Implementing a Demonstration of Enhanced Oil Recovery Using Carbon Dioxide

Executive Summary

The Energy White Paper, *Our Energy Future - Creating a Low Carbon Economy*, put the UK on a path to a 60% reduction in carbon dioxide (CO_2) emissions by 2050. Central to this policy was 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. CO_2 capture and storage (CCS), in which CO_2 from fossil fuel combustion plant is separated and committed to long-term storage, was also recognised to be strategically important. CCS would enable the continued use of fossil fuels, thereby giving a longer timeframe to achieve a transition to a fully sustainable energy system. It would also facilitate the use of a greater diversity of energy sources, thus enhancing security of supply.

At the time of the Energy White Paper a review of CCS was underway, and preliminary results were showing that CO_2 storage in depleted oil fields was a potentially important option for near-term action. This prompted inclusion in the Energy White Paper of a commitment to "set up an urgent detailed implementation plan with developers, generators and the oil producers to establish what needs to be done to get a demonstration [of EOR] project off the ground".

The Energy White Paper's commitment was concerned with getting a demonstration of CO_2-based EOR off the ground, and did not explicitly consider the source of CO_2 to be used. However, the commitment also acknowledged "the potentially significant strategic role that might be played by CCS in longer-term energy security". Therefore, at the outset of the project, the aim was to look for opportunities to demonstrate the full chain of CCS technologies, including capture from a large combustion plant and bulk transportation, as well as EOR itself. Nonetheless it was recognised that a pragmatic approach was needed since cost and logistic considerations would determine both the size of the scheme and the source of CO_2 to be used.

The main action for examining implementation options was to canvas the views of individual stakeholder organisations through a series of one-to-one meetings. These meetings involved oil producers (some also operated refinery plant), power generation companies, equipment suppliers and one broker of a CO_2 delivery system. The consultations were based on a standard set of questions, which sought to gauge the value of an EOR demonstration project and the interest of the stakeholder in becoming involved. These questions were:

- What are the barriers (technical, economic, contractual, regulatory, etc) in the way of CO_2-based EOR in the UK North Sea?
- Would a demonstration project help give a better understanding of these barriers and uncertainties and how they can be reduced?
- What needs to be done to define the most appropriate UK-based CCS demonstration project?
- Under what conditions would your company be prepared to host an EOR demonstration scheme in the UK North Sea?

- Under what conditions would your company be prepared to take a stake in, and operate, a demonstration electricity generation plant incorporating CO_2 capture?
- Could CO_2 emission credits enhance the prospects for EOR?
- Which international funding sources should be contacted to seek support for a UK EOR demonstration?
- What can government do to reduce investment uncertainties?
- What can government do to bring stakeholders together?

This process showed that oil producers regarded CO_2 based EOR as a proven technique from experience with onshore applications, and that they knew how to apply it in the North Sea without need for a demonstration project. The consultation also confirmed the conclusion of the CCS Review that under current market conditions EOR using CO_2 is not a commercial option for the UK North Sea.

The level of support needed to bridge the economic gap and encourage investment in EOR is uncertain, but stakeholders thought it unlikely that carbon emission credits from the European Union Emissions Trading Scheme (EU ETS) would be sufficient. Consequently, if EOR is to be deployed broadly in the UK North Sea additional market changes will be needed. The main approach available to government would be to adjust the tax system applying to oil production in the UK North Sea to reduce any barriers this presents to investment in EOR.

The PILOT initiative has recently set up a 'brown fields think tank', to address the technical and commercial barriers to further development of mature oilfields. It is very likely that the application of EOR methods (including CO_2 injection) will be included in the variety of techniques for increasing oil recovery evaluated by this group, and it is to be expected that the industry side will bring up the issue of taxation of this incremental activity. The 'brown fields think tank' has only just started its work and its report is expected later in 2004.

Setting aside wide scale deployment, CO_2 based EOR offers an option for a one-off demonstration of the full chain of CCS technologies. EOR has the advantage of providing some financial return to partially offset costs, and the injection of CO_2 into oil reservoirs underlying the North Sea is accepted to be permissible under the London and Ospar Treaties controlling the dumping of wastes in the North Sea.

Consultations with potential stakeholders have identified four options for implementing a one-off EOR demonstration. Three are full-scale demonstrations applying to offshore oil fields and are distinguished by the sources of CO_2 to be used:

(a) CO_2 produced through existing North Sea oil/gas production

(b) CO_2 captured from high concentration sources

(c) CO_2 captured from power plant.

The capital investments required for these options are likely to be in the order of £300M-500M. CO_2 separated from "raw" natural gas is likely to be the cheapest option and CO_2 capture from a power plant the most expensive.

The fourth option is a smaller-scale demonstration with an onshore oil field and will be the least expensive for implementation and subsequent monitoring. However, as the eventual intention is for offshore CCS there is some reservation that this would provide appropriate experience.

Drawing on the CCS Review the key requirements to be covered by an offshore demonstration are provision of:

- A practical base to gain experience in the regulation, authorisation and monitoring of CCS.
- A practical base for establishing how to include CCS in national greenhouse gas inventories.
- An additional site to research and establish the long-term integrity of geological storage of CO_2.
- A showcase to help establish and increase public awareness and confidence in the technology.
- A showcase of full-scale CO_2 capture from a power generation plant.

All four options would deliver all of these benefits, with the exception of a full scale demonstration of CO_2 capture from a power generation plant, which is only covered by Option (c), and is also the most expensive.

Among the stakeholders the equipment suppliers were most keen for a demonstration to go ahead in the near term in order to showcase UK CCS capabilities (particularly capture) to the potentially large world market. However, they had differing views on which capture technology should be demonstrated. Power generators were also interested in a demonstration project including capture to enhance their position as "informed buyers", but stressed that they were not considering investment in new UK plant at the present time. Oil producers were also interested in EOR and CCS, but through their global operations they had more options to gain experience.

Taking account of the above findings it has been concluded that it would be wrong to press ahead immediately with a full-scale demonstration of CO_2-based EOR. Indeed, with the low level of interest shown by key stakeholders this may not be feasible. However, CO_2-based EOR does have advantages as a base for demonstrating CCS, and therefore is worth further consideration over a longer time-scale. This should be done as part of an overall strategy for the development of near to zero emission fossil fuel technologies.

The strategy to develop near to zero emission fossil fuel combustion plant is being developed through DTI's Carbon Abatement Technologies (CAT) programme. The Cleaner Fossil Fuels Unit of the DTI is currently reviewing and revising its strategy with substantial input from industry stakeholder groups. It is planned to finalise the

new CAT strategy by summer 2004. This will address a number of strategic issues which need to be considered before making a decision on any demonstration of CCS. These issues include:

- The timing of a CCS demonstration in relation to expected commercial deployment.
- Demonstrating the key elements of CCS. For example, demonstrating reliable storage is a long-term task and should be started as soon as possible. On the other hand capture and separation technologies probably need further development to reduce costs and increase efficiency before going to full-scale demonstration.
- The nature of the demonstration – should it cover the full chain of CCS technologies including CO_2 from a large combustion plant or should R&D and demonstration be undertaken separately for the various elements of CCS?
- The type of capture technology that should be favoured for any such demonstration.
- How a UK CCS demonstration can add value to the global effort to demonstrate the long-term integrity of geological storage of CO_2.
- How to develop verification and monitoring protocols acceptable to the European Commission to enable a CCS demonstration to qualify within the EU ETS.
- Engaging the UK agencies that will be responsible for regulating and authorising CCS in the UK.
- Examining possible funding mechanisms, including international sources, and their acceptability within the requirements of UK and EU policy frameworks.
- How best to increase the UK's collaboration with other countries and in particular those bordering the North Sea that face similar issues and challenges.

Overall the potential value of a demonstration of CCS, whether it be simply for CO_2 storage or CO_2 EOR, has been recognised. Accordingly a set of interim actions has been identified and will be implemented to take the concept forward for possible inclusion in the overall CAT strategy. This programme of actions is listed in Annex II of this report.

Contents

1. Introduction

1. The Energy White Paper, *Our Energy Future - Creating a Low Carbon Economy*[1], put the UK on a path to a 60% reduction in carbon dioxide (CO_2) emissions by 2050. Central to this policy was 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. CO_2 capture and storage (CCS), in which CO_2 from fossil fuel combustion plant is separated and committed to long-term storage, was also recognised to be strategically important. CCS would enable the continued use of fossil fuels thereby giving a longer timeframe to achieve a transition to a fully sustainable energy system. It would also facilitate the use of a greater diversity of energy sources, thus enhancing security of supply.

2. At the time of the Energy White Paper the DTI was undertaking a review of CCS, and preliminary results were showing that CO_2 storage in depleted oil fields was a potentially important option for near-term action. There were two reasons for this. Firstly, with favourable oil fields the injection of CO_2 towards the final stages of production could mobilise additional oil, leading to Enhanced Oil Recovery (EOR), thus gaining a financial return to offset partially the costs of CO_2 capture. Secondly, several of the large mature oil fields in the UK North Sea (eg Forties) suited for CO_2-based EOR, were thought to be approaching cessation of production. This prompted inclusion in the Energy White Paper of a commitment to "set up an urgent detailed implementation plan with developers, generators and the oil producers to establish what needs to be done to get a demonstration [of EOR] project off the ground".[2]

3. The Energy White Paper's commitment was concerned with getting a demonstration of CO_2-based EOR off the ground, and did not explicitly consider the source of CO_2 to be used. However, the commitment also acknowledged "the potentially significant strategic role that might be played by CCS in longer-term energy security". Therefore, at the outset of the project, the aim was to look for an opportunity to demonstrate the full chain of CCS technologies, including capture from a large combustion plant and bulk transportation, as well as EOR itself. Nonetheless it was recognised that a pragmatic approach was needed since cost and logistic considerations would determine both the size of the scheme and the source of CO_2 to be used.

4. This report describes the results of a study undertaken to fulfil the Energy White Paper commitment and produce an implementation plan for a demonstration of CO_2-based EOR. It begins with a summary of the main findings of the DTI's CCS Review[3] that are relevant to EOR, followed by a description of the consultation undertaken with potential stakeholders (eg developers, equipment suppliers,

[1] Cm 5761, published by TSO (also available at www.dti.gov.uk/energy/whitepaper/index.shtml#wp), February 2003.
[2] This action was to follow the review of carbon dioxide capture and storage, and was to be completed within 6 months (Energy White Paper paragraph 6.63).
[3] Review of the feasibility of CO_2 capture and storage in the UK, available from Charles Pearce, Cleaner Fossil Fuel Unit, DTI, 1 Victoria Street, London, SW1H 0ET (also available at www.dti.gov.uk/energy/coal/cfft/co2capture/index.shtml), September 2003.

electricity generators and oil producers) on an implementation plan. An assessment is made of options for implementing a demonstration project based in the UK and of potential funding mechanisms. The report concludes with recommendations on how the UK should go forward to the demonstration stage.

2. Main findings of the CCS Review

5. The review of CCS, which was guided by an advisory committee drawn from industry, research organisations, academia and government, was published in September 2003. It considered capture of CO_2 from large coal and natural gas fired power plant and its storage through EOR or one-off injection into either exhausted natural gas reservoirs or deep saline aquifers. Several of the key findings of the report were important for guiding the develop of an implementation plan for an EOR demonstration:

   - Drawing on previous analytical work in support of the Energy White Paper, it was concluded that CCS could be needed as part of a strategy to deliver a low carbon energy system from about 2020–2030. This deployment would be for both electricity and hydrogen production.

   - CO_2-based EOR is commercially deployed with onshore oil fields in North America, but has yet to be used offshore.

   - The present day cost of full-scale implementation of CO_2-based EOR in the North Sea was estimated to be of the order of £28-35 per tonne of CO_2 utilised. This fell to £4-10/te CO_2 when credit was taken for the additional oil produced.

   - By comparison, the cost of CO_2 storage through one-off injection into an exhausted natural gas reservoir, with no recovery of additional hydrocarbons, was estimated to be £22-27/te CO_2.

   - There is a limited window of opportunity for initiating EOR in the UK North Sea since it needs to be implemented before cessation of conventional oil production. At the time of the review this was estimated, for some of the larger more mature fields, to be before 2010.

   - Not all the CO_2 injected into geological formations can be counted as abated emissions because additional energy is used in capturing, compressing, transporting and injecting the gas. When this is taken into account the net cost of CO_2 emissions abatement through EOR was estimated to be £6-50/te CO_2.

   - CO_2-based EOR is permitted, but one-off injection for storage from existing production platforms is prohibited, under the London and OSPAR treaties controlling the dumping of wastes in the North Sea.

   - There is considerable international interest in the development and deployment of CCS. This includes recognition that the technologies need to be demonstrated at levels approaching full-scale over the next ten years for them to be available for commercial deployment by 2020. EOR offers a lower cost option for such demonstrations.

6. Overall, the review showed that, while EOR had advantages for supporting a demonstration of CCS, it was unlikely to be viable commercially without some additional financial support. However, it was also recognised that a demonstration project would deliver benefits that go beyond technology development, including:

   - Acting as the nucleus for establishing an infrastructure for CO_2 collection and transportation.
   - Deriving additional oil from the UK's North Sea reserves.
   - Give experience to regulatory bodies in the authorisation and control of the technology.
   - Giving project stakeholders (eg developers, power generators, oil companies) experience of working together.
   - Providing an additional test site for establishing the long-term integrity of geological storage of CO_2.
   - Helping establish public awareness of, and confidence in, the technology.
   - A showcase for UK technology to the potentially much larger global market.

3. Approach to the Implementation Plan

7. As explained in the Introduction, the Energy White Paper's commitment was concerned with getting a demonstration of CO_2-based EOR off the ground, and did not explicitly consider the source of CO_2 to be used. However, the commitment also acknowledged "the potentially significant strategic role that might be played by CCS in longer-term energy security". Therefore, the aim at the outset of the project was to demonstrate the full chain of CCS technologies, including capture from a large combustion plant and bulk transportation, as well as EOR itself. However, in practice three potential sources could be used:

   - CO_2 produced with "raw" natural gas, and which needs to be separated before natural gas is dispatched for use.
   - Concentrated CO_2 streams arising from industrial processes such as hydrogen production in ammonia plant and in oil refineries.
   - CO_2 produced in fossil fuel power generation plant.

   Generally, the combined cost of capture and transportation would be expected to increase in moving down this list. Consequently, it was recognised that economic and logistic considerations might lead to a project that did not include capture from a large combustion plant, but this should not preclude a demonstration going ahead.

8. Successful implementation of an EOR demonstration depends on the participation of all the necessary stakeholders. These are CO_2 suppliers (eg owners of industrial or power plant), oilfield operators and potential operators of the CO_2 transport

systems. Therefore the main activity for examining implementation options was to canvas the views of individual stakeholder organisations through a series of one-to-one meetings. This approach was adopted to minimise any problems of commercial confidentiality, which it was thought might impede discussions in a broader gathering, although no organisation asked for their discussions to be treated as confidential. These meetings involved oil producers (some also operated refinery plant), power generation companies, equipment suppliers and one broker of a CO_2 delivery system. The full list of organisations consulted is listed in Annex 1. The oil producers were selected with advice from the DTI's Licensing and Consents Unit, and were those operating oilfields considered to be suitable for CO_2-based EOR.

9. The consultation meetings were based on a standard set of questions, which sought to gauge the value of an EOR demonstration project and the interest of the stakeholder in becoming involved. These questions were:

   - What are the barriers (technical, economic, contractual, regulatory, etc) in the way of CO_2-based EOR in the UK North Sea?
   - Would a demonstration project help give a better understanding of the above barriers and uncertainties and how they can be reduced?
   - What needs to be done to define the most appropriate UK-based CCS demonstration project?
   - Under what conditions would your company be prepared to host an EOR demonstration scheme in the UK North Sea?
   - Under what conditions would your company be prepared to take a stake in, and operate, a demonstration electricity generation plant incorporating CO_2 capture?
   - Could CO_2 emission credits enhance the prospects for EOR?
   - Which international funding sources should be contacted to seek support for an UK EOR demonstration?
   - What can government do to reduce investment uncertainties?
   - What can government do to bring stakeholders together?

4. Findings from the Stakeholder Survey

10. The findings of the survey are discussed below for each of the questions listed in paragraph 9.

11. **What are the barriers (technical, economic, contractual, regulatory, etc) in the way of CO_2-based EOR in the North Sea?** This question was designed to gain better understanding of the factors affecting full commercial implementation of CO_2-based EOR and if these would be reduced through a demonstration

project. In particular, would an EOR demonstration lead to replication of the technology or be a "one off" initiative?

12. The main respondents to this question were the oil producers, who were united in identifying project economics as the main barrier. There was a general view that the DTI's economic assessment, undertaken in support of the CCS Review, had underestimated the costs of adapting production platforms and well completions to handle CO_2, and that consequently the economic gap was greater than the estimates presented in the CCS Review (Section 2). Some companies commented that CO_2 would need to be supplied to the production platform at zero cost to make CO_2-based EOR commercially attractive. This implies an economic gap of £21-29 per tonne of CO_2 delivered.

13. The electricity generators also considered the economics of the process to be the main barrier to their investment in capture technology. However, they were also concerned about their lack of experience in design, construction and operation of capture plant, and saw benefits from a demonstration project in strengthening their capabilities as "informed buyers". The generators were also concerned that EOR would involve a new contracting situation between themselves and the oil producers, and thought a demonstration project would give useful experience of this.

14. A further problem affecting both oil producers and electricity generators was the different timescales for operating capture plant and EOR. To get an acceptable return for investing in a full size (ie >1 Mt CO_2 per year) capture plant would require about ten years operation, but oil producers, looking to minimise the high cost of operations in the North Sea, would aim to complete EOR on a single oil field in 5-6 years.

15. Equipment suppliers looked beyond EOR and the North Sea to the potential future, much bigger, world market for carbon dioxide capture technologies, and were concerned to retain and strengthen their position. Their concern was that, as the market develops, orders would go to those suppliers with demonstrated technology. They saw an EOR demonstration as an opportunity to showcase UK technology to the world.

16. **Would a demonstration project help give a better understanding of the above barriers and uncertainties and how they can be reduced?** This question addressed the value of a demonstration project in reducing barriers and uncertainties thereby facilitating the commercial deployment of CO_2-based EOR.

17. The general view of the oil producers was that there was limited benefit to be gained from a demonstration of CO_2 based EOR in the North Sea. The materials and plant modifications needed to handle CO_2 were well understood from land-based EOR projects. There was no experience of operating a CO_2/EOR project offshore, where the low density of injection and production wells compared with onshore fields made EOR more difficult to manage. However, the companies thought that the knowledge gained from a demonstration would mainly be field-specific since there are considerable geological variations between reservoirs. Consequently the benefits that were identified were mainly concerned with the development of technology for monitoring the EOR process (eg 4D-seismic), and

assessing environmental and social impacts. These benefits, although important, would not lead to replication of EOR because they do not address, and would not reduce the economic gap, which is the fundamental barrier to EOR deployment.

18. Stakeholders agreed that there was a greater need for an upstream demonstration of CO_2 capture on a power station or some other large combustion plant. The technologies needed for capture (eg gasifiers, amine scrubbers, pressure swing absorption plant, etc) have all been deployed commercially in other facilities, but have not been brought together for CO_2 capture.

19. Power generators were interested in an upstream demonstration of CO_2 capture to establish and strengthen their position as informed buyers of the technologies. However, they offered no views on which of the capture technologies (ie capture by post-combustion, pre-combustion or oxy-firing) should be targeted.

20. Equipment suppliers were keen for an upstream demonstration of capture to act as a showcase for UK technology. However, there were divided views on which technology to demonstrate, and it was clear that the suppliers could not finance such a demonstration on their own.

21. Significantly, the oil producers considered that the window of opportunity for EOR was wider than thought at the time of the CCS Review. This is because producers are beginning to use other advanced methods for extracting additional oil from reservoirs (eg directional drilling into pockets by-passed by water sweeps) that are moving back cessation of production dates.

22. **What needs to be done to define the most appropriate UK-based CCS demonstration project?** This question anticipated a positive response to the proposal for an EOR demonstration and was concerned with designing the project to deliver maximum benefit to stakeholders.

23. Not surprisingly, given their position on CO_2-based EOR, the oil producers had no firm views on the design of a demonstration project. Their position was that, with the right market conditions they would go ahead without a demonstration. Under current market conditions, their interest, if any, would focus on possible niche opportunities where free CO_2, for example that associated with natural gas production, could be separated and used for EOR. To be viable such opportunities would also look to exploit existing pipeline facilities that were capable of handling CO_2.

24. The electricity generators took the view that current policy and market conditions were accelerating the phase-out of coal-fired plant. Under such circumstances they thought that carbon capture was best demonstrated on plant fired on natural gas. However, no views were given on the choice between post- and pre-combustion capture technology.

25. Equipment suppliers were concerned that a CO_2-based EOR demonstration should be seen within an overall strategy to develop near to zero emission technology for fossil fuel combustion plant. Therefore any such demonstration should not divert attention from other technical developments that had the potential for more near-

term commercialisation, in particular options for reducing CO_2 emissions through improved conversion efficiency.

26. **Under what conditions would your company be prepared to host an EOR demonstration scheme in the North Sea?** For the reasons discussed above, oil producers were not particularly interested in hosting an EOR demonstration project. They were prepared to implement CO_2-based EOR on their oilfields if this offered a satisfactory financial return.

27. **Under what conditions would your company be prepared to take a stake in, and operate a demonstration electricity generation plant incorporating CO_2 capture?** The electricity producers indicated that they were unlikely to invest in any generation plant under current market conditions.

28. **Could CO_2 emission credits enhance the prospects for EOR?** It was generally agreed that emissions credits under the European Union Emissions Trading Scheme (EU ETS) for greenhouse gases was a key mechanism that could, at least partially, bridge the economic gap for EOR. At the time of the CCS Review it was thought that capture and storage would be precluded from the ETS until guidelines had been establish for monitoring and reporting on the CO_2 captured and stored. However, the draft ETS guidelines have been modified to permit Member States to submit interim guidelines, which when accepted by the European Commission would acknowledge CO_2 emissions abated by CCS.[4]

29. The ETS will provide a financial inducement for CO_2 capture projects involving plant covered by the scheme, which includes power plant and oil refineries. The size of the financial support will depend on the level at which emissions permits are traded within the ETS, and is thought unlikely to be sufficient in the near term to bridge fully the economic gap discussed above.

30. **Which international funding sources should be contacted to seek support for an EOR demonstration?** It was generally agreed that, outside of the standard commercial arrangements applying to EOR, international funding might be forthcoming for the pre-competitive demonstration of upstream capture technology. Specifically, the European Union has a range of strategic assessments underway, and it is likely that these will point to the need for a demonstration project as a showcase for European technology against competitive developments in North America and Japan. Linking such a demonstration to EOR in the North Sea would provide some offsetting financial return, and an accessible and legally permitted store for the CO_2.

31. **What can government do to reduce investment uncertainties?** All stakeholders considered that some direct financial support was needed to get an EOR demonstration off the ground. This was particularly important for demonstration of capture plant, since these are at the pre-competitive stage of development in advance of a potentially large future world market for near to zero emission technologies.

[4] Draft Commission Decision, Establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

32. **What can government do to bring stakeholders together?** Stakeholders looked to government to help reduce the economic gap sufficiently to enable a demonstration project to go ahead. This could be through direct support and/or by facilitating access to international funding, most probably through the European Union's framework R&D programme. A second role for government was to take the lead in getting regulation and monitoring frameworks in place, which would clear the way for acceptance into the EU ETS.

5. Options for an EOR Demonstration Project

33. Notwithstanding the views on the commercial viability of CO_2 based EOR, the consultation with stakeholders identified four options for implementing a demonstration in the UK. These are:

- EOR in the North Sea using CO_2 separated from "raw" natural gas
- EOR in the North Sea using CO_2 captured from concentrated sources (eg ammonia plant)
- EOR in the North Sea using CO_2 captured from large combustion plant (eg power generation)
- EOR applied to an onshore oilfield.

34. The first three options would involve the same offshore costs for EOR, but would have different upstream costs for supplying CO_2. The options are not mutually exclusive and could complement each other. For example, CO_2 capture from a concentrated source could be used to supplement CO_2 separated from natural gas.

EOR in the North Sea using CO_2 separated from "raw" natural gas

35. Some natural gas fields in the North Sea contain an appreciable amount of CO_2 that has to be separated before the gas can be sold. A key example is the Norwegian Sleipner field where 1Mte CO_2 is separated annually. Encouraged by Norway's carbon emission tax of 315NOK/te CO_2 (£26/te CO_2), this gas is injected into an aquifer. At least one UK field produces similar quantities of CO_2, which is currently separated and vented, but could be returned to an oil field for EOR.

36. This is probably the lowest cost option for large-scale supply of CO_2 since the gas has to be separated before the natural gas can be used commercially, and is located close to the oilfields, hence minimising transport costs. Even so, it may not be fully commercial especially if new pipelines are needed to transport the CO_2.

EOR in the North Sea using CO_2 captured from high concentration sources

37. Large quantities of hydrogen are currently produced in the UK in oil refineries and fertiliser plant. Most of this is produced from natural gas or other hydrocarbons by steam reforming processes that generate a high-pressure exhaust gas rich in CO_2. Under these conditions CO_2 is relatively easy and cheap to

separate, at a purity suitable for transportation and use in EOR, through physical absorption techniques.

38. CO_2 obtained from this source would involve additional investment in capture plant and would probably involve transportation over longer distances, and therefore would be more costly than CO_2 separated from natural gas.

EOR in the North Sea using CO_2 captured from a power plant

39. The ultimate goal for CCS is its broad application to fossil-fuelled combustion plant as part of a strategy for large cuts in CO_2 emissions (eg the Energy White Paper target for a 60% reduction by 2050). Therefore, as discussed in Section 3, the ultimate aim is to include CO_2 capture from a power plant as part of an EOR demonstration. However, the capture of CO_2 from power plant is likely to require greater capital investment, and would be the most expensive of the supply options irrespective of whether this is done by retrofitting to an existing station or with a purpose built facility.

EOR applied to an onshore oilfield

40. The consultation identified one additional option for an EOR demonstration which was, to apply it to one of the UK's onshore oilfields. This would be a smaller operation using of the order of 50,000 to 100,000 te CO_2/year, but would avoid the high investment cost of a large capture plant, and reduce the costs of transportation and implementation compared with an offshore project. The level of CO_2 required would not justify investment in separation plant on a power station (with the possible exception of the modular amine scrubbing technology), but could be supplied from the hydrogen production facilities mentioned above.

6. Benefits of an EOR demonstration

41. The stakeholder consultation confirmed the earlier conclusion of the CCS Review that CO_2 based EOR was not fully commercial in the UK North Sea. Indeed the consultation with the oil producers suggested that the CCS Review had been optimistic in its assessment of the economic gap. This position will be improved by the EU ETS, which places a value on the CO_2 emissions abated, but not sufficiently to make EOR fully commercial. It therefore seems likely, unless further measures are taken (see Section 7), that CO_2-based EOR will not be widely deployed. Given this position it is important to review the benefits to be gained from what could be a one-off demonstration.

42. In these circumstances the benefits to be gained from an EOR demonstration are linked to development of the full chain of CCS technologies that may be needed in the longer term as part of a low carbon future. EOR remains important, but mainly because it provides some revenue to offset costs and a technically sound and legally acceptable storage medium for the CO_2. Drawing on the CCS Review the key requirements to be covered by a demonstration are provision of:

    - A practical base to gain experience in the regulation, authorisation and monitoring of CCS.

- A practical base for establishing how to include CCS in national greenhouse gas inventories.
- An additional site to research and establish the long-term integrity of geological storage of CO_2.
- A showcase to help establish increased public awareness and confidence in storage technology.
- A showcase of full-scale CO_2 capture from a power generation plant.

43. The merits of each of the demonstration options identified in Section 6 are assessed against these key requirements in Table 1. This shows all options should yield the downstream benefits (eg monitoring, experience with regulation, etc). The option involving full-scale demonstration of CO_2 capture on a power plant is the most expensive option, while the land-based scheme offers a route to a relatively low cost demonstration.

Table 1 Assessment of the benefits and weaknesses of options for an EOR demonstration

Option	Benefits	Weaknesses
EOR in the North Sea using naturally produced CO_2	• A full-scale project (1-2Mte CO_2/yr) • Provides test bed for developing EOR monitoring and verification techniques • Provides experience with the regulation and monitoring of CCS technology • Provides a test site for establishing the long-term integrity of CO_2 storage • Helps to raise public awareness and win confidence in the technology	• Capital investment >£250M • Does not demonstrate CO_2 capture technology on a combustion plant
EOR in the North Sea using CO_2 captured from low cost sources	• A full-scale project (1-2 Mte CO_2/yr) • Provides test bed for developing EOR monitoring and verification techniques • Provides experience with the regulation and monitoring of CCS technology • Provides a test site for establishing the long-term integrity of CO_2 storage • Helps to raise public awareness and win confidence in the technology	• Capital investment >£350M • Does not demonstrate CO_2 capture technology on a combustion plant
EOR in the North Sea using CO_2 captured from power plant	• A full-scale project (1-2 Mte CO_2/yr) • Includes a demonstration of full-scale capture • Provides test bed for developing EOR monitoring and verification techniques • Provides experience with the regulation and monitoring of CCS technology • Provides a test site for establishing the long-term integrity of CO_2 storage • Helps to raise public awareness and win confidence in the technology	• Capital investment >£500M
EOR applied to an onshore oilfield	• Provides test bed for developing EOR monitoring and verification techniques • Provides experience with the regulation and monitoring of CCS technology • Provides a test site for establishing the long-term integrity of CO_2 storage • Helps to raise public awareness and win confidence in the technology	• Capital investment ~£10-20M • Not a full-scale demonstration • Planning requirements could slow implementation • Does not demonstrate CO_2 capture technology on a combustion plant

Note: Capital costs are only indicative estimates and in practice could be highly project-specific.

7. Potential mechanisms to support an EOR demonstration

44. The main message from the stakeholder consultation was that CO_2 capture, and its utilisation for EOR in the UK North Sea, is not a commercially attractive option under current market conditions. Moreover, it was considered unlikely that, at least to 2010, the EU ETS would place a high enough value on CO_2 abatement to change this position. These findings are consistent with the analysis undertaken in support of the Energy White Paper, which showed that CCS was not likely to be needed as part of a low CO_2 emission energy system until 2020 to 2030[5]. By this time emissions reductions of 30% to 40% will be sought, on the path to a 60% reduction by 2050. Reductions of this size are substantially more than the present target of the EU ETS.

45. Consequently, there are three basic options for moving forward with CO_2-based EOR in the near term:

Option A	Provide additional market-based support for EOR
Option B	Develop a targeted scheme to support a one-off demonstration of CCS involving EOR
Option C	Do nothing about EOR but move forward on developing the right conditions for the eventual deployment of CCS.

46. The main approach available to government for ***Option A*** would be to adjust the tax system applying to oil production in the UK North Sea to reduce any barriers this presents to investment in EOR. This goes beyond a demonstration project to general deployment where CO_2-based EOR would compete with other EOR options. Because of this it was concluded that Option A was best considered within the overall framework managing the exploitation of the UK's North Sea oil reserves. PILOT[6] has recently set up a 'brown fields think tank', to address the technical and commercial barriers to further development of mature oilfields. It is very likely that the application of EOR methods (including CO_2 injection) will be included in the variety of techniques for increasing oil recovery evaluated by this group, and it is to be expected that the industry side will bring up the issue of taxation of this incremental activity. The 'brown fields think tank' has recently commenced its work and its report is expected later in 2004.

47. Some stakeholders commented that market conditions were more favourable for CO_2-based EOR and CO_2 capture and storage in the Norwegian sector of the North Sea. For example the Sleipner project (Section 4) that stores 1Mte CO_2

[5] Options for a Low Carbon Future Phase 2 (FES, February, 2003) (http://www.dti.gov.uk/energy/whitepaper/index.shtml)

[6] PILOT is a joint consultation programme involving the North Sea Oil production industry and government.

annually in a geological aquifer, encouraged by Norway's carbon emission tax of 315NOK/te CO_2 (£26/te CO_2). Also, Norway is examining the possibility of applying CO_2-based EOR to the Gulfaks field. The UK maintains an ongoing dialogue with the Norwegian Government concerning CO_2 capture and storage. Current understanding of the Norwegian position is summarised in the box.

Position on CO_2 capture and EOR in the Norwegian North Sea Oilfields

Norway's Sleipner Project currently separates and commits about 1Mte CO_2 per year to storage in a saline aquifer beneath the North Sea. The CO_2 is produced in association with natural gas from the Sleipner Field, and needs to be separated before the natural gas can be exported for commercial use. The separated CO_2 could be vented to atmosphere, but injection is encouraged by Norway's carbon emission tax of 315NOK/te CO_2. Sleipner is not an EOR project because the CO_2 is not used to enhance production.

Norway is presently planning a second CO_2 capture and storage initiative based on the Snohvit natural gas field. Once again this is driven by the need to separate the CO_2 prior to shipping the natural gas, and does not involve enhanced oil recovery (EOR). Snohvit differs from Sleipner in that the "raw" natural gas will be brought onshore before the CO_2 is separated. With both Sleipner and Snohvit the additional cost of CO_2 sequestration is limited to the cost of compression and injection because CO_2 separation is essential to the commercial expliotation of the natural gas.

The potential for using CO_2 for EOR is currently being examined for Norway's Gullfaks oil field. This field is particularly suited for Water Alternating Gas (WAG) EOR using CO_2, but the project has a low rate of return at the $16/bbl oil price used by most oil companies for project appraisal.

One option proposed by the Norwegian oil producers[7] for improving the attractiveness of all EOR investment options is a Volume Allowance for each additional barrel of oil produced. It has been suggested that this should be worth $2.15/bbl (15NOK/bbl) after tax, which at current Norwegian petroleum production tax rates is worth about $9.77/bbl before tax. The effect of such an allowance would be to guarantee oil producers a greater return per additional barrel produced, thus increasing the rate of return on EOR projects. On the other hand the Norwegian Government would incur a net reduction in tax revenue, despite the greater oil production, when oil prices are low. However, at high oil prices tax revenue would be greater than if EOR were not implemented. Effectively, the Volume Allowance means that government carries some of the risk of oil prices being low.

At present the proposal for a Volume Allowance is being considered by the Norwegian Government. It is unlikely that the Gullfaks EOR project will go ahead without this, or some other measure of similar value to the oil producers.

[7] Norwegian Petroleum Industry at the Crossroads, Kon-Kraft, August 2003, (http://www.olf.no/english/konkraft/?18939.pdf

48. Overall, the position in Norway is that the CO_2 sequestration project at Sleipner, and that proposed for Snohvits, are based on the requirement to reduce the CO_2 content of the produced natural gas before it can be shipped and sold into the commercial market. Because the CO_2 has to be separated the only additional cost is for injection, which is offset by avoidance of the Norwegian carbon emissions tax. Neither of these projects involves EOR. The potential for EOR on the Gullfaks oil field is being considered, but like similar projects in the UK North Sea, it is not an attractive investment to oil producers. Mechanisms to encourage EOR, including a Volume Allowance for the additional oil produced have been proposed but no decision has yet been made by the Norwegian Government.

49. Notwithstanding future developments it is clear that Norway and the UK have many common interests in both CO_2-based EOR and CO_2 storage under the North Sea. There is an established ongoing dialogue with Norway and this should be enhanced to examine further opportunities for collaboration.

50. ***Option B*** would benefit from any general measure to support EOR under Option A. Three additional methods for support have been considered:

    - credit for the CO_2 emissions abated
    - price support for power generation plant with CO_2 capture
    - direct support for the construction of a CO_2 capture facility.

51. Before examining these mechanisms it is necessary to consider the level of incentive likely to be needed. Estimates were made as part of the CCS Review for an oil price of $20/bbl and have been recalculated for a price of $16/bbl. The results for the two capture technologies found to be most cost effective in the review (ie new IGCC and retrofitting to GTCC[8]) are listed in Table 2. The financial support is expressed in two forms to match with the alternative support mechanisms. As reported previously, some of the oil producers consulted indicated that they would consider EOR only if the CO_2 were delivered to the production platform effectively free of charge. The reason for this is that the companies believe the costs of refitting platforms and wells to handle CO_2 is significantly higher than the costs estimated for the CCS Review. As Table 2 shows, such a requirement would substantially increase the financial support needed.

Table 2 Estimated financial support required for a large-scale EOR project

	CO_2 Abatement Credit	**Electricity Price Support**
Oil Price $20/bbl	£6-12/te CO_2	0.2-0.3p/kWh
Oil Price $16/bbl	£10-30/te CO_2	0.3-0.6p/kWh
CO_2 free at platform (oil price $16/bbl)	£26-47/te CO_2	0.9-1.5p/kWh

Estimates are based on an exchange rate of £1=$1.6, an average recovery of 2.7bbl/te CO_2 and use a discount rate of 10%.

[8] IGCC = Integrated (coal) gasification combined cycle and GTCC = Gas turbine combined cycle

A range of uncertainty of at least +/-30% needs to be applied to the values in the table to reflect site-specific variations in costs. Also there is potential for additional costs associated with a "first of a kind" development.

Credit for CO_2 Abated

52. The Energy White Paper indicated the Government's intention to make carbon emissions trading a central plank of future greenhouse gas (GHG) abatement policies. This will be achieved through participation in the EU ETS, which is expected to begin in 2005. At the time of the CCS Review it appeared that CO_2 capture and storage would not be accepted into the scheme until GHG inventory methods including monitoring, reporting and verification had been agreed internationally. However, the recent draft Decision of the European Commission on "Establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC" (the ETS Directive) permits Member States to submit interim guidelines which, when accepted by the European Commission, would enable credit to be claimed for CO_2 emissions abated by CCS.

53. The benefit of carbon trading to EOR will depend on the value at which permits trade. From the data in Table 2 permits would need to trade at around £10–30/te CO_2 for EOR (oil price $16/bbl) to be viable. Modelling carried out for the European Commission suggests the EU15 could achieve its Kyoto Protocol 8% target with a marginal abatement cost of €20/te CO_2 (£13/te CO_2)[9], which would go some way to making EOR commercially viable. However, permit prices may be lower due to the participation of the new Central European Member States that have lower cost abatement options.

Price support for electricity generated with CO_2 capture

54. This mechanism focuses on the upstream capture of CO_2 in power plant. By providing price support for plant fitted with capture technology this would enable the power producers to sell the CO_2 at a lower price to the oil producers while still covering their costs. The cost of such an approach depends on the level of support needed. For example, if price support of 1p/kWh was given to a power plant with an electricity generation capacity of 500MW and annual load factor of 80% it would cost about £35M per year.

55. Incentives of this type are currently offered to encourage the development of renewable energy sources through the Renewables Obligation and by the exemption of good quality combined heat and power (CHP) plant from the Climate Change Levy (CCL). The CCL is presently 0.43p/kWh to industrial electricity users. If electricity from fossil plant fitted with CO_2 capture technology was exempt from the levy, that would go some way to closing the economic gap for EOR.

[9] Blok, K., de Jager, D. and Hendricks, C. (2001) *Economic evaluation of sectoral emission reduction objectives for climate change*, ECOFYS Energy and Environment, Netherlands; AEA Technology, UK; National Technical University of Athens, Greece.

Direct support for the construction of a CO_2 capture facility

56. Direct support involves the provision of government funding towards the construction of a CO_2 capture facility that would enable it to offer CO_2 for EOR at a price acceptable to oil field operators. However, a full-scale EOR demonstration is likely to require a capital investment exceeding £500M (Table 1), which is large compared with innovation budgets. Certainly, it would be impractical to support demonstrations of all three of the basic capture technologies (ie pre-combustion, post-combustion and oxy-firing).

57. A smaller-scale demonstration using an onshore oilfield would require substantially less funding. However, the stakeholder consultation indicated that this would not advance capture technology where the general view of equipment suppliers was that a full-scale demonstration should be the next step.

58. ***Option C*** would mean not doing anything to demonstrate CO_2 EOR but instead to concentrate on preparing the ground for eventual CCS involving one-off injection. This recognises the current lack of interest in CO_2 EOR, instead, taking the long view to focus on R&D and Demonstration activity to prepare for CCS

8. Strategic role of an EOR Demonstration Project in the development of CCS

59. One key conclusion to emerge from this study is that the main benefit to be gained from a demonstration of CO_2-based EOR is not EOR itself but demonstration of the full chain of technologies involved in CCS. Therefore, the role of such a demonstration needs to be examined in relation to the broader development of CCS. This requires consideration of both the current status of CCS on the research, development, demonstration and deployment path and the likely timing of commercial deployment.
60. The DTI is currently establishing a new Carbon Abatement Technologies (CAT) strategy, which would support the development of low to zero emissions technologies for fossil-fuelled power generation including CCS technologies. To support this exercise an industry perspective of the strategy for developing low to zero emission plant was commissioned[10]. This concluded that the CAT programme should have a balanced portfolio of work covering developments to meet near term-market needs as well as longer-term CCS requirements. Thus the report highlights the near-term requirement to demonstrate high efficiency plant, not having CO_2 capture (which can still reduce emissions by up to 25%). The demonstration of CO_2 capture plant, as part of an overall CCS demonstration, is considered a longer-term requirement to be undertaken when the market is more clearly defined.
61. The timing for the commercial deployment of CCS technologies will depend on national and global targets for the abatement of GHG emissions. As mentioned previously, with the UK aiming to reduce CO_2 emissions by 60% by 2050, CCS technologies may be required from about 2020-2030. The timing of the market for CCS technologies in other countries will depend on the timescale and size of

[10] APGTF Strategy for Carbon Management of Fossil Fuels (to be published by the Advanced Power Generation Technology Forum).

their abatement targets. To have CO_2 capture technology ready for commercial deployment in 2020-2030 would require construction to start around 2015-2025. For this to benefit from a demonstration project it would need to be commissioned between 2010-2020. This timescale is broadly in line with the US Futurgen demonstration of CCS, which currently plans to commence construction around 2010[11].

62. However, a CCS demonstration should include the geological storage of CO_2, which is important for building confidence in the long-term integrity of such a storage system. Because of the long-term nature of the processes involved (eg migration, mineralisation) this aspect of CCS would benefit from an earlier start to the demonstration.
63. The above shows that there are other actions needed, besides an EOR demonstration, to take CCS forward. Specifically, the CCS Review concluded that key technical objectives were to:
    - develop the technologies for CO_2 separation and capture, in particular to reduce the costs
    - demonstrate the reliability of CO_2 storage.

64. Overall, therefore, a CO_2-based EOR project should be considered as a convenient, legally accepted and relatively low cost means for large-scale demonstration of CO_2 storage. However, it should be considered as part of an integrated strategy to develop low to zero emission fossil fuel technologies rather than being pursued in isolation.

9. Conclusions on Implementation Plan

65. This study has confirmed the conclusion of the earlier CCS Review that EOR using CO_2 is not a commercial option for the UK North Sea under current market conditions. The level of support needed to bridge the economic gap and encourage investment in EOR is uncertain, but stakeholders thought it unlikely that carbon emission credits from the EU ETS would be sufficient. Consequently, if EOR is to be deployed broadly in the UK North Sea, additional market changes will be needed. The main approach available to government would be to adjust the tax system applying to oil production in the UK North Sea to reduce any barriers this presents to investment in EOR.

66. The PILOT[12] initiative has recently set up a 'brown fields think tank', to address the technical and commercial barriers to further development of mature oilfields. It is very likely that the application of EOR methods (including CO_2 injection) will be included in the variety of techniques for increasing oil recovery evaluated by this group, and it is to be expected that the industry side will bring up the issue of taxation of this incremental activity. The 'brown fields think tank' has only just started its work and its report is expected later in 2004.

67. Setting aside wide-scale deployment, CO_2-based EOR still offers an attractive option for a one-off demonstration of the full chain of CCS technologies. EOR has the advantage of providing some financial return to partially offset costs, and

[11] www.fossil.energy.gov/programs/powersystems/futuregen/

[12] PILOT is a joint consultation programme involving the North Sea Oil production industry and government.

the injection of CO_2 into oil reservoirs underlying the North Sea is accepted to be permissible under the London and Ospar Treaties controlling the dumping of wastes in the North Sea.

68. Consultations with potential stakeholders have identified four options for implementing a one-off EOR demonstration. Three are full-scale demonstrations applying to offshore oilfields and are distinguished by the sources of CO_2 to be used.

    (a) CO_2 produced through existing North Sea oil/gas production

    (b) CO_2 captured from high concentration sources

    (c) CO_2 captured from power plant.

    The capital investments required for these options are likely to be in the order of £300M-500M. CO_2 separated from "raw" natural gas is likely to be the cheapest option and CO_2 capture from a power plant the most expensive. The fourth option is a smaller-scale demonstration with an onshore oilfield and will be the least expensive for implementation and subsequent monitoring. However, as the eventual intention is for offshore CCS there is some reservation that this would provide appropriate experience.

69. Drawing on the CCS Review the key requirements to be covered by an offshore demonstration are provision of:

    - A practical base to gain experience in the regulation, authorisation and monitoring of CCS.
    - A practical base for establishing how to include CCS in national GHG inventories.
    - An additional site to research and establish the long-term integrity of geological storage of CO_2.
    - A showcase to help establish increased public awareness and confidence in the technology.
    - A showcase of full-scale CO_2 capture from a power generation plant.

    All four options would deliver all of these benefits, with the exception of a full-scale demonstration of CO_2 capture from a power generation plant, which is only covered by Option (c), and is also the most expensive.

70. Among the stakeholders the equipment suppliers were most keen for a demonstration to go ahead in the near term in order to showcase UK CCS capabilities to a potentially large world market. However, they had differing views on which capture technology should be demonstrated. Power generators were also interested in a demonstration project including capture to enhance their position as "informed buyers", but stressed that they were not considering investment in new UK plant at the present time. Oil producers were also

interested in EOR and CCS, but through their global operations they had more options to gain experience.

71. Taking account of the above findings it has been concluded that it would be wrong to press ahead immediately with a full-scale demonstration of CO_2-based EOR. Indeed, with the low level of interest shown by key stakeholders this may not be feasible. However, CO_2 based EOR does have advantages as a base for demonstrating CCS, and therefore is worth further consideration over a longer timescale. This should be done as part of an overall strategy for the development of near to zero emission fossil fuel technologies.

72. The strategy to develop near to zero emission fossil fuel combustion plant is being developed through the DTI's Carbon Abatement Technologies (CAT) programme. The Cleaner Fossil Fuels Unit of the DTI is currently reviewing and revising its strategy with substantial input from industry stakeholder groups. It is planned to finalise the new CAT strategy by summer 2004. This will address a number of strategic issues needing to be considered before making a decision on any demonstration of EOR/CCS. These issues include:

    - The timing of a CCS demonstration in relation to expected commercial deployment.

    - Demonstrating the key elements of CCS. For example, demonstrating reliable storage is a long-term task and should be started as soon as possible. On the other hand, capture and separation technologies may need further development to reduce costs and increase efficiency before going to full-scale demonstration.

    - The nature of the demonstration – should it cover the full chain of CCS technologies including CO_2 from a large combustion plant or should R&D and demonstration be undertaken separately for the various elements of CCS.

    - The type of capture technology that should be favoured for such a demonstration.

    - How UK CCS demonstration can add value to the global effort to demonstrate the long-term integrity of geological storage of CO_2.

    - How to develop verification and monitoring protocols acceptable to the European Commission to enable a CCS demonstration to qualify within the EU ETS.

    - Engaging the UK agencies that will be responsible for regulating and authorising CCS in the UK.

    - Examining possible funding mechanisms, including international sources, and their acceptability within the requirements of UK and EU policy frameworks.

73. The potential value of a demonstration, whether it be for CO_2 storage or CO_2-based EOR has been recognised. Accordingly, a set of interim actions have been identified and will be implemented to take the concept forward for possible inclusion in the overall CAT strategy. This programme of actions is listed in Annex II to this report.

Annex I Stakeholder organisations consulted on the Implementation Plan

Organisation	Representing
Alstom Power	Equipment Supplier
Fluor	Equipment Supplier
Mitsui Babcock	Equipment Supplier
Apache	Oil Producer
BP	Oil Producer
EnCana	Oil Producer
ExxonMobil	Oil Producer
Shell	Oil Producer
Star Energy	Oil Producer
Talisman	Oil Producer
Total	Oil Producer
Powergen	Electricity Generator
Scottish Power	Electricity Generator
Scottish and Southern	Electricity Generator
CENS Project	Project Developer

Annex II List of interim actions to take CO_2-based EOR forward

Issue to be examined	Action	Timescale
The timing of a CCS demonstration in relation to expected commercial deployment.	This issue is being considered as part of the development of the new CAT Strategy.	CAT Programme Strategy to be published in Autumn, 2004.
The nature of the demonstration – should it cover the full chain of CCS technologies including CO_2 from a large combustion plant?	This issue is being considered as part of the development of the new CAT Strategy.	CAT Programme Strategy to be published in Autumn, 2004.
What type of capture technology should be favoured for a demonstration?	Project design studies to produce fully costed assessments of different capture options.	Industry to be invited to bid for such studies as part of the Fourth Call of the Cleaner Fossil Fuel Programme to be launched in March, 2004.
How can a CCS demonstration add value to the global effort to demonstrate the long-term integrity of geological storage of CO_2?	Study to be commissioned to advise on how an additional demonstration of CO_2 storage could be best designed to add to the knowledge being acquired from existing projects.	Study to be commissioned in April 2004 to be completed in 6 months.
How to develop verification and monitoring protocols acceptable to the European Commission to enable a CCS demonstration to qualify within the EU ETS.	1. DTI and Defra to initiate discussion with European Commission on likely requirements.	Starting April 2004

Annex II List of interim actions to take CO_2-based EOR forward (continued)

Issue to be examined	Action	Timescale
How to develop verification and monitoring protocols acceptable to the European Commission to enable a CCS demonstration to qualify within the EU ETS (continued)	2. Depending on outcome of discussions with the European Commission a study to prepare draft verification and monitoring methods will be commissioned. 3. Develop a dialogue with other European countries on the development of common verification and monitoring methods.	June, 2004 Has been initiated and will run through 2004.
Engaging the UK agencies that will be responsible for regulating and authorising CCS in the UK.	Gap analysis of existing regulation and authorisation procedures	Being initiated by DTI in March 2004 as an input to the international Carbon Sequestration Leadership Forum.
Examining possible funding mechanisms, including international sources, and their acceptability within the requirements of UK and EU policy frameworks.	Consider opportunities for EU funding for a European Demonstration of CCS.	DTI is supporting the EU's Fenco Project, which is examining the possibility of setting up a European Research Area Network to cover this technology. Fenco reports in November, 2004.

Annex II List of interim actions to take CO_2-based EOR forward (continued)

Issue to be examined	Action	Timescale
Feasibility of a smaller onshore demonstration project	1. Technical and economic assessment of the application of CO_2-based EOR to one of the UK's onshore oilfields. 2. Initiate a study to advise on planning and authorisation processes for an onshore demonstration.	Project has been commissioned by DTI's Licensing and Consents unit and will report in April, 2004. April 2004, depending on outcome of technical and economic assessment.
Possibility of an EOR project utilising CO_2 separated from natural gas.	DTI is maintaining contact with developers examining this option.	The assessment is industry-led and ongoing.
Further collaboration with Norway.	Further bilateral meetings between government officials. Joint stakeholder workshop.	April/May 2004. UKTP aiming to host joint workshop in London in June/July, 2004.