 2006

Annex II

The following tables give approximate conversion factors for weight, volume and calorific content for crude oil, natural gas, liquid natural gas and coal.

Energy units

	To:			
	Thousand tonnes of oil equivalent (toe)	Terajoules (TJ)	Gigawatt hours (GWh)	Million therms
From:	**Multiply by:**			
Thousand tonnes of oil equivalent (toe)	1	41.87	11.63	0.3968
Terajoules (TJ)	0.02388	1	0.2778	0.009478
Gigawatt hours (GWh)	0.08598	3.6	1	0.03412
Million therms	2.52	105.5	29.31	1

Crude oil

	To:			
	Tonnes (metric)	Kilolitres	Barrels	US gallons
From:	**Multiply by:**			
Tonnes (metric)	1	1.165	7.33	307.86
Kilolitres	0.8581	1	6.2898	264.17
Barrels	0.1364	0.159	1	42
US gallons	0.00325	0.0038	0.0238	1

Natural gas (NG) and Liquid Natural Gas (LNG)					
	To:				
	Billion cubic metres NG	Billion cubic feet NG	Million tonnes oil equivalent	Million tonnes LNG	Million barrels oil equivalent
From:	**Multiply by:**				
Billion cubic metres NG	1	35.3	0.90	0.73	6.29
Billion cubic feet NG	0.028	1	0.026	0.021	0.18
Million tonnes oil equivalent	1.111	39.2	1	0.805	7.33
Million tonnes LNG	1.38	48.7	1.23	1	8.68
Million barrels oil equivalent	0.16	5.61	0.14	0.12	1

Coal

1.5 tonnes of hard coal is approximately equivalent to one tonne of oil equivalent.

Sources: DBERR 2007, BP 2007.