RWE npower

Research & Development

HM Treasury – Carbon Capture and Storage: A Consultation on Barriers to Commercial Deployment (Consultation Responses by RWE npower)

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Table of Contents

1. About RWE npower

- RWE npower, part of the RWE Group, is one of the UK's largest energy suppliers, with around six million customers and a diverse portfolio of over 9,000 MW of generation capacity in the UK including coal, oil and gas-fired power stations. Our subsidiary npower renewables is one of the UK's leading renewable energy developers and operators in the wind, hydro and bio-fuel generating sectors. We operate around 300 MW of onshore and 60 MW of offshore wind farms and anticipate significant future growth both onshore and potentially offshore. npower renewables also operates around 60 MW of hydro plant in the UK. npower Cogen, our cogeneration division, is one of the foremost developers and operators of industrial combined heat and power (CHP) in the UK with a portfolio of 15 sites which have a combined electrical capacity of 560 MW electric and 1500 MW of thermal capacity.

- Our retail division, npower, supplies electricity and gas to residential and business customers. Through our programmes such as Spreading Warmth and Health Through Warmth we work with key external stakeholders in fulfilling our responsibility to protect vulnerable customers. We develop innovative energy products and services and advise on energy efficiency measures to enable all of our customers to make sustainable energy choices. We also provide energy management, carbon reduction, and energy efficiency services through our energy services and energy solutions teams to our business customers and actively promote the efficient and effective use of energy to them.

2. RWE – clean coal experience

- RWE npower recently announced (12 April 2006) that it intends to commence a feasibility study into the construction of a 'clean coal' power plant at Tilbury on the Thames Estuary. The new carbon capture and storage technology could be ready by 2016.

- The study will be based around supercritical boiler plant and carbon capture systems based around amine scrubbing and oxyfuel technology. The study will look at the end-to-end process from planning and consents to transport and storage options. The combustion test facilities at Didcot Power Station in Oxfordshire will be used to further examine both oxyfuel and amine scrubbing systems.

- RWE Power Germany has also announced (30 March 2006) that it intends to investigate the building of a Euro 1bn CO_2 free plant in Germany. The coal-fired power plant with an expected gross output of around 450 MW could be available by 2014 subject to the necessary political framework and authorisations being in place.

- RWE Power intends to explore the gasification of hard coal and lignite in parallel, with a decision being made in the second half of 2007 as to the primary energy source for this new plant.

- RWE Power is investigating both onshore and offshore CO_2 storage with expertise coming from RWE Dea for the evaluation of the suitability of geological formations.

3. What are the barriers to commercial development of CCS

- The consultation document is seeking to addresses several important issues that need to be understood in order to establish whether there is a case for incentivising the development and use of CCS in the UK. The issues are grouped together under five main headings:

  - Potential carbon reductions
  - Technology
  - Engineering & manufacturing capability
  - Regulation, liability and public acceptance; and
  - Cost

- Our responses to these five questions is set out below in question three onwards. However, the overarching question posed by HM Treasury is:

3.1. What are the barriers to commercial development of CCS?

This question is addressed immediately below.

- Dialogue between the relevant industries that have a potential role to play in delivering CCS is at an early stage and the development of appropriate commercial arrangements and structures is some way off. RWE believes that Government, its agencies and industry need to work together to agree a route map to facilitate UK CCS development. The objective would be to develop a shared understanding of the steps needed to deliver the commercialisation of CCS technology by 2020 in the most efficient manner while minimising the economic, regulatory and political risks to the parties involved. It would also ensure Government funding and resource was deployed in the most effective manner. This needs to take account of the issues listed below, although this list is not exclusive. An illustrative outline high-level route map is set out in figure 1 below.

- CCS research & development requirements to prove technology, improve efficiency & reduce capital cost.

- Identification of most likely sites for early commercial development of CCS (e.g. LCPD opted-out coal-fired power station sites) and storage of CO_2 (including EOR opportunities).

- CCS demonstration projects with at least 5 years of operational data ahead full commercialisation and major investment infrastructure.

- Development of national and international regulatory framework for the transport and storage of CO_2 and management of longer-term liabilities.

- Development of post-Kyoto and EUETS frameworks to take appropriate account of CCS

- CO_2 transport network development both onshore and offshore.

- International collaboration required to ensure availability of best technology.

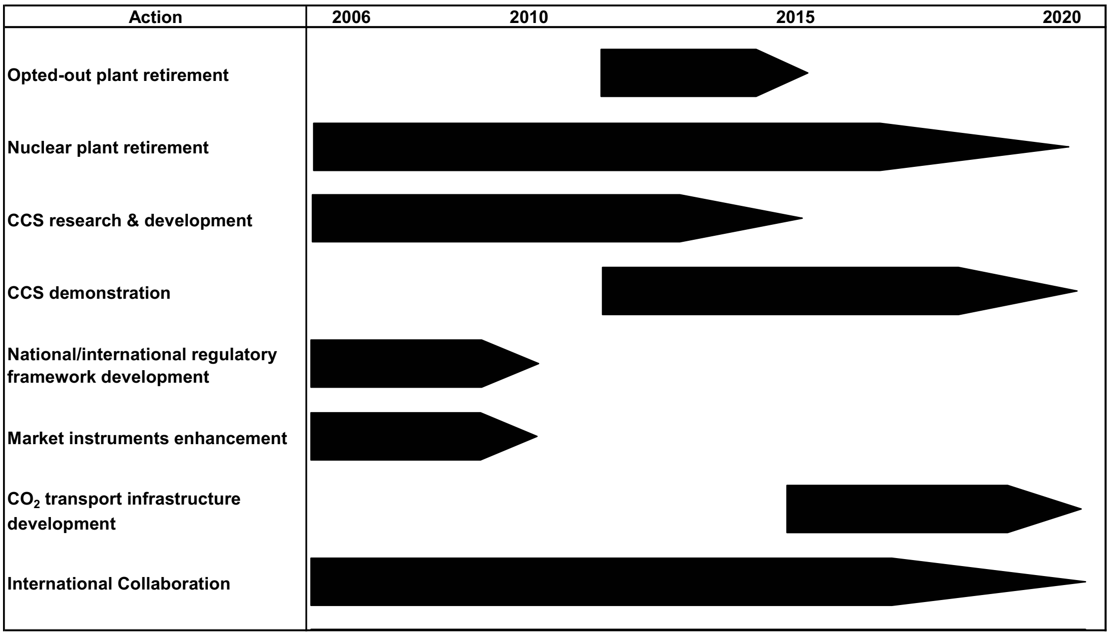

Figure 1 High level route map to UK CCS development

- There are a large number of constraints currently affecting the deployment of CCS. These can be broadly grouped as follows:
    - Economic/financial constraints
    - Legal/regulatory constraints
    - Technological constraints

3.1.1. Economic/financial constraints

- Two or three credible demonstration projects required to prove the various technologies.

- EOR for early demonstration projects for capture technologies will provide a financial bonus on the overall capital cost of the projects. However, it must be noted that several hundred millions pounds will be still required to demonstrate the capture and storage technologies alone.

- The first CCS demonstration projects will require significant financial support from Government as the market will not otherwise reward the high capital costs, lower efficiencies and risks of these projects.

- RWE believes that the Government should initially consider the merits of CCS projects on a case by case basis and, if appropriate, facilitate investment through tax-based mechanisms such as the R&D tax credit and/or enhanced capital allowances regimes.

- In the longer-term, the EU-ETS will be the main instrument for facilitating greenhouse gas abatement. Investors in new CCS plant have to be confident that the market will remunerate CCS generation. An early EU commitment to the EU-ETS phase 3 with an allocation period of at least 15 years would be a distinct advantage. A strong price for CO_2 in the cost of power, and confidence that this would be sustained is critical to any commercial investment.

- Initial projects would each require very substantial support over their lifetimes (£100s millions) but subsequent projects would benefit from this investment, through the establishment of re-usable infrastructure, reduced costs and improved knowledge and expertise.

- In the future new pipeline infrastructure may be needed to transport CO_2 hydrogen across the country. A study into the potential demand for, and delivery of, these new networks should be commissioned by the Government to inform thinking about the long-term potential and development of this technology.

- The first CCS projects would only be viable if the costs of providing, or buying access to the pipeline infrastructure for transporting to the storage fields could be recovered as CO_2 quantities are small by comparison with the capacities and thus operating costs of most existing pipelines There is likely to be a minimum scale at which a transport and storage project would be viable.

3.1.2. Legal/regulatory constraints

- A legal framework encompassing all aspects of the CCS supply chain will be required, covering both onshore and off shore storage needs. RWE understands that the Government has already initiated the re-negotiation of the relevant offshore regimes, which would have an impact on offshore storage.

- A number of key issues must be clarified in discussions between the Government, regulatory bodies and potential developers:

    - Information required by the DTI, EA and HSE to authorise new CCS projects
    - Legal liability for the CO_2 at each point in the supply chain
    - Once stable storage has satisfactorily been demonstrated, the transfer of liability to the Government
    - Fair and equitable third party access to transportation and storage infrastructure

- Planning and grid consents – in general inquiries should not attempt to revisit national policy but remain focused on local issues, and grid connection applications in a similar area should not present disproportionate risks or liabilities to potential developers.

- The legality of injecting CO_2 into offshore repositories and in particular the North Sea is covered by three treaties:

    - Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters 1972 (The London Convention)
    - The 1996 Protocol to the London Conventions
    - Convention for the Protection of the Marine Environment of the North East Atlantic 1992 (the OSPAR Convention)

- The different treaties contain inconsistencies regarding the legality of offshore carbon storage and introduce considerable regulatory uncertainties to developers. RWE welcomes the fact that the Government has initiated the process of seeking agreement between the parties to both OSPAR and the London Treaties for CO_2 storage.

- The liabilities for the long-term storage of CO_2 could depend on how CO_2 credits are applied under the EU-ETS and Kyoto mechanisms. If a power station operator is allowed to discount emissions if CO_2 is put into long-term storage then the ownership (and liabilities) could remain with the power station operator but in practice would need to be transferred under commercial arrangements with the storage facility operator. If on the other hand the owner of the storage facility is given a CO_2 credit for each tonne stored, then long-term ownership and liability could be expected to remain with the storage facility operator.

- The issue of ultimate long-term liabilities needs to be considered. The DTI Carbon Abatement Strategy notes that it has been proposed that ownership could be transferred from the operating company to the state after an agreed period. The liability for long-term monitoring and any future works must lie with the Government or the storage facility operator. In addition, issues of liability for long-term storage will need to be considered in conjunction with treatment of carbon capture under both EU ETS and Kyoto mechanisms.

- There is currently no mechanism to reward carbon capture and storage within either EU ETS or Kyoto. Since EU ETS allowances are linked to Kyoto targets after 2008, unless CCS is recognised within the Kyoto Protocol it is unlikely to be accepted within the EU ETS. Two issues need to be addressed: changes to monitoring and reporting protocols under both EU ETS and Kyoto; and whether CCS can be used as part of the Kyoto flexible mechanisms.

- It is important that there is early clarification of treatment within EU ETS and Kyoto in order to provide confidence to investors in potential projects.

- The UK has initiated work on the standards that would be needed to regulate the operation of a storage site. A gap analysis has been undertaken of existing regulatory systems but has not yet been published by the DTI. According to the DTI Strategy for Carbon Abatement Technologies, a working group of regulatory agencies is to be set up to develop any additional systems needed. We welcome these developments and encourage Government to involve industry in the development of standards.

- Planning and authorisations issues would need to be considered at all stages in the life-cycle of a carbon capture and storage project; capture, transport, injection and post-injection. Key issues for any development project would be associated with capture, and potentially transport, as any Section 36 consent may need to take into account the impact of a CO_2 pipeline.

3.1.3. Technological constraints

- There are a number of prospective projects under discussion in the UK for demonstration of a broad range of CCS technologies.

- The different technology options are discussed in a later section.

- Although CO_2 capture is proven technology and has been used for many years in separating CO_2 from natural gas and hydrogen (Syngas), there, applications with flue gas are limited). There are significant barriers to be overcome to apply CO_2 capture to large scale power station boiler, as well as technological issues associated with integrating capture technologies with other emissions abatement technologies and with storage technologies. These issues need to be resolved before any significant investment will be made across the sector. The presence of oxidising conditions in flue gas makes the most commonly proposed scrubbing process, amine scrubbing, more difficult in terms of avoiding reagent oxidation and process plant corrosion.

- The alternative route of oxyfuel firing requires very large air separation units (with associated cost, permitting and flexibility issues) and the need for much lower air in-leakage rates than those encountered on today's coal fired power plants.

- Fuel burn can increase by as much as 30% due to the lower efficiencies associated with CCS (mainly as a result of power requirements for gas separation units and compression). Hence, the fitting of CO_2 capture equipment to low efficiency plant is not considered a cost-effective option in the UK (a high base efficiency is needed for economic net power production after accounting for the efficiency losses due to operation of the abatement equipment). However, CCS may still be an option for some existing plants overseas (e.g. in China and the CIS), where low, non-exportable grades of fuel are in abundance locally at attractive rates and CCS represents the only means of curbing CO_2 emissions (i.e. limited or no possibilities for biomass co-firing).

- To a first approximation the fraction of the power plant optimised on carbon capture is inversely proportional to the square of the power plant efficiency.

4. Potential carbon reductions

4.1. What CO_2 savings could be delivered by CCS, and how do these savings vary between different options for deployment, different fuels, and different kinds of technology at each stage of the CCS process? Can the life-cycle CO_2 savings be estimated comparably with those of other technologies?

- The potential CO_2 savings are dependent upon the fuel that is being displaced. Coal fired power plants produce around 1 kg of carbon dioxide per kWhr of electricity generated. Natural gas fired power plants use a fuel with a lower carbon to hydrogen ratio and have a higher thermal efficiency so they emit about half the carbon dioxide per kWhr of coal fired power plant. Coal has at least 10% more carbon than natural gas and, in general, coal plants tend to be larger so that the cost of applying CCS tends to be more economical. 1 GW of coal-fired capacity fitted with CCS would save typically 5 million tonnes of CO_2 per year for a plant with a typical operational load capacity of 85% (this is realistically the maximum that can be achieved allowing for plant maintenance). The installation of CCS on 12 GW or about 40% of current coal-fired capacity would achieve a 10% reduction in the UK's energy related emissions of carbon dioxide (based on 1990 figures), which is the targeted CO_2 reduction for the UK by 2010 and this is without any contribution to reductions from transport or other energy-intensive industries. There is considered to be sufficient CO_2 storage capacity for a much greater level of conversion.

- Most studies suggest that a carbon dioxide capture plant would capture 80 to 90% of the incoming carbon dioxide. However in a wider envelope this does not simply equate to 80 or 90% of the power plant carbon dioxide flow upstream of the capture process. The energy required for the capture process reduced the electricity sent out from the power plant and any complete analysis should consider the fact that reducing the net output of one power plant is likely to mean increased generation of electricity elsewhere.

4.2. How do the potential CO_2 savings compare with other options for reducing carbon emissions?

- Over the short term (up to 20 years) coal with CCS is likely to be economically preferable to substitution by natural gas, biomass (with co-firing), nuclear, wind and hydro. However, over the longer-term wind, nuclear and hydro may be more economic as fossil fuel prices increase, though it should be noted that hydro and especially wind have limited availability. Biomass with energy cropping and without fossil fuel co-firing may also become economic over this period (biomass with co-firing has limited capacity to replace carbon). However, even into the longer term there is likely to be prospects for CCS, since fossil fuel combustion with sequestration offers a principle route to the generation of hydrogen, which has longer-term prospects as a zero-carbon transport fuel.

- There are many published studies comparing the potentially achievable reductions in gaseous carbon dioxide emissions which can be achieved by various technologies and also economic estimates of the costs per unit of carbon dioxide. It is clear that there is no single route to large reductions in emissions and that several options need to be pursued.

- Emissions from motor vehicles have also shown continued and unrelenting growth, despite the significant improvements in the fuel efficiency of the internal combustion engine that has been achieved, and the move towards more efficient diesel engines. Motor vehicles may be categorised into three groups; those powered by internal combustion (IC) engines, electric vehicles (EV), and hybrids that have an electric power train but use an IC engine to charge a battery system. In the medium term electric hybrids probably offer the best prospect of reducing carbon emissions from motor vehicles since when the overall emission of CO_2 are considered EVs account for slightly higher emissions than hybrids given the current generation mix. However, a move to a mix of generation with more low carbon generation sources could swing the balance in favour of EVs.

- A significant growth in EVs would have major implications for electricity generating capacity and network infrastructure. It has been estimated that if half of the current stock of motor cars were EVs then under an optimistic charging regime it would increase electricity consumption and demand by around 10%, thus requiring a further 7-8GW of generating capacity. Major reinforcement of distribution networks would be required as well as the establishment of a recharging infrastructure for the vehicles themselves.

- A lower carbon emitting generation mix would make the promotion of EVs a logical step in the development of a low carbon economy. However, experience in the US suggests that any transition is likely to require fiscal incentives to stimulate a move away from IC based motor vehicles. The implications for new electricity infrastructure will also require that a regulatory and planning climate that will facilitate investment in low carbon generating technologies can be established.
- It is generally believed that there remains considerable scope to improve the energy efficiency of residential buildings. The building regulations should be the main vehicle for improving the standard of new buildings and extensions to existing buildings.

- Improving the insulation standards of existing buildings should create very considerable prospects for reducing energy consumption and thus CO_2 emissions. However, as we have noted in our response to Question 1 the Energy Efficiency Commitment (EEC) placed on suppliers may not be the most effective mechanism for this. The EEC is input led and dominated by cavity wall and loft insulation as the means of its delivery. There are major difficulties with customer perception of the value of the scheme, as well as resource limitations in the provision of the chosen instruments.

- It is our view that the EEC should be recast so that it could become output based with suppliers having the freedom to promote more technically based solutions to reducing carbon emissions. This would encourage the introduction of smart metering and technologies such as micro CHP, ground source heat pumps and other technologically based solutions to be introduced as part of the scheme. Drawing on the technical expertise that is appropriate to the electricity supply industry to create innovative solutions to improving energy efficiency is likely to be a more productive route than using this platform to encourage the insulation of existing homes.

- Retrofitting of better insulation to the existing housing stock should still be a priority, especially where fuel poverty is apparent. However, this might be more effectively achieved through local council schemes such as linking installation to financial incentives such as a reduction in Council Taxes.

- Most critical is the need for better information to be provided to residential customers on the schemes that are available and why they should be embraced. The government’s intended programme in this respect might be expanded, but linking the information to discernible fiscal benefits is likely to be the most effective way by which customer enthusiasm in energy efficiency can be stimulated.

5. Technology

5.1. What are the different technological options currently available and in development for each stage of the CCS process – and what are the costs of these options?

- The CCS process can be separated into the following components[1]:

    - Capture
    - Transport
    - Storage

5.1.1. Capture

- Three technology options are available for CO_2 capture:

    - Pre-combustion
    - Post-combustion
    - Oxyfuel

[1] Intergovernmental Panel on Climate Change “Carbon Dioxide Capture & Storage” 2005

- Pre-combustion - This method is used extensively in the manufacture of fertilizer and the production of hydrogen in the chemical process industries. Prior to combustion the fuel is converted into a syngas comprising of carbon monoxide and hydrogen. In a further water-gas shift reaction the carbon monoxide is converted with steam into CO_2 and hydrogen. The CO_2 is then separated and liquefied prior to the hydrogen being used in combustion. For power generation, the gasification component of the technology has been demonstrated but such plant has been fraught with problems and hours of successful operation are limited. Further improvements are needed for commercialisation.

- Post-combustion - In this process the fuel is burnt in a conventional power station. After combustion the CO_2 is separated from the flue gas in a washing process prior to being liquefied. The capture of CO_2 from a flue gas is a mature technology within the gas processing industry where amine scrubbers are typically used for this process but flue gas conditions are very different to natural gas purification. However, there is limited experience with the technology for application to flue gas streams and ten-fold scale-up is needed for it to be usefully applied to power plant.

- Oxyfuel - Instead of using air, the coal is fired in an atmosphere of pure oxygen and re-circulated flue gas. In this process the CO_2 can be dried and thus concentrated to approximately 98% PROVIDED NITROGEN OR AIR INLEAKAGE IS LOW. The CO_2 is then liquefied prior to transportation. Oxyfuel is still in the early stages of development. This technology has not been demonstrated at full scale. There are significant hurdles to be overcome with respect to safety, operational flexibility (which affects the cost of electricity production) and CO_2 purification prior to storage.

- Of the above technologies, pre-combustion has the highest capital costs but the lowest operating costs (due to higher efficiencies and lower fuel use). However, pre-combustion does not offer operational flexibility and rapid start up, which in the current market would result in additional cost penalties. Oxy-fuel is similar in terms of flexibility but in this case capital costs are lower but operating costs (fuel-related) are higher.

5.1.2. Transport

- It is likely that pipelines will be the preferred method of transport for large amounts of CO_2 with ships being used to transport smaller quantities of CO_2 over large distances, similar to the transport of LNG. It should be remembered that tanker transport will require twice the number of ships to remove the carbon dioxide as are used to supply the coal for a power plant with carbon dioxide capture.

- Pipeline transport of CO_2 is a mature market particularly within the US where over 2,500 km of pipelines transport more than 40 million tonnes of CO_2 annually[1]. Dry CO_2 is not corrosive to these lines, however, any wet CO_2 must be dried, as the costs of installing expensive corrosive-resistant pipelines. There may be differences in the safety analyses for pipelines in densely populated parts of the UK, particularly in valleys. Pipe linings would make transport too expensive to be economically viable.

5.1.3. Storage

- Storage of CO_2 in deep, onshore or offshore geological formations uses many of the same technologies that have been developed by the oil and gas industry.

- If CO_2 is injected into suitable saline formations or oil or gas fields, at depths below 800 m, various physical and geochemical trapping mechanisms would prevent it from migrating to the surface.

- Coal bed storage may take place at shallower depths and relies on the adsorption of CO_2 on the coal, but the technical feasibility largely depends on the permeability of the coal bed.

- The combination of CO_2 storage with Enhanced Oil Recovery or, potentially, Enhanced Coal Bed Methane recovery could lead to additional revenues from the oil or gas recovery but it must be remembered that some of the methane will return to the surface with the extracted hydrocarbon product.

- Geological storage in saline aquifers offers great potential for CO_2 storage but the total capacity is uncertain due to a lack of information and an agreed methodology i.e. the capacity of oil & gas reservoirs is much better understood.

5.2. What scope is there for applying these technological options to different forms of power generation (particularly gas and coal) and other large-scale sources of CO_2 emissions, and can they be installed on the basis of both new-build and retrofitting?

- The energy use penalty of capturing carbon dioxide from power plants is very sensitive to efficiency, the fraction of the power plant output used being approximately inversely proportional to the square of the power plant efficiency. It therefore makes no environmental or commercial sense to retrofit carbon dioxide capture to an inefficient power plant unless there is a specific local use for that carbon dioxide. However if the existing power plant is upgraded to the efficiency of the latest technology plants, has sufficient land available and has the ability to extract process steam at suitable points then the existing and new power plants can be considered on the same basis.

- Retrofitting has limited prospects in the UK. For new plant there are some EOR opportunities in the north of the UK that can possibly only be exploited if technology is retrofitted. However, many coal-fired plants have limited lifetimes due to the impact of the EC Large Combustion Plant Directive and the ability of older plant to achieve other emissions targets. Also, power consumption by CO_2 separation and compression plant means that it is more viable to apply CCS to new-build plant.

5.3. At what level of market readiness are these various technological options?

- Coal gasification power plants are economically less attractive than conventional coal fired power plants, have lower availabilities and are less well suited to load following. However the penalty of adding carbon dioxide capture to gasification power plants is reasonably well known making the parameters and risks of such projects more quantifiable than for other plant configurations.

- Amine scrubbers are well proven under reducing conditions but their behaviour under oxidising conditions found in flue gas is less widely understood. Particular issues relevant to flue gas include solvent degradation due to oxygen and acidic components, corrosion of plant, achievable carbon dioxide loadings in circulating solvents and energy requirements.

- Oxyfuel remains unproven at significant scale. Outstanding issues include avoidance of air in-leakage, avoidance of flue gas leakage out, operation and permitting of large air separation units on power plants, corrosion, load following and energy use.

- There are a number of alternative technologies in the early stages of development. These include oxygen donor processes.

- None of the available options are at a stage of commercial readiness but all of them are developed to the extent that they could be applied at demonstration scale. This would require financial support to supplement investment by industry and offset both technological and commercial risks.

5.4. What limitations exist when it comes to selecting from the options at each stage to form a full CCS process?

- Feasibility studies are required to confirm this but it is likely that the type of technology to be employed at each stage would need to be pre-selected. For example, modifications to plant to improve efficiency could be pre-engineered to accommodate later retrofit of CCS technologies (so-called "capture-ready" plant). However, it would probably be necessary to select between oxy-fuel and post-combustion capture at an early stage. At the present time, further work is needed to fully assess the economics of these options. The economic regarding storage options cannot really be assessed until the legislative framework is clear.

6. Engineering and manufacturing capability

6.1. What would be the costs and benefits of early adoption of this technology in the UK?

- As noted in the DTI "A Strategy for Developing Carbon Abatement Technologies for Fossil Fuel Use" published in 2005, the development and implementation will require the involvement of a large number of business sectors including power engineering, electricity generation, process engineering, fuel supply and oil and gas.

- Many of the companies that makeup these market sectors already have a strong presence in the UK.

- Given that the UK is endowed with natural resources for the long-term storage of CO_2 early adoption of these new technologies and operating experience is feasible and would give rise to potential for UK industry to sell its services internationally in the form of manufacturing, consultancy and licensing.

- It is clear that fossil fuels will play an increasing role in developing economies such as China and India. CCS is the only credible option for reducing the impact of CO_2 emissions in these countries. Early adoption of CCS in the UK could be of great significance in terms of demonstrating international leadership in tackling climate change and persuading others to exploit this technology.

6.2. Are there skills gaps that could create barriers to the development of CCS in the UK?

- In line with many other organisations. RWE believes that the potential skills cap over the next 10 years needs to be addressed as a matter of urgency across all levels within our education system if the UK it to maintain its competitive position.

- Declining number of undergraduates studying engineering and pure sciences.

- Decreasing level of interest and awareness amongst school age students of engineering and science.

- Concern/effect of highly paid jobs particularly within the city affecting the availability of numerate graduates with relevant disciplines.

7. Regulation, liability and public acceptance

7.1. What scope is there to develop and use CCS within the current regulatory framework?

- A legal and regulatory framework encompassing all aspects of the CCS supply chain will be required, covering both onshore and off shore storage needs. Areas for consideration are as follows:

    - Planning
    - EU – ETS and the treatment of CCS
    - Storage of CO_2 in offshore geological formations
    - Long-term ownership/liabilities of stored CO_2
    - Monitoring and verification

7.2. What regulatory framework would need to be put in place to support the development of CCS technology while also ensuring protection of human health and the environment?

- A legal framework encompassing aspects of the CCS project chain will be required, covering both onshore and offshore storage needs. The Government has initiated the renegotiation of relevant international offshore regimes which would have an impact on offshore storage.

- In addition a number of key issues must be clarified in discussions between the Government, regulatory bodies and potential developers including:

    - The information required by DTI, EA and HSE to authorise new CCS projects;
    - The environmental limits applicable to CCS projects;
    - Legal liability for the CO_2 at each point in the chain. For example, the producer should be responsible for the capture part of the process and the shipper and storage operator should hold the liability for their parts of the process;
    - Once stable storage has been satisfactorily demonstrated, the transfer of liability to Government; and,
    - Fair and equitable third party access to transportation and storage infrastructure.

- Planning and grid consents: in general planning inquiries should not attempt to revisit national policy but remain focused on local issues, and grid connection applications in a similar area should not present disproportionate risks or liabilities to potential developers.

- UK measures such as the Renewables Obligation for electricity supply and the Climate Change Levy do not extend to CCS.

7.2.1. Legality of North Sea Disposal

- Injection of CO_2 into any offshore repository would be covered by three treaties:

  - Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters 1972 (The London Convention).
  - The 1996 Protocol to the London Convention.
  - Convention for the Protection of the Marine Environment of the North East Atlantic 1992 (the Ospar Convention).

- The different treaties contain inconsistencies regarding the legality of offshore carbon storage and introduce considerable regulatory uncertainties to developers. We welcome the fact that the UK Government has begun the process of seeking agreement between the parties to both OSPAR and the London treaties to consider amendments to cover CO_2 storage and develop common regimes for the authorisation and regulation of CCS activities. It is important to achieve this agreement to give potential developers in CCS projects confidence that it will be possible to dispose of CO_2 in the future.

7.2.2. Liabilities of long-term storage and ownership of CO_2

- Liability for long-term storage could depend on treatment of CCS under EU ETS and Kyoto mechanisms. If a power station operator is allowed to discount emissions if CO_2 is put into long-term storage then the ownership (and liabilities) could remain with the power station operator. If on the other hand the owner of the storage facility is given a CO_2 credit for each tonne stored, then long-term ownership and liability could be expected to remain with the storage facility operator.

- The issue of ultimate long-term liabilities needs to be considered. The DTI Carbon Abatement Strategy notes that it has been proposed that ownership could be transferred from the operating company to the state after an agreed period. The liability for long-term monitoring and any future works must lie with the Government or the storage facility operator. In addition, issues of liability for long-term storage will need to be considered in conjunction with treatment of carbon capture under both EU ETS and Kyoto mechanisms.

7.2.3. Treatment of storage within EU ETS and the Kyoto Protocol

- There is currently no mechanism to reward carbon capture and storage within either EU ETS or Kyoto. Since EU ETS allowances are linked to Kyoto targets after 2008, unless CCS is recognised within the Kyoto Protocol it is unlikely to be accepted within the EU ETS. Two issues need to be addressed: changes to monitoring and reporting protocols under both EU ETS and Kyoto; and whether CCS can be used as part of the Kyoto flexible mechanisms.

- It is important that there is early clarification of treatment within EU ETS and Kyoto in order to provide confidence to investors in potential projects.

7.2.4. Planning and Authorisation

- The current planning and licensing process is a protracted and costly exercise, involving multiple agencies, several rounds of public consultations and with a completely open-ended timescale.

- If new CCS power stations are to be constructed in the UK, a legislative and regulatory framework is required that:

    - Is based on a clear statement of energy policy with broad political support
    - Provides durable public reassurance that the potential health, safety and environmental effects have been considered.

- Fundamental to this is a Strategic Environmental Assessment by the Government for new build CCS plant, which would provide an opportunity to consult with stakeholders, engage the public and document the generic environmental impact of such a programme.

- The UK has initiated work on the standards that would be needed to regulate the operation of a storage site. A gap analysis has been undertaken of existing regulatory systems but has not yet been published by the DTI. According to the DTI Strategy for Carbon Abatement Technologies, a working group of regulatory agencies is to be set up to develop any additional systems needed. We welcome these developments and encourage Government to involve industry in the development of standards.

- Planning and authorisations issues would need to be considered at all stages in the life-cycle of a carbon capture and storage project; capture, transport, injection and post-injection. Key issues for any development project would be associated with capture, and potentially transport, as any Section 36 consent may need to take into account the impact of a CO_2 pipeline.

- There are some issues relating to the way that emissions controls for species other than CO_2 are regulated that might cause problems with CCS. For example, with CCS the overall emissions of species of NO_X and SO_2 per unit energy produced would fall but the concentrations in flue gases might increase with some CCS technologies (because the volume of flue gas decreases). Currently, emissions are regulated on concentrations at the stack so these regulatory issues need to be addressed before CCS could be introduced.

7.2.5. Monitoring and verification

- EU-ETS requires monitoring and verification procedures to ensure that all contracting parties give accurate declarations of their emissions in relation to their holding of emissions permits. This process would have to be extended to include CCS with additional measures being put in place to account for potential leakage of CO_2 during transport and injection and also due to seepage during storage.

- RWE understands that the UK Government has recently started looking at the monitoring and verification procedures that would be required albeit on an ad hoc basis with other EU Member States.

7.3. What additional costs and considerations are created by the long-term liability implications attached to CCS, and how can these be best managed?

- See monitoring and verification above.

- As stated earlier the liability for long-term monitoring and any future works must lie with the Government or the storage facility operator (presumably a public body).

7.4. What issues arise concerning (short-term) liability for CO_2 at particular points in the CCS process? Are there costs attached to these and what are they?

- Short-term liabilities might include:
  - At plant start-up it might not be possible or economic to capture CO_2, however during this period of operation the costs incurred would be the same as if the CO_2 were captured so if capture were funded only by credits this would generate a liability for the short-fall in income.
  - There would be CO_2 losses at the compression stage and at transfer stations (to or between pipelines, onto ships or at storage sites). Again it is not clear how the credits for these losses might be dealt with and who would be liable but the losses are unavoidable.
  - There would be specific short-term liabilities during a demonstration. In particular, the scale might not be sufficient for CO_2 to be economically transported and stored but the costs of capture would still be incurred. If power station operator's emissions are zero because CO_2 goes into storage then storage facility operator will only take on this liability for payment. Issues around how to assess what would be reasonable for this given uncertainties at start of process.

- Carbon dioxide is likely to require storage at elevated pressures (up to 80 bar) as a liquid. It is a heavy gas. There may therefore be significant costs in safely storing this at intermediate locations.

7.5. What might be the likely public reaction to concerns about CCS, and how could concerns be addressed?

- A key concern in any decision to commit to such a large capital investment is continuity of political and public support.

- For CO_2 pipeline transport reported accident numbers reported per kilometre of pipeline are very low and comparable to those for hydrocarbon pipelines. A sudden and large release of CO_2 would pose immediate dangers to human life and health if thee were exposure to concentrations of CO_2 greater that 7 – 10% by volume in air[1].

- Pipeline transport of CO_2 through populated areas requires attention to route selection, overpressure protection and leak detection.
- Two scenarios can be envisaged in which leakage may occur for storage of CO_2 in geological reservoirs.

  - Firstly, injection well failure or leakage up abandoned wells could create a sudden and rapid release of CO_2. This is likely to be detected very

early and stopped with techniques use in the oil & gas industry today. This type of leak would affect workers in the vicinity of the release.
  - Secondly, leakage could occur through undetected faults or fractures. This type of release would generally affect drinking water aquifers and ecosystems. This could cause acidification of soils and displacement of oxygen in soils. Additionally, if leakage to the atmosphere were to occur in low-lying areas with little wind, human and animals could be harmed if the leak were to go undetected.

- Considerable effort would be required to raise public awareness of the issues relating to CCS and why it is being considered as an option for CO_2 reduction. It is the role of Government to ensure that all the necessary stakeholders are brought together to discuss the issues.

- There is really no way to demonstrate the long-term viability for all storage applications. Each one has to be evaluated on its own merits and cannot be predicted into the future. Clearly experience will generate confidence but this will take many years to build.

8. Cost

8.1. What are the costs currently associated with the development of different potential CCS technologies and forms of deployment?

- CCS has the potential to contribute to a diverse national generation mix by 2020, provided that the Government increases its existing support well beyond the £35 million currently committed for R&D funding of demonstration projects aimed at bringing this technology to market.

- The first CCS demonstration projects will require significant financial support as the market will not otherwise reward the high capital costs, lower efficiencies and risks of these projects. However, it is likely that, in the long-term, higher carbon prices combined with cost reductions in the technology would make CCS an economic option providing that long-term CO_2 prices could be guaranteed.

- Our suggestion would be that Government should initially consider the merits of CCS projects on a case by case basis and, if appropriate, facilitate investment through a tax-based mechanism (tax credits, enhanced capital allowances) consistent with the treatment of other low or zero carbon technologies (for further details please refer to the description in Appendix 1).

- Government can also improve the competitiveness of CCS projects through the way they are treated in related policy measures, for example, the Climate Change Levy and the EU ETS.

- Initial projects would each require very substantial support over their lifetimes (£100s millions) but subsequent projects would benefit from this investment, through the establishment of re-usable infrastructure, reduced cost curves and improved knowledge and expertise.

- The first CCS projects would only be viable if they could recover the costs of buying access to pipeline infrastructures to transport CO_2 to storage fields. There is a strong likelihood that early projects will need to make use of existing gas pipelines, which can be converted to carry CO_2, or make use of tankers.

- Companies such as RWE are owners and operators of power plant and hence large CCS projects are likely to need the involvement of many players throughout the whole supply chain.
- Utility companies would be able to look after the carbon capture component of CCS but would need to know the gate price for transport and storage of the CO_2.
- In the future new pipeline networks may be needed to transport CO_2 and/or hydrogen across the country. A study into the potential demand for, and delivery of, these new networks should be commissioned by the Government to inform thinking about the long-term potential and development of this technology.

8.2. How might these costs change over time and what is the evidence for any estimates of this?

- Cost estimation for CCS projects is in a very early stage. Current tendency appears to be for cost estimates to rise as overlooked items are identified and allowances made for risks, especially permitting difficulties. It is reasonable to expect the first few power plant retrofits to be the most expensive in terms of £ per tonne of carbon dioxide captures and then for costs to fall with experience and the economies of replication. Carbon dioxide transport and storage costs are likely to be location and opportunity specific. There is little supporting evidence for current estimates which are largely untested in significant size commercial projects.
- Some important issues are:
    - Equipment costs will fall relatively with time i.e. chemistry and material costs will decrease with further technology development.
    - Transport costs will only reduce when a significant number of plants are operating.
    - Storage costs could actually increase as alternative storage sites have to be used.
    - Net power costs will be heavily dependent on the price of CO_2.

8.3. How might changes in the relative prices of coal and gas in the framework governing emissions of CO_2 and other pollutants affect the costs and profitability of CCS?

- Over the timescales applicable to CCS (2014 onwards) gas prices are likely to increase dramatically. Currently coal costs follow the same trend as gas. However, CCS offers the prospect of longer-term stability in prices for coal. The ability to take advantage of CCS at an early stage would facilitate the early establishment of a stable contract prices for coal and would thus increase the benefits of investing in the technology. Reduced power generation demand for gas would also benefit domestic and other industrial gas consumers.
- CCS can be applied to coal or gas. Issues include the relative prices of the fuel, the CO_2 production per unit of electricity from each fuel, long term issues of fuel security and diversity, the higher partial pressures of carbon dioxide achievable in pre-combustion capture processes, the low carbon dioxide partial pressures in flue

gas from gas turbines and various trace species present in greater quantities in flue gas from coal fired power plants than in flue gas from gas fired power plants.

8.4. To what extent does EOR reduce costs and increase the commercial viability of CCS?

- The overall cost of CCS is typically built up from the costs of the three separate components: capture (including compression), transport and storage including monitoring).
- As EOR is highly site specific it is unclear to what extent EOR would reduce costs. However, any income would help to partially offset the costs mentioned above.

8.5. How does EOR using CO_2 compare in cost terms to EOR using other means?

- The oil & gas industry are in a much better position to offer an informed opinion on financial aspects.

8.6. Is the use of CO_2 for EOR appropriate on the UK continental shelf and at what stage in the life of a specific field is it appropriate to use EOR?

- It would seem that the use of CO_2 EOR on the UK continental shelf is an appropriate option although it is generally considered to have a fairly narrow time window of opportunity.
- There is an imbalance between coal fired power plant site locations, electricity grid constraints, UK population and North Sea oilfields locations.
- However, the oil & gas industry are in a much better position to offer an informed opinion.

8.7. What are the costs associated with building capture-ready plant and how do they differ from the cost of constructing fully operational CCS facilities? To what extent can any additional costs be mitigated by decisions on design, location etc?

- The energy use penalty of capturing CO_2 from power plant is very sensitive to efficiency. Hence, it makes no environmental or commercial sense to retrofit CCS to an inefficient plant. The plant would have to be upgraded to the latest technology i.e. supercritical boiler.
- “Capture ready” is not a precisely defined term. Capture ready implies ready for a specific technology and set of operational parameters which may not prove the optimum in light of future process developments. Plant layout issues such as ensuring flue gas and steam pipework and diversions can be inserted later at suitable points are not expensive provided the suitable points are correctly identified. Ensuring sufficient steam turbine flexibility for large changes in mass throughput as CO_2 capture is implemented is currently an area of study. Ensuring suitable land area for later retrofit of equipment is a site specific issue. Transport routes from power plants to suitable stores (which have not yet been assigned) are clearly also site specific. A major unknown is the cost of permitting carbon dioxide

capture, transport and storage systems and also the degree to which such permitting uncertainties need to be addressed in capture ready plants.

8.8. Is the use of CCS currently a profitable option for businesses in the electricity supply sector and other sectors and, if not, what is the shortfall? Under what conditions might it become profitable?

- RWE does not believe that CCS is currently profitable or likely to be for the near-term foreseeable future. Long-term stable high carbon prices may help change the situation. However, uncertainty in the longer-term EU ETS, as previously described, does not provide any incentives for the development of CCS.

9. Economic initiatives

9.1. What is the impact of the current policy framework on the development of CCS?

- Many companies within the UK have announced their interest in CCS with a view to conducting techno-economic studies over the coming year. Unless the issues described above are addressed and financial support is provided it is unlikely that many of the CCS projects will progress much beyond feasibility studies or, at best, capture-ready demonstration.

9.2. Are there any particular issues that need to be taken into account with regard to CCS when considering the use of policy mechanisms to reduce CO_2 emissions in the UK economy?

- There is currently no mechanism to reward carbon capture and storage within either EU ETS or Kyoto. Since EU ETS allowances are linked to Kyoto targets after 2008, unless CCS is recognised within the Kyoto Protocol it is unlikely to be accepted within the EU ETS. Two issues need to be addressed: changes to monitoring and reporting protocols under both EU ETS and Kyoto; and whether CCS can be used as part of the Kyoto flexible mechanisms.

- It is important that there is early clarification of treatment within EU ETS and Kyoto in order to provide confidence to investors in potential projects.

- A legal framework encompassing all aspects of the CCS supply chain will be required, covering both onshore and off shore storage needs.

- CCS has the potential to contribute to a divers national generation mix by 2020, provided that the Government increases its existing support well beyond the £35 million currently committed for R&D funding of demonstration projects aimed at bringing this technology to market.

Appendix 1 – Tax Issues re low carbon technologies including CCS

- A company's overall objective, as a matter of general principle, is to be in a position to claim immediate tax relief for all expenditure, in a way that reduces the existing tax burden. Set out below are some of the potential tax mechanisms and Treasury policy positions that might facilitate this, but also some of the existing features of UK tax law that could frustrate it, and would therefore need to be addressed.

- Given the commercial uncertainty faced by bona-fide business ventures in light of recent trends in the volume of tax legislation, it would be useful for the potential investors in CCS to have the opportunity to work with HMRC to achieve some certainty on the tax outcome before committing to substantial investment. This might well be possible through existing tax clearance procedures.

Use of existing mechanisms

- If project expenditure could be brought within either of two existing regimes covering Research and Development and Enhanced Capital Allowances, then 100% tax relief might be possible in principle, subject to the caveat below regarding timing.

- As an absolute minimum, capital expenditure on CCS should be excluded from the unfavourable long life asset (LLA) regime.

- Potential problem areas:

Tax Nothings

- The CBI has made extensive representations on the feature of the UK tax system that has been called "tax nothings". These are items of bona-fide business expenditure which nevertheless do not qualify for any sort of tax relief – either as revenue or eligible capital expenditure. Arguably, a modern tax system should have already eliminated these to make it competitive internationally, but progress in the UK has been slow.

- In the context of a new low carbon development programme, there is a risk of some expenditure being treated as capital for tax purposes, and therefore not qualifying for revenue relief, but also not qualifying for capital allowances. That would be a tax nothing, which would clearly worsen the economic prospects of a project.

- We are aware of potential tax nothings in the area of gas storage, particularly regarding creation of underground storage facilities. This feature may also arise in carbon capture and storage infrastructure and would need to be addressed.

- The tax treatment of decommissioning costs would also need to be considered. We understand there are currently special provisions relating to the offshore oil and gas industry in this respect. Depending how the commercial arrangements for decommissioning costs were organised, it may be necessary to introduce new tax rules for low-carbon technologies to ensure that useful tax deductions would be available.

Timing of tax relief

- If expenditure does avoid being classified as a tax nothing, and is also in principle eligible for an immediate tax relief, the last hurdle to clear is for that tax relief to be utilisable.

- If, for commercial, regulatory or legal reasons, the CCS development activity was in a new legal entity, then that would need to be accepted as “trading” for tax purposes for the tax reliefs to be of use. Otherwise, they would merely be deferred until the entity commenced commercial operations. This lead time could be significant for new technologies, for instance due to lengthy planning/consenting regimes. This would therefore greatly diminish the value of any tax reliefs.

- Any structure or tax regime where the tax reliefs were unavailable until successful operation of the plant, perhaps due to lack of trading for tax purposes, would represent a significant disadvantage.

Additional measures for major technology development

- In light of the particular commercial risk attaching to early stage major plant investments which are dependent on long-term CO_2 prices for a return, we raise the possibility of a targeted relief which produced tax credits equal in value to the full cost of any such abortive expenditure. This would go further than our generally stated objective above, but would be one way to mitigate the higher risks, unless some other method of reimbursement was available in the event of losses attributable to EU or Government intervention.

- A mechanism to deliver this could perhaps be based on a suitably modified and enhanced version of the current Research & Development tax credits regime. If the design program went ahead to construction, then there could be a claw-back of the enhanced tax relief given.