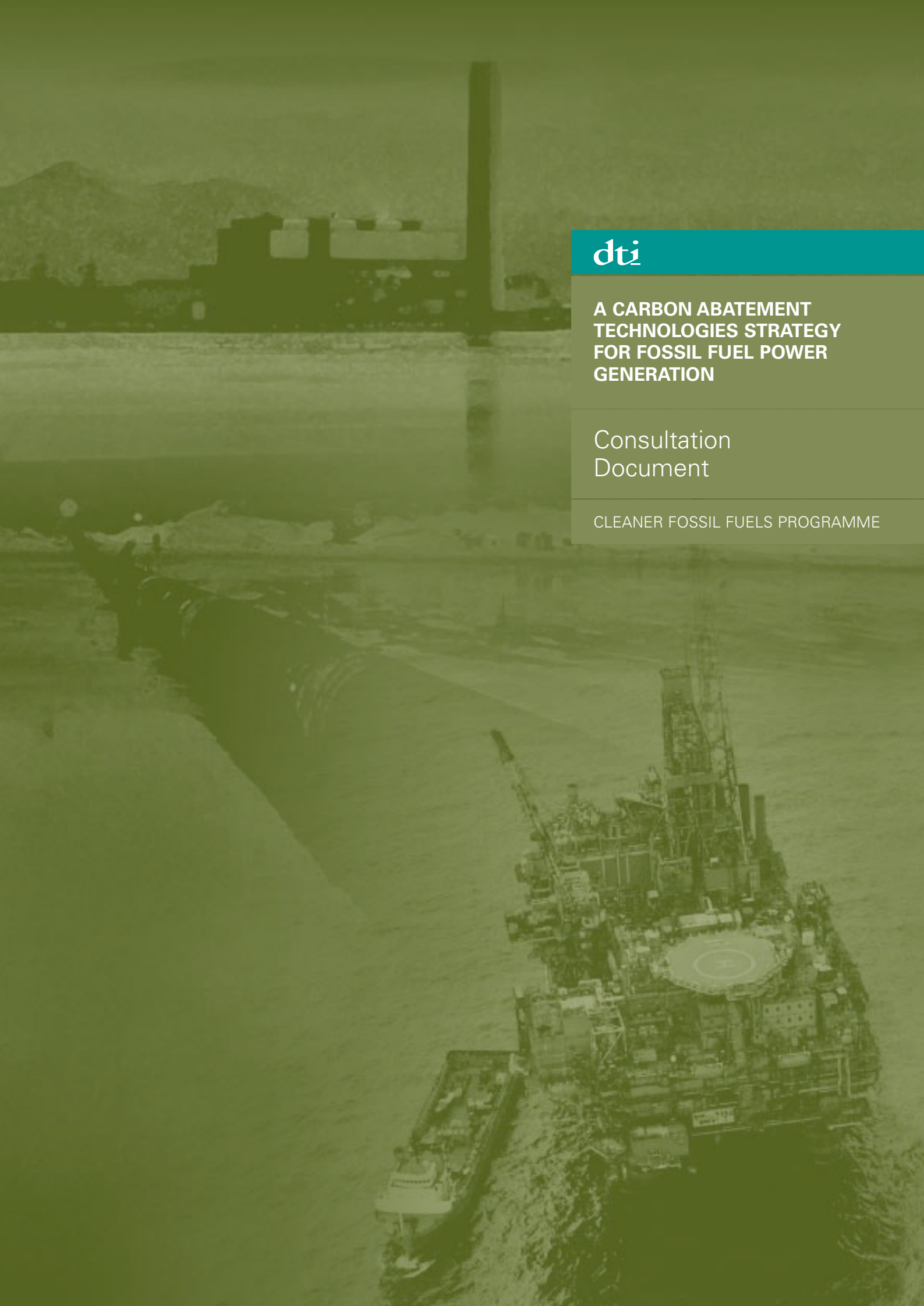


dti

# A CARBON ABATEMENT TECHNOLOGIES STRATEGY FOR FOSSIL FUEL POWER GENERATION

## Consultation Document

CLEANER FOSSIL FUELS PROGRAMME

dti

The DTI drives our ambition of 'prosperity for all' by working to create the best environment for business success in the UK. We help people and companies become more productive by promoting enterprise, innovation and creativity.

We champion UK business at home and abroad. We invest heavily in world-class science and technology. We protect the rights of working people and consumers. And we stand up for fair and open markets in the UK, Europe and the world.

# Contents

# 1. Introduction and Summary

This Consultation is seeking views on the content of a Carbon Abatement Technology (CAT) Strategy which is currently being developed by the DTI's Cleaner Fossil Fuels Unit. It is planned to publish the new Strategy at the end of this year and this Consultation forms an important component, among a number of other tasks, in the Strategy's development. So that we can meet the deadline for the publication of the Strategy we will require responses to this Consultation by 29 October 2004. If you have any enquires about it please contact Brian Morris, Head of the Cleaner Fossil Fuels Unit; his contact details can be found on page 2 of this document.

The Energy White Paper - *Our Energy Future - Creating a Low Carbon Economy,* laid the path for achieving the Government's target for a 60% reduction in carbon dioxide ($CO_2$) emissions by 2050. The initial stages for achieving this goal place the emphasis on the development and deployment of renewables technologies, such as wind power, as well as improvements in energy efficiency, and set out medium-term targets for these up to 2020. The White Paper recognises however, that beyond 2020 additional ways for reducing $CO_2$ emissions will need to be found if the 60% reduction is to be achieved.

It is expected that beyond 2020 there will still be a significant reliance on fossil fuels to meet our energy needs. New technologies will have to be developed therefore to significantly reduce or even eliminate $CO_2$ emissions caused by the use of these fuels. It is now internationally agreed that the Research and Development (R&D) required to develop these technologies to the point where they are commercially attractive to use will take upwards of the next 15 years or so. In parallel we need to consider potential improvements in the efficiency of combustion/conversion technologies, which also offer $CO_2$ emissions reductions, but which are more near to market.

CATs can be considered to cover two key technological areas:

(a) The evolutionary developments of existing power generation technologies to gain improvements in generation efficiency and costs and hence reduce $CO_2$ emissions in the short to medium term.

(b) The development of $CO_2$ capture and storage (CCS) technologies, which are much more radical but provide the opportunity to significantly reduce, if not eliminate, emissions from fossil fuel use, in the longer term - ie beyond 2020.

It is appropriate therefore, that a CAT Strategy be developed to identify what needs to be done, with the aim of having these technologies ready by 2020. There is a variety of issues to be considered around such a Strategy, covering not only technical development but also non-technical issues such as regulatory requirements and environmental issues, to name but a few. Through this Consultation we are seeking your views on issues around the rationale and objectives of the Strategy, its scope and what it needs to do to achieve its objectives. This paper is divided into a number of sections; the key ones are:

- Section 3 outlines in more detail why we think a Strategy is required.
- Section 5 discusses the issues in depth and seeks your views on them.
- Annex C provides the background to the development of the Strategy.
- Annex D provide descriptions of CATs

Annex E contains a Glossary of Terms.

# 2. How to Respond to this Consultation

To helps us formulate a Strategy for the future development of CATs we are gathering views and opinions from a range of stakeholders with an interest in this area. If you would like to contribute to this process would you please write to:

Jemma Howland
Future Energy Solutions
Harwell
Didcot
Oxfordshire
OX11 0QJ
Tel: 0870 190 6152
Fax: 0870 190 6323
E-mail: jemma.howland@aeat.co.uk

We would be happy to receive your views through the post or by e-mail. **We need these by 29 October 2004**. We have set out some of the issues we think are relevant to the development of the Strategy in Section 5 and we would like to hear your views on these.

We have a commitment to produce the new Strategy by the end of 2004 and in order to meet this deadline we need to have all the responses to this consultation by 29 October. We are planning to arrange a public workshop on the Strategy some time in October, possibly in Birmingham. If you are interested in attending, please contact Jemma Howland at the above address. She will send details when they are finalised.

Other versions/formats of the document, eg in Braille, other languages or audiocassette are available on request. Your response may be made public by the DTI. If you do not want all or part of your response or name made public, please state this clearly in the response. Any confidentiality disclaimer that may be generated by your organisation's IT system or included as a general statement in your fax cover sheet will be taken to apply only to information in your response for which confidentiality has been requested. We will handle any personal data you provide appropriately in accordance with the Data Protection Act 1998.

Please feel free to pass on this Consultation Paper to anyone else you think may be interested, or alternatively suggest to us other interested parties and we will arrange to send them a copy. A list of individuals and organisations that have been consulted by the DTI is given in Annex F.

Further copies of this Paper are available on the DTI's Web site at http://www.dti.gov.uk/energy/coal/cfft/catscon/index.shtml or paper copies can be obtain from:

Jemma Howland
Future Energy Solutions
Harwell
Didcot
Oxfordshire
OX11 0QJ
Tel: 0870 190 6152
Fax: 0870 190 6323
E-mail: jemma.howland@aeat.co.uk

If you have any questions about the policy aspects of this consultation then please feel free to contact Brian Morris, the Head of the Cleaner Fossil Fuels Unit at:

Coal and Emerging Energy Technologies Unit
Department of Trade and Industry
1 Victoria Street, London, SW1H 0ET.
Tel: 020 7215 6110
Fax: 020 7215 2840
E-mail: brian.morris@dti.gsi.gov.uk

Alternatively, if you have any comments on how this consultation has been conducted then please contact:

Nick Van Benschoten
Consultation Co-ordinator
Department of Trade and Industry
Room 723
1 Victoria Street, London, SW1H 0ET.
Tel: 020 7215 6206
Fax: 020 7215 0534
E-mail: nick.vanbenschoten@dti.gsi.gov.uk

Annex B sets out the "Consultation Criteria" which apply to public Consultations.

# 3. The Proposal

The Government is starting to prepare a CAT Strategy that will provide a framework for the future development of low to zero $CO_2$ emissions technologies that use fossil fuels. A more detailed discussion of what we mean by CATs can be found at Annex D to this Paper.

Although the Energy White Paper - *Our Energy Future - Creating a Low Carbon Economy*[1], placed the emphasis over the next 15 years or so on the development and deployment of renewables technologies, such as wind and solar energy, and improving energy efficiency, it does recognise that beyond about 2020 we will need to find additional ways of reducing $CO_2$ emissions if we are to meet our 2050 target of a 60% reduction.

**The Energy White Paper - Our energy future - creating a low carbon economy - put the UK on a path to a 60% reduction in $CO_2$ emissions by 2050.**

Beyond 2020 it is highly likely that we will still be very dependent on fossil fuels for much of our energy needs. To meet the 2050 target therefore it will be necessary to develop fossil fuel technologies with low to zero $CO_2$ emissions (referred to as CATs in this document). A number of countries now agree that it will take around 10 to 15 years of research and development to bring some of these technologies to a point where they can be commercially deployed. The aim of the CAT Strategy is therefore to set out what needs to be done, and the approach we should adopt over the next 15 years, to develop these technologies such that they are ready for use from 2020.

CATs cover two key categories of abatement technology:

- The evolutionary development of existing power generation technologies to gain improvements in generation efficiency and costs and hence reduce $CO_2$ emissions in the short to medium term.

- The development of CCS technologies, which are much more radical but provide the opportunity to significantly reduce, if not eliminate, emissions from fossil fuel use in the longer term - beyond 2020.

These technologies are best applied to large combustion plant that offer significant economies of scale for both the capture and transportation of $CO_2$. In the past, the development of technologies to reduce emissions from fossil fuels has related primarily to electricity generation as this has been seen as the main source of emissions of $CO_2$ and other noxious gases. Coal used for electricity generation in particular is a significant source producing more than twice the amount of $CO_2$ per unit of electricity generated than natural gas. Given the Government's aspiration for 20% of electricity to come from renewables technologies by 2020 the remaining demand will still need to be met by a combination of fossil fuel based electricity (ie from gas, coal or oil) or from nuclear plant. Consequently, power generation is an important area for the CAT Strategy. Large industrial sources, such as iron and steel making, ammonia production and oil refining, also produce large quantities of $CO_2$ as part of the production processes. CATs could also help to reduce $CO_2$ emissions significantly from these applications. Furthermore, looking

[1] Energy White Paper: Our energy future – creating a low carbon economy (February, 2003) (http://www.dti.gov.uk/energy/whitepaper/index.shtml)

to the future, fossil fuels with $CO_2$ capture are a competitive source of hydrogen, which is an important long-term option for reducing emissions from road transport.

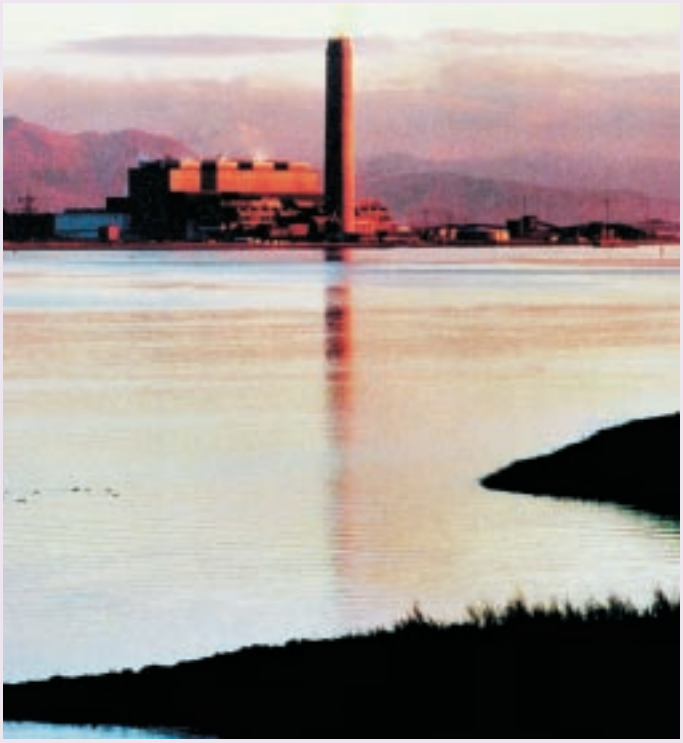
It is generally agreed that the key areas for long-term development of CATs are:

i. New approaches to greater efficiency in combustion and conversion processes, eg via new materials or advanced systems integration.

ii. $CO_2$ capture.

iii. Geological storage of $CO_2$.

**The UK's large coal-fired power stations are typical of large point sources of $CO_2$ emissions releasing 5-10 million tonnes per year. These emissions could be reduced through efficiency improvements and by the fitting of $CO_2$ capture technology. (Courtesy of Scottish Power)**



For areas i and ii above the R&D and demonstration work could range from the advancement of existing technologies, so that their emissions are reduced, to new technologies for separation and capture. For $CO_2$ storage (iii) there is an even broader range of requirements covering non-technical as well as environmental and geological issues, and critically the need to demonstrate that we can safely and reliably store $CO_2$ away from the atmosphere.

As part of the process for developing the Strategy a draft objective has been prepared which attempts to cover the two key components:

*"To facilitate the development of CAT technologies which significantly reduce or eliminate $CO_2$ emissions from industrial processes that use fossil fuels.*

*To address market and regulatory factors that will affect the implementation of CATs."*

In Section 5 we ask for comments on this objective.

We are keen to receive the views of stakeholders and other parties interested in this topic so that we can develop a strategy that is both relevant and realistic in its objectives. Annex C sets out the background to this Consultation and the role CATs could play in Government's longer-term objectives for reducing $CO_2$ emissions. As part of this Consultation we are seeking views on a number of key issues that will help to eventually shape the Strategy. These are described more fully in the Section 5 "Key Issues around Carbon Abatement Technologies and the development of a Strategy".

We have produced an initial Regulatory Impact Assessment (RIA) at Annex A for this Consultation but we are not clear at this stage if the Strategy itself will involve any regulatory impact. However, it is recognised that for

storing $CO_2$ a regulatory regime will need to be developed within the next 5-10 years. We would welcome views on the requirement for a RIA.

The Consultation is addressed to all stakeholders with an interest in these technologies as well as those concerned about the impact of $CO_2$ on the environment. A list of those organisations and individuals initially consulted is at Annex F. These include potential designers, developers, manufacturers, investors and operators of plant, fuel suppliers, non-governmental organisations concerned with the environment and climate change, and the general public.

To aid respondents a number of supporting documents covering the work completed to date on the investigation of CATs are available on the DTI's Web site at: http://www.dti.gov.uk/energy/coal/cfft/catscon/index.shtml

# 4. What Will Happen Next?

Once we have received the feedback to this Consultation we will analyse the responses and utilise them in the development process of the Strategy. In parallel with this Consultation further work is also being undertaken, including:

- Energy system analysis using the DTI's Markal Model to investigate the possible energy mix we will have in a long-term, low carbon future.

- An analysis of relevant UK business areas to assess their potential strengths for developing and exploiting CATs.

A report summarising the responses to this Consultation Paper will be published alongside the new Strategy when it is published at the turn of the year.

# 5. The Key Issues Around Carbon Abatement Technologies and the Development of a Strategy

## Rationale and Objectives of the CAT Strategy

The Energy White Paper's[2] long-term target to reduce $CO_2$ emissions by 60% by 2050 is challenging because most energy services are based on fossil fuels, such as coal and gas. This position is set to continue well into the future. Central to the White Paper's policy objectives is an enhanced drive for greater efficiency in all areas of energy supply and consumption; together with an expansion of low to zero emissions supply options, in particular renewable energy sources. While these are clearly priority areas, studies in support of the White Paper showed that to achieve the 60% reduction in $CO_2$ emissions by 2050 would also require other measures. CATs, in particular CCS, would enable the continued use of fossil fuels, thus providing a bridge to the eventual use of fully sustainable non-fossil energy sources.

CATs are most effectively applied to large combustion plant where they benefit from economies of scale. Consequently the focus of this Consultation is tilted towards $CO_2$ emissions from electricity generation and other large industrial activities. Looking further ahead, fossil fuels with CCS could be a major source of hydrogen as a means of reducing emissions from transport.

A number of countries are either already investing, or planning to invest, in CATs. This is particularly the case for those countries that have a heavy dependence on coal for electricity generation such as the USA and Australia. On the other hand the UK is moving more towards the use of natural gas for power generation, which produces less $CO_2$ per unit of output, although emissions from this source will also need to be reduced or eliminated if the 60% target for 2050 is to be achieved. New DTI energy projections[3] point to a need for a substantial reduction in fossil fuel related $CO_2$ emissions if we are to stay on our path for a 60% reduction by 2050.

**The Dakota Gasification Company's Great Plains Synfuel Plant supplies around 2 million tonnes per year of $CO_2$ for enhanced oil recovery in Canada's Weyburn oil field.**

In summary, the reductions in $CO_2$ emissions which are needed to address global climate change are set to become increasingly challenging as we move towards a 60% cut by 2050. CATs can contribute to this target at a comparable level with other major options such as more conventional energy efficiency, renewable energy and nuclear power. Our view is that CATs will enable us to continue to derive benefit from fossil fuel resources, and their supporting infrastructures, while making a long-term transition to more sustainable energy sources. The challenge facing the development of CATs is that they may not be needed for broad commercial deployment before about 2020, and consequently the market signals to encourage their development are weak. However, the development and

[2] Energy White Paper: Our energy future – creating a low carbon economy (February, 2003) (http://www.dti.gov.uk/energy/whitepaper/index.shtml)

[3] Updated UK Energy Projections – Working Paper (May 2004) http://www.dti.gov.uk/energy.sepn/uep.pdf

demonstration of the technologies will take 10-15 years and need to start now. In these circumstances Government has a role in facilitating development of the technologies.

## Given this background, some questions you may wish to consider are:

i. **Do you accept that Carbon Abatement Technologies (as defined in Annex D) are relevant to the future of UK energy supply?**

ii. **In your opinion will the draft objective (in Section 3) provide adequate direction for government action in respect of CATs in order to achieve the aims of the Energy White Paper?**

iii. **Do you think the UK has strengths and weaknesses in any particular areas of CATs? Are there any particular areas of CATs that you think we should focus on?**

iv. **Given that the power sector (and other sectors) are becoming increasingly global in ownership and operation do you consider that the UK should itself develop CATs or should it leave this to other countries (such as the USA) and buy these in when required?**

v. **What do you think would be the economic benefits for the UK in developing CATs both in terms of the UK economy and its role in global markets? In addition to power generation what other sectors do you think would benefit from a CAT programme and why?**

vi. **Given the opportunities for hydrogen production from fossil fuels, how do you think this should feature in the Strategy?**

vii. **What do you consider to be the potential barriers to the development and introduction of CATs? In your view how can the Government help to address them, for example through pricing of $CO_2$ emissions through emissions trading or similar policies?**

viii. **What do you think are the key features for CCS systems? How do you think $CO_2$ storage should be monitored in the long term?**

## Scope of the CAT Strategy

CATs include $CO_2$ separation or capture, transportation and long-term storage. In each of these areas there are a number of technical options as well as issues to be resolved. It is important to get the scope right so that the Strategy effectively contributes to the Energy White Paper's longer-term objectives. This requires consideration of a number of factors such as: should the UK focus on only part of the technology chain (eg storage), on key components, on developing design/ engineering expertise, on monitoring and verification methods, etc? In turn, this requires consideration of the UK's specific needs and the strength of our technology base and businesses to meet the challenge and grasp the opportunities presented in bringing a new technology to market.

The emphasis of previous Government R&D has been on coal, given its high level of $CO_2$ emissions compared with other fossil fuels. However, natural gas now accounts for around a third of electricity generation in the UK and recent projections anticipate this share increasing up to 2020[4].

[4] Updated UK Energy Projections – Working Paper (May 2004) http://www.dti.gov.uk/energy.sepn/uep.pdf

Natural Gas has less than half the $CO_2$ emissions of coal but will still need the application of CAT plant if the 60% reduction target for 2050 is to be achieved. Furthermore, it also offers one of the lowest cost options for producing hydrogen (with CCS technologies), which is a leading option for reducing $CO_2$ emissions from road transport.

**Schematic of Progressive Energy's design for a 460MW IGCC power station at Drym, Wales. Such $CO_2$ "capture ready" coal-fired plant designs are one route for advancing CATs.**

$CO_2$ emissions in the UK come from a number of stationary and mobile sources. Table 1 provides a broad overview of the sources of $CO_2$ emissions in 2002, which makes clear that power generation is the major group of point source emissions. Other major industrial sources of $CO_2$ emissions include iron and steel making, ammonia production and oil refining. Furthermore, looking to the future, fossil fuels with $CO_2$ capture are a competitive source of hydrogen, which is an important option for reducing emissions from road transport.

Evidence to date suggests that capturing $CO_2$ from certain non-power generation point sources offers lower cost opportunities for developing CCS technologies, which could eventually be applied to electricity generation plant.

CATs involve a broad range of disciplines and technologies including power generation equipment, consulting and process

**Table 1 $CO_2$ emissions by source, 2002[5]**

| Source | Million Tonnes of Carbon Dioxide | % |
|---|---|---|
| Central Power Generation | 157.7 | 29.4 |
| Refineries | 16.1 | 3.1 |
| Combustion in fuel extraction and transformation | 22.0 | 4.1 |
| Industry | 91.7 | 17.0 |
| Domestic | 87.3 | 16.3 |
| Services | 26.4 | 4.9 |
| Transport | 129.4 | 24.0 |
| Other | 6.2 | 1.2 |
| **Total** | **536.8** | **100** |

engineering, upstream oil and gas operations and geological sciences. Consequently, the benefits from a CAT programme may be captured from a broader range of consultancy and design services as well as manufacture.

It is generally agreed that the key areas for development with CATs are:

- New approaches to increased combustion and conversion efficiency, (in particular new materials and process integration).
- $CO_2$ capture on large combustion and process plant, and
- The geological storage of $CO_2$.

For $CO_2$ capture, R&D and demonstration could range from new concepts to the improvement and optimisation of existing technologies. For $CO_2$ storage there is an even broader range of requirements. For example there is a need for studies to guide the selection of suitable storage sites, for specifying operating conditions and for establishing high integrity

[5] Source – Energy Trends 2003

methods for final closure of an injection site. There is also a requirement for sensitive and cost effective long-term monitoring techniques to confirm that the $CO_2$ is behaving as expected. Finally there is a need to demonstrate storage so that we can fully understand the process in practice.

**With these factors in mind we would like your views on the following:**

i. **To what extent do you think that a strategy should focus on CATs for coal plant and natural gas plant? Should it, for example, give equal weight to reducing $CO_2$ emissions from both fuels?**

ii. **Do you agree that the CAT Strategy should cover all major sources of $CO_2$ emissions from fossil fuel use, not just power generation? If so why?**

iii. **What businesses and organisations do you think we should involve as stakeholders in a new CAT Strategy?**

iv. **In your view, what should be the main components making up the scope of a CAT Strategy?**

## What does the Strategy need to do to achieve its objectives?

The Advanced Power Generation Technology Forum (APGTF) developed a power industries view of a future strategy for developing CATs (A Vision for Clean Fossil Fuel Power Generation - Recommendations for a UK Carbon Abatement Programme for Fossil Fuel Power Generation 2004)[6]. This has advocated a twin track approach involving:

(a) The evolutionary development of power generation technologies to gain improvements in generation efficiency and costs.

(b) More radical development of $CO_2$ capture options.

The APGTF argues that these two approaches are complementary because efficiency improvements will benefit $CO_2$ capture by reducing the energy penalty and hence its cost. Paragraph 1 of Annex D introduces three classes of technology for managing carbon emissions. These are seen to cover the key future technologies for $CO_2$ reductions from fossil fuels, although CCS could be seen as the main thrust of the Strategy.

The existing Cleaner Coal Technology Programme provided Government support for UK-based collaborative industrial R&D. In all, some 39 projects covering a variety of technologies for reducing emissions from coal combustion received upwards of a third of the costs, about £9M, from the Programme. From the last Call a further 9 projects could received support for which a further £4M is being made available. A recent review by NERA[7] considered this to have been a successful programme. However, in the case of CATs that involve a chain of technologies and therefore a broader range of technology providers, or require major investment to demonstrate at near to full-scale and have much greater international interest, a different approach may be appropriate. As part of the Strategy development, Technology Transfer and Export Promotion activities (which have been part of the Cleaner Coal Technology Programme) will be reviewed to determine if they should remain a part of the CAT Strategy.

The Research Councils, particularly EPSRC, as well as the new UK Energy Research Centre (UKERC) also have an interest in R&D into CATs. The Carbon Trust also includes CCS in its portfolio of sustainable technologies. The

[6] Available at www.dti.gov.uk/energy/coal/cfft/catscon/apgtfreport.pdf

[7] Evaluation of the Cleaner Coal Technologies Programme, NERA, July 2004

British Coal Utilisation Research Council (BCURA) finances university R&D to about £300k per year - the DTI Cleaner Fossil Fuels programme funds about half of this. Clearly there should be a continuum between basic and applied science, industrial research and development and demonstration. It is important that there should be a clear liaison and interface between the work funded by the Research Councils and the "industrial R&D" supported by the DTI.

If CATs are to be deployed on a commercial scale after about 2020 there will be a need for major demonstration projects ahead of this date. Because of their size such projects will involve a high capital investment, and therefore only a few are likely to be implemented worldwide. The recent review on an Enhanced Oil Recovery[8] demonstration project using $CO_2$ found that this technology was not considered commercially feasible to warrant a demonstration, although it could still offer a lower-cost option for a demonstration of $CO_2$ storage in the North Sea. It may also be possible to implement a demonstration of storage alone, thus avoiding the high investment in capture facilities, by using $CO_2$ that is produced in association with natural gas. Of course not demonstrating capture misses a key technology area, but would address another key issue which is the integrity of long-term storage.

The UK is presently involved in a range of international activities aimed at advancing CATs. These include the Carbon Sequestration Leadership Forum (CSLF); a project with Germany investigating the possibilities of collaboration within the EU; programmes organised through the International Energy Agency (IEA), including the IEA Greenhouse Gas R&D Programme; and Framework Programmes sponsored by the European Commission. Additionally, the UK has bi-lateral collaborations with the USA and China under Memorandums of Understanding for joint activities on the development of advanced energy technologies. It is widely considered that given the very high cost of developing new technologies such as CCS, the best approach will be for collaboration with other countries.

**The pilot-scale facility at the Boundary Dam power plant in Canada is used to test key components for $CO_2$ capture.**

In addition to technical development there is a range of other factors needing to be addressed before CATs can be fully deployed. These cover the issues around the transport and storage of $CO_2$, and the Review of the Feasibility of $CO_2$ Capture and Storage in the UK[9] identified the key issues as:

- Legal and regulatory standards for storage.
- Monitoring and verification standards for storage.

[8] Implementing a Demonstration of Enhanced Oil Recovery using $CO_2$, DTI, April 2004

[9] Review of the Feasibility of $CO_2$ Capture and Storage in the UK, DTI, 2003

- Acceptance under international emissions inventory conventions including the process for reviewing inventories submitted to the United Nations Framework Convention on Climate Change.

- Acceptance into the EU emissions trading system.

- Relationship to other international treaties including (for disposal in strata below the sea bed) the OSPAR and London Conventions.

CATs are being advocated because of the growing need to reduce and reverse the trend in greenhouse gas emissions. However, the issues around the deployment of CATs will go beyond these and will impact on the public more generally. For example, in the case of CCS, local populations will be affected in the short term by the construction of capture plant and transport pipelines. Also there will be understandable concerns about the long-term integrity of the storage sites and the implication of any technical failures over the capture, transport and storage chain. NGOs and the public in general will want to weigh these potential impacts against similar concerns about energy options (eg wind energy, nuclear power).

**The Sleipner Project injects about 1 million tonnes of $CO_2$ a year into a sub-seabed aquifer in the North Sea. This is acting as a test bed for monitoring and confirming the long-term confinement of $CO_2$ in geological storage. (Courtesy of Statoil)**

## With these factors in mind we would like your views on:

**i. What do you see as the critical technologies for development over the next 15 years?**

**ii. Do you think the CAT Strategy should follow a two-track approach supporting incremental improvements to fossil fuel combustion technologies as well as CCS?**

**iii. What do you think should be the balance between CCS and other CAT technologies?**

**iv. Do you think we should have a further programme of supported R&D activity in the UK alone or should we place the emphasis more on international collaborative projects with some UK funding?**

**v. Do you agree with the classification of CATs given in Annex D and what actions should we take to mesh with the work done in other areas and programmes, such as the work of the Research Councils?**

**vi. Do you think there are any specific actions needed to ensure that there is effective cooperation between academic and industrial research programmes on CATs?**

**vii. Do you think a large-scale demonstration project would be worthwhile in the near future? What do you think should be its objective and scope?**

*Continued overleaf…*

viii. **Do you think the UK should seek to host such a project and, if so, how should we seek to capture the benefits; or would we gain better value by collaborating with a project elsewhere?**

ix. **Do you think there should be broad collaboration with a large group of countries (such as the CSLF) or should we concentrate on setting up further bi-lateral collaborations with key partners?**

x. **Do you agree with the key issues for CCS technologies identified in the DTI's feasibility review of CCS technologies? Are there other issues or barriers that government should be addressing?**

xi. **How do you think CATs should be positioned against other long-term abatement options?**

xii. **What actions do you think the UK Government should undertake to facilitate an informed public debate on the choices that will need to be made?**

xiii. **Do you consider that we should retain the Technology Transfer and Exports Promotion activities of the old Cleaner Coal Technology programme in the new CAT Strategy?**

xiv. **What if any, additional actions do you think the UK Government should be undertaking to assess risks associated with CCS, either alone or in collaboration with other countries?**

xv. **What if any, additional actions do you think the UK Government should be undertaking to develop emissions inventory, monitoring and verification methods for CCS, either alone or in collaboration with other countries?**

## Any other Aspects?

1. Although we have attempted to cover the key issues above we recognise that there could be other important issues that should be taken into account when developing the Strategy.

   - **Are there any other issues that you think we should be considering in developing this Strategy?**

2. We have attached an initial Regulatory Impact Assessment to the Consultation Paper, although the CAT Strategy itself may not require one at this stage. It is recognised that if any Regulatory regime for CCS is developed then a full RIA will be required.

   - **We would welcome your views on whether there will be a regulatory impact as a result of this Strategy being implemented.**

# Annex A Initial Regulatory Impact Assessment

This is an initial RIA as we are concerned at this stage with early policy development. If required, a fuller RIA will be developed once the Strategy is in place. It is not proposed that this Consultation paper will lead to the development of Regulations for Carbon Abatement Technologies. Indeed, it is rather seeking advice from the public about the nature and shape of a strategy for developing these technologies and for essentially providing a regime in which they can be successfully deployed. We are asking what we should be doing to be effective in helping to bring these technologies to the market place by about 2020. It is thought that in the case of $CO_2$ transport and storage a regulatory regime will need to be developed but this will be the subject of a new Consultation Process when it is required. At this stage it is thought that it is likely that any regulatory regime for CCS will be similar to the existing oil/gas regulatory regimes that are already applied in the North Sea.

## The Issues

Annex C to this Consultation Paper sets out the issues surrounding the initiative to develop the Carbon Abatement Technology Strategy. The objective for developing the strategy is to provide a clear direction and framework for the future development of technologies that either reduce or are capable of eliminating carbon emissions from stationary industrial sources using fossil fuel combustion. Given over half of $CO_2$ emissions are generated from power generation, this is clearly a target area for any strategy, although there are other industries emitting $CO_2$ which might also benefit from the eventual deployment of these technologies.

The area is a complex one and covers a number of issues from a variety of disciplines, as follows:

i. R&D ranging from "blue sky" to "close to the market" technologies, not only for carbon capture technologies but also for making existing combustion technologies more efficient and less polluting.

ii. Geological issues around the storage of $CO_2$ beneath the ground.

iii. The development of measurement and verification regimes for measuring the behaviour of the sequestered $CO_2$.

iv. Systems for controlling the transport and injection of the $CO_2$ to ensure there are no seepages to atmosphere.

v. Public outreach so that there can be informed debate about the benefits and risks associated with these technologies.

vi. There are many other issues that will have to be considered in time, such as financing regimes for CCS projects.

The Consultation seeks to identify what we need to be doing to develop technologies and the associated regimes that will tackle carbon emissions from fossil fuel use.

## The Risks

The Strategy is being developed because it is important to identify and address those areas where market failure will discourage the long-term development of these technologies. It is important to understand therefore what Government needs to do to encourage R&D and the eventual deployment of these technologies. At this stage it is not possible to quantify the risks until a more detailed set of

proposals has been developed. However, it is clear that there is a risk that by not developing a strategy little will be done in the UK at the moment to develop new sustainable fossil fuel based technologies. It is fully expected that Government will need to work with stakeholders over the next 15 years to ensure that the right technologies and regimes are developed for their successful introduction.

## The Options

There are no regulatory versus non-regulatory options to be considered at this stage. As already stated, it is not expected that there will be a regulatory impact arising directly from this Strategy although this Consultation is seeking views on this. It is very likely that, later, a regulatory regime will need to be defined for the transport and storage of $CO_2$, but this would be subject to a separate consultation.

## Business Areas Affected

This strategy will involve businesses in the energy sector, although it is possible that other industrial sectors emitting $CO_2$, such as the chemical, metal and oil refinery industries, could also be involved.

## Costs and Benefits

Costs and benefits associated with Strategy will be determined as part of its development.

## Unintended Consequences

Unintended consequences are not anticipated at this stage.

## Distributional Impacts

It is not expected that there will be distributional impacts as a result of this strategy.

## Competition Issues

Competition issues will need to be assessed once the Strategy is in place. When it is developed, it would enable the UK's energy industry to keep up with other countries in the field of CATs.

# Annex B The Consultation Criteria

## The Consultation Code of Practice Criteria

Consult widely throughout the process, allowing a minimum of 12 weeks for written consultation at least once during the development of the policy.

Be clear about what your proposals are, who may be affected, what questions are being asked and the timescale for responses.

Ensure that your consultation is clear, concise and widely accessible.

Give feedback regarding the responses received and how the consultation process influenced the policy.

Monitor your department's effectiveness at consultation, including through the use of a designated consultation co-ordinator.

Ensure your consultation follows better regulation best practice, including carrying out a RIA if appropriate.

The complete code is available on the Cabinet Office's Web site, http://www.cabinet-office.gov.uk/servicefirst/index/consultation.htm.

## Comments or Complaints

If you wish to comment on the conduct of this Consultation or make a complaint about the way this Consultation has been conducted, please write to Nick Van Benschoten, DTI Consultation Co-ordinator, Room 723, 1 Victoria Street, London SW1H 0ET or telephone him on 020 7215 6206 or e-mail to: nick.vanbenschoten@dti.gsi.gov.uk.

# Annex C Background to the Development of a Carbon Abatement Technology Strategy

The Strategy's aim is to encourage the development of CATs, which produce much less $CO_2$ than at present, and, in the longer term, technologies with near to zero $CO_2$ emissions. For electricity generation there are a variety of ways we can reduce $CO_2$ emissions in the near term; this can be achieved either by making our existing coal and gas power stations produce less $CO_2$ by improving their efficiency or by mixing the coal and gas with $CO_2$-neutral materials, such as energy crops. These technologies have the potential to reduce emissions by the order of 10-20% and consequently would not be sufficient for us to meet our 2050 target. A more radical approach is to prevent the $CO_2$ from getting into the atmosphere in the first place by developing technologies that would capture it at the power station/combustion plant and then store it deep under the ground - in effect putting it back into the ground. The UK has such potential storage sites in the depleted oil and gas fields under the North Sea where the $CO_2$ could possibly be stored permanently. There are also other storage sites, such as saline aquifers, where the water is unlikely to be of use in the future. In all, estimates from the British Geological Survey indicate that we have sufficient storage capacity under the North Sea to store $CO_2$ for well over 100 years if we continued to emit it at the same rate as we do at present.

If we are to have these technologies ready for use either before or by 2020, such that they are commercially attractive for companies to use, then we need to address the challenges affecting their development. To get to this point we believe a number of activities will be required on several fronts:

- Significant R&D will be needed over the next 15 years to reduce the cost and increase the efficiency of the technologies used to separate the $CO_2$ from plant emissions.
- We need to extend our knowledge about how the $CO_2$ will behave once it is stored geologically beneath the surface in order to support assessments of the risks of its escaping back to the atmosphere.
- We also need to develop the right legal and regulatory regimes to ensure that the $CO_2$ is managed responsibly and that the chances of its leaking to the atmosphere are minimised, not only after injection but also during its transportation from the point where it was captured to the storage site.

To support the development of this Strategy the DTI has more recently undertaken a number of studies. Among these studies are:

- A review of the feasibility of using Carbon Capture and Storage technologies in the UK[10]. This review found that these technologies do have the potential to almost completely eliminate $CO_2$ emissions from large combustion plant and could make a major contribution to attaining the Energy White Paper's target. It recommended 'that a new fossil fuel carbon management programme be developed to complement or possibly replace the existing Cleaner Coal Technology Programme, to include the development of activities for $CO_2$ capture and storage'. **www.dti.gov.uk/energy/coal/cfft/co2capture/review.pdf**
- A recent independent review of the Cleaner Coal Technology Programme by NERA also advised on the future direction of a CAT Strategy. **www.dti.gov.uk/energy/coal/cfft/catscon/nerareport.pdf**
- A Study following on from the White Paper recommendations examined the feasibility

[10] Review of the Feasibility of $CO_2$ Capture and Storage in the UK, DTI, 2003

of Enhanced Oil Recovery using $CO_2$. This concluded that $CO_2$-based Enhanced Oil Recovery in the North Sea was not currently commercially viable, but offered a lower cost and legally acceptable route for demonstrating capture and storage.
**www.dti.gov.uk/energy/coal/cfft/eorreportfinal.pdf**

- A review of the feasibility of Underground Coal Gasification, which suggested that this technology might be viable beyond 2020.
**www.dti.gov.uk/energy/coal/cfft/gasification.shtml**

- A study by the industry-led Advanced Power Generation Technical Forum (APGTF) defined its view of a strategy for $CO_2$ reduction from power generation.
**www.dti.gov.uk/energy/coal/cfft/catscon/apgtfreport.pdf**

- Reports on the findings of the DTI's International Technology Partnership missions to the USA, Canada and Australia.
**www.globalwatchonline.com/missions/tmsmrep**

These reports can be found on the DTI Web sites as indicated above.

# Annex D What are Carbon Abatement Technologies?

Fossil fuel CATs may be defined as technologies that enable large fossil fuel plant to operate with substantially lower, or possibly near to zero, $CO_2$ emissions. They can be conveniently regarded as falling into three groups of complementary development options:

- Improvement in combustion/conversion efficiency.
- Co-firing with $CO_2$-neutral biomass fuels.
- Techniques for capturing $CO_2$ from the combustion process and committing it to long-term storage (CCS technologies).

The first two options offer reductions in emissions of the order of 10-20%, and are near-term and of limited risk to implement, while the latter option can give very radical reductions, but over a longer time-scale. Consequently, efficiency improvement and co-firing should be regarded as short-term abatement options, whereas CCS is the only fossil fuel option that can help deliver the 20-60% cut in emissions needed from 2020 to 2050.

Many of the improvements in combustion/conversion efficiency represent the normal development and improvement of a technology. They involve a range of incremental advances such as improved gas and steam turbines, more efficient boilers, more efficient gasifiers and advanced concepts in plant integration. These in turn are underpinned by enabling developments including advanced computer simulation models, high temperature materials and better control and condition monitoring sensors.

Using a proportion of waste and biomass (eg energy crops) as a fuel for fossil plant offers the opportunity to advance this form of renewable energy supply, without the high capital cost of a dedicated biomass power plant. This also has the benefit of supporting the development of an energy crop supply chain (ie planting, harvesting, storage and preparation) before dedicated plant are built.

In contrast to efficiency improvements and co-firing, CCS incorporates a chain of technologies for $CO_2$ capture, transportation and storage. Transportation of $CO_2$ by pipeline, road, rail and sea are established methods, but there are considerable opportunities for development in the capture and storage phases. There are three basic options for $CO_2$ capture, namely:

- Post-combustion capture in which the $CO_2$ is separated from flue gases.
- Pre-combustion capture in which the $CO_2$ is captured prior to combustion, generally by a shift reaction to convert fuel gases to $CO_2$ and hydrogen.
- Oxy-firing in which fuel is burnt in an oxygen/$CO_2$ mixture, thus producing a $CO_2$-rich flue gas that is easier to capture.

A related option is Underground Coal Gasification, in which coal is gasified in the seam and brought to the surface where $CO_2$ separation would take place. When commercially viable, this would enable the UK to exploit the considerable virgin coal reserves it has under the southern section of the North Sea.

The favoured options for $CO_2$ storage utilise injection into geological formations, and include:

- Deep saline aquifers where the water resource is unlikely to be of use in the future.
- Depleted oil and natural gas reservoirs.
- Coal seams in which the $CO_2$ may displace coalbed methane that may be collected and used as an energy source.

- Depleted oil reservoirs where the $CO_2$ can mobilise some of the remaining oil thus facilitating enhanced oil recovery.

R&D is needed to improve the capture technologies by:

- Reducing their capital costs.

- Improving significantly their efficiency in using fuels for generation and for the separation process itself.

Also, at an appropriate stage, there will be a need to demonstrate the technology to gain experience in its operation, regulation and management.

R&D is also needed for geological storage, particularly to build up a knowledge base to help select suitable storage media, specify operating conditions, establish high integrity post-injection management and generally give confidence that reliable and safe long-term storage can be achieved. There is also a requirement to establish a portfolio of monitoring and verification techniques that can be used to check the containment of the $CO_2$.

# Annex E Glossary of Terms

| | |
|---|---|
| **APGTF** | Advance Power Generation Technology Forum. An industry-led body that liaises with Government on advanced power generation issues. |
| **Carbon Trust** | An independent not-for-profit company set up by the Government with support from business to encourage and promote the development of low carbon technologies. Key to this aim is its support for UK business in reducing CO2 emissions by supporting technological innovation and by encouraging more energy efficient practices. |
| **Carbon Dioxide ($CO_2$)** | A greenhouse gas. |
| **CAT** | Carbon Abatement Technology - technologies that reduce or eliminate carbon emissions from industrial processes especially fossil fuel electricity generation. Carbon Capture and Storage is one form of CAT. |
| **CCS** | Carbon Capture and Storage or Carbon Sequestration - the process by which $CO_2$ is separated from the flue gas, captured and then permanently stored beneath the ground. |
| **CSLF** | Carbon Sequestration Leadership Forum - a grouping initiated by the US Department of Energy in June 2003 to facilitate international cooperation in the development of CCS. The CSLF presently has 17 member countries plus the European Commission. |
| **EPSRC** | Engineering and Physical Sciences Research Council. |
| **Enhanced Oil Recovery (EOR)** | Increased production of oil from an oil field brought about by injecting gas (eg $CO_2$) and/or water to mobilise and move more oil out of the field. |
| **EU ETS - European Union Emissions Trading Scheme** | A scheme covering all EU Member States, to be introduced in April 2005, in which greenhouse gas emissions are controlled by setting a cap on total emissions and allowing participating market sectors to reach an economically balanced response via trading of emissions allowances. |
| **Greenhouse Gases** | Gases that contribute to global warming through the "Greenhouse Effect". |
| **Hydrogen** | A gas that burns without producing $CO_2$, and therefore may be used as an alternative energy source for certain applications such as road transport without producing $CO_2$ at the point of use. |
| **International Energy Agency (IEA)** | An autonomous body established in 1974 within the framework of the OECD to implement an international energy programme. |

| | |
|---|---|
| **IEA Greenhouse Gas R&D Programme** | An implementing agreement arranged under the auspices of IEA to undertake research and assessment of CCS technologies. |
| **Research Councils** | The bodies charged with managing Government funding for academic research in the UK. |
| **UKERC** | UK Energy Research Centre - a body to be established by the research councils to act as a focal point for energy-related academic research. |

# Annex F List of Consultees

Abb Combustion Services Ltd
Abb Lummus Crest
Abb Power Construction Ltd
Abmec
Abr Automation
Advantica
Advisory Committee on Business & the Environment
Aea Environment
Drax Power Ltd
Air Products Plc
Ait
Alcan Primary Metal - Europe
Alcan Smelting & Power
Alkane Energy Plc
Alstom Power UK Ltd
Amerada Hess International Ltd
AMEC Group Plc
Andrew Robertson & Associates
Apache Oil
Arup Energy
Ashwell Engineering Services Ltd
Association for the Conservation of Energy
Association Of Manufacturers Of Power Generation Systems
Association of Electricity Producers
Aston University
Atkins Global
Aube Energy & Environment
Babcock King Wilkinson
Bcra Scientific & Technical Services Ltd
BCURA
Bdt Engineering
Beel Industrial Boilers Plc
Bloomberg
Blue Circle Industries Plc
BNFL
Boc Gases
Boiler Energy Services Ltd
BP plc
BRINDEX
British Energy Plc
British Geological Survey
British Nuclear Industry Forum
Byworth Boilers
Cambridge Econometrics
Cambridge University
Caminus Energy
Carbon Trust
Carew Mountain
Casella Cre Energy
Celtic Energy Ltd
Centrica
Chemical Industry Association
Christison (Scientific Equipment) Ltd
Cinar Ltd
City University
Clyde Bergemann Ltd
CO2Net
Coal Authority
Coal International
Coal Products Ltd
Coal Research Forum
Coalfield Communities Campaign
Coalite Smokeless Fuels
Coaltrans International
Codel International
Combined Heat & Power Association
Conoco
Confederation of British Industry
Confederation Of UK Coal Producers (Coalpro)
Coolkeeragh Power Ltd
Corus Engineering Steels
Corus R, D & T
Countryside Council For Wales
Cpl Industries
Cranfield University
Crown Estates
Dargo Associates Limited
David Wolfenden & Co Ltd
Davis Derby Ltd
Davy International Environment Division
Dce Ltd
DEFRA
Delkor Limited
Derek Parnaby Cyclones Int Ltd
DFID
Dirk European Holdings
Dnv Consulting
Doncaster College
Dosco Overseas Engineering Ltd
Dunsley Heat Ltd
Dyson Industries Ltd
Ecosecurities Ltd
Edison Mission Energy
Edt
Electricity Association
Electrowatt Engineering Services UK Ltd
Elsevier Science Ltd
Elyo UK Limited
Emc Environment Engineering
Energy & Internet Services
Energy Intelligence & Marketing Research Ltd
Energy Savings Trust
Energy Watch
Engineers' and Managers' Association
Environment Agency
EPSRC
Ergotech
Eure Enterprise
Exxon Mobil
Fernwood Holdings Ltd
Fichtner Consulting Engineers Limited
Finning Ltd
Fletcher Smith Limited

Fluor Ltd
Foster Wheeler Energy Ltd
Forum for the Future
Friends Of The Earth
Fuel Cells UK
Gamos Ltd
Gas Forum
GASTEC At CRE Ltd
Geodrilling International
George Waterhouse Consultants Ltd
Georgia Pacific Ltd
GPU Power
Glasgow Caledonian University
Global Energy Europe Ltd
Gray Associates
Green Alliance
Greenpeace
H2Net
Hamworthy Combustion Engineering
Heriot Watt University
Honden Drilling Equipment
House Of Commons
House of Lords
Howden Power Ltd
Icel Developments Ltd
ICI Chemicals & Polymers Ltd
ICI Engineering Technology
IEA Coal Research
IEA Greenhouse Gas R & D Programme
IMC Group Consulting Limited
Imi Marston Ltd
Imperial College Of Science, Technology & Medicine
Inco2
Incoteco Aps
Industrial And Power Association
Inspectorate Griffith Ltd
Institution Of Chemical Engineers
Institution Of Civil Engineers
Institute of Directors
Institution Of Electrical Engineers
Institution of Gas Engineers
Institute of Energy
Institution Of Mechanical Engineers
Institution Of Mining & Metallurgy
Institute of Public Policy Research
Intergen
Interim Energy Management Ltd
International Power
International Technology Promoters (Itp) Programme
J Flack & Sons Ltd
Jacobs Engineering UK Ltd
Jilland Engineering
John Brown Engineers & Constructors Ltd
Johnson Matthey Technology Centre
Kaye & Associates Limited
Keepmere Eng Ltd
Ken Fergusson
Ken Parker Consultant Apc
Kingfisher Industrial
Kleinwort Benson
Kpmg
K-S Tech Ltd
Kvaerner E&C
LE Group plc
Lodge Sturtevant Ltd
London Convention
London Power Company Plc
M.W. Kellogg Ltd
Major Energy Users Council
Martin R Fry & Associates
Maxwell Mineral Services Ltd
Mccloskey Coal Information Service
Me Engineering
Metrode Products Ltd
Microscal Ltd
Middlesex University
Miro (Mineral Industry Research Organisation)
Mitsui Babcock Energy Ltd
Modern Power Systems
Mott Macdonald Ltd
National Economic Research Associates (Nera)
National Energy Action
National Grid Transco Plc
National Union Of Miners
NEL
Newcastle Upon Tyne University
Nifes Consulting Group
Nifes Energy Supplies
Nnc Ltd
Norec Ltd
Northern Electric plc
Nottingham University
Nottinghamshire County Council
Nrcods
Nuclear Electric Ltd
OFGEM
Oldham Crompton Batteries Ltd
Orenstein & Koppel Ltd
Orion Technical Services
OSPAR Commission
Oxford Economic Research Associates
P Cammack Consultants
P.R. Marriott Drilling Ltd
Pan Canadian Petroleum UK
Parsons Brinckerhoff Ltd
Particle Consultants Ltd
Patrick Associates
PB Power Ltd
Peddada Consultants Inc
Pentol Enviro UK Ltd
Plymouth Marine Laboratory
Policy Studies Institute
Polton Ltd
Polysius Ltd

Power Engineering Ltd
Powergen UK Plc
PriceWaterhouseCoopers
Process Engineering
Procon Engineering Ltd
Progressive Energy Ltd
Purvin & Gertz Inc
Queen Mary College, University Of London
Quintessa
Reeves Technologies Ltd
Renewable Power Systems Ltd
Richard Mozley Ltd
Rio Tinto Technical Services
Rock Mechanics Technology
Rolls-Royce
Royal Academy of Engineering
Royal Commission on Environmental Pollution
Royal Society For The Protection Of Birds (RSPB)
Rs Darby
Rtz Technical Services Ltd
Rwe Innogy
Salford College
Schlumerberger Oilfield Services
Scottish Coal Company Ltd
Scottish Executive
Scottish and Southern Energy
ScottishPower
Seeboard Energy Limited
Senior Thermal Engineering Ltd
Servomex Group Ltd
Shell UK
Shannon Consultants
Sheffield Hallam University
Siemens Plc
Sir Alexander Gibb & Partners Ltd
Society of British Gas Industries
Southampton Oceanography Centre
Ssm Coal Ltd
Ssy Consultancy & Research Ltd
Staffordshire University
Star Energy
Statoil R&D Centre
Steffen Robertson & Kirsten (UK) Ltd
Strutt & Parker
Talisman Energy UK
Taylor Woodrow Construction Ltd
Technology Initiatives
Texaco
The Carborundum Company Ltd
The Chemical Engineer
The Economist Intelligence Unit Ltd
The Geological Society
The Institute Of Materials
The Institution Of Civil Engineers
TotalFina
Tower Colliery Ltd
Trade & Industry Select Committee
Trade Partners UK
Trade Union Congress
Tyndale Centre (UMIST)
Txu Europe Power Ltd
UEA
UKAEA
UK Coal Plc
UK Offshore Operators Association
UK Petroleum Industry Association
UMIST
Union Of Democratic Mine Workers
United Kingdom Off-Shore Operators Association
University of Leeds
University of Liverpool
University College London
University Of Bath
University Of Birmingham
University Of Bradford
University Of Bristol
University Of Cambridge
University Of Durham
University Of Edinburgh
University Of Glamorgan
University Of Greenwich
University Of Leeds
University Of Newcastle Upon Tyne
University Of Nottingham
University Of Sheffield
University Of Sunderland
University Of Surrey
University Of Teesside
University Of The West Of England
University Of Ulster
University Of Wales
University Of Sheffield
Wardell Armstrong
Welsh Assembly
Welsh Energy
West Nottinghamshire College
Western Power Distribution
World Coal Institute
Ws Atkins
World Wide Fund for Nature UK
Yorkshire Electricity Group Plc
Zennith Oil

R262

Printed on paper containing a minimum of 75% post-consumer waste.

DTI/Pub URN 04/1476