The Role of Carbon Dioxide Capture and Storage in a Low Carbon Economy

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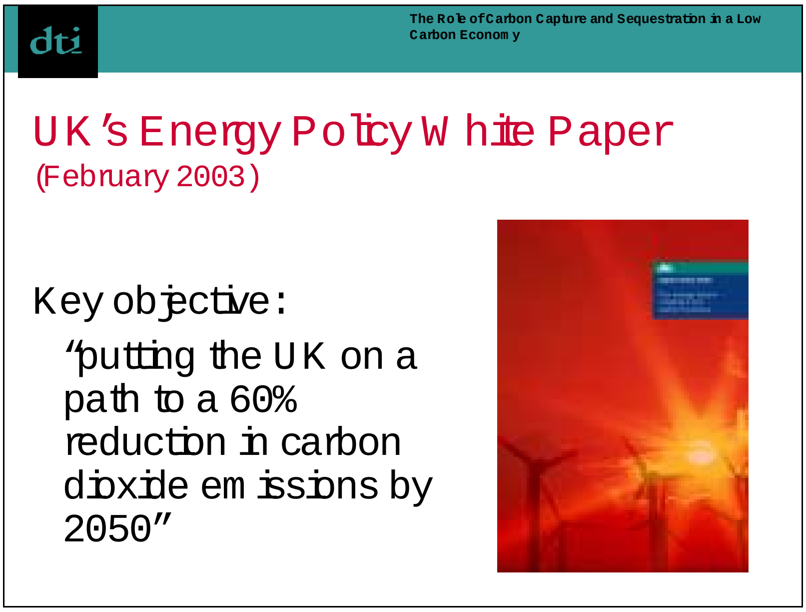
Introduction

The UK has a long track record of supporting the research, development and demonstration of cleaner fossil fuel technologies. For many years the focus of this work was to assist with the development of the cleaner coal technologies needed to meet increasingly stringent environmental standards. However, in recent years the emphasis has moved to the need to reduce greenhouse gas emissions and in particular carbon dioxide (CO_2) arising from the combustion of fossil fuels. Studies by the Intergovernmental Panel on Climate Change (IPCC) have indicated that the likelihood of significant environmental and social damage arising from climate change increases significantly if average CO_2 concentrations in the atmosphere exceed about 550 ppm (roughly twice the present level). To stabilise CO_2 concentrations at, or below, this level over the next 100 years would require a reduction in global emissions, relative to the business as usual trend, of 50% to 60% by 2050 and 70% to 90% by 2100



In the UK the views of the IPCC were endorsed by a report from the Royal Commission on Environmental Pollution that recommended that the UK should aim for a 60% reduction in CO_2 emissions compared to current levels by 2050. The UK government accepted this recommendation, and a key theme in the Energy Policy White Paper of February 2003 was to put the UK on a path to a 60% reduction in CO_2 emissions by 2050. Central to this policy is an enhanced drive for greater efficiency in all areas of energy supply and consumption together with an expansion of low to zero emissions supply options, in particular renewable energy sources. It is in these areas that most near-term actions are being taken. However, the White Paper also recognised the strategic importance of CO_2 capture and storage. CCS would enable the continued use of fossil fuels thereby giving a longer timeframe in which to achieve a transition to a fully sustainable energy system. This paper examines the potential role of carbon dioxide capture and storage (CCS) technologies in delivering these targets for the UK.

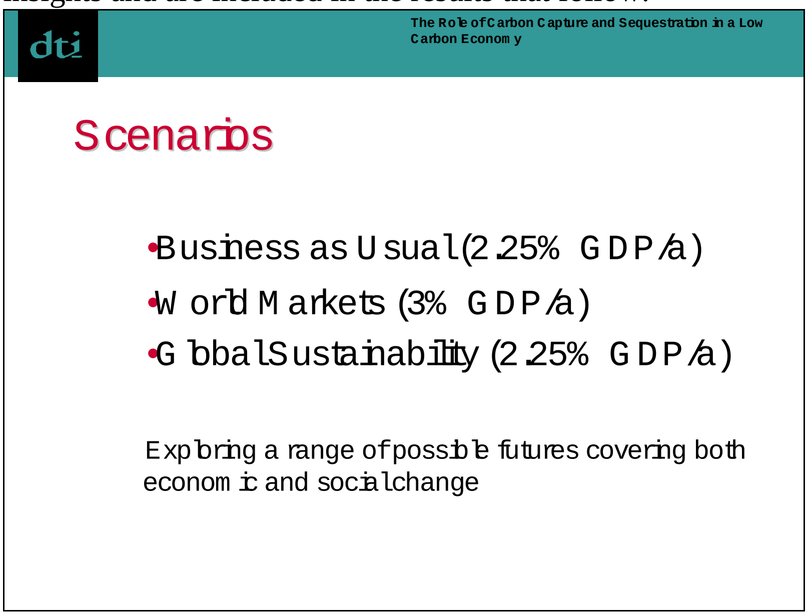
Background

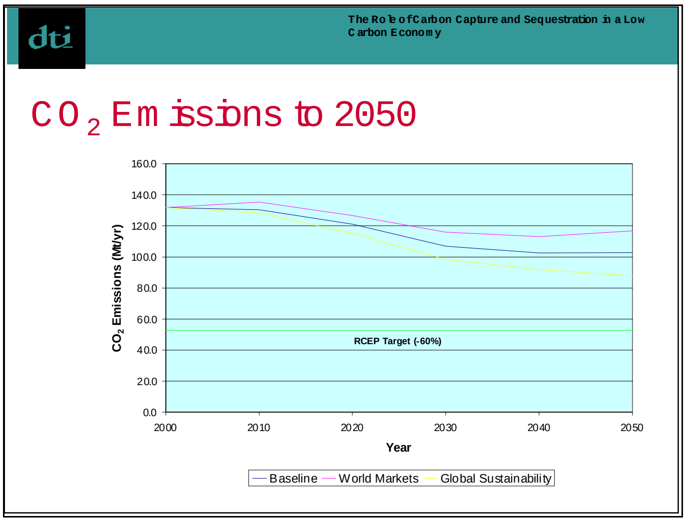
Two key studies have been carried out in the UK to examine the potential role of CCS in delivering a low carbon energy economy. The first of these was work undertaken to advise the Energy White Paper. This took an overall view of the UK energy system and the technical options and costs for delivering the 60% reduction in CO_2 emissions by 2050. The study used the MARKAL energy system model to examine the balance of measures needed on both the supply and demand sides of the energy economy. It also investigated the size and timing of the deployment of competing technology options and the implications for the overall cost to the economy.

Secondly, and subsequent to the White Paper, a more detailed review of the feasibility of carbon dioxide capture and storage in the UK was undertaken. This made a broader assessment of the economics of CCS and also examined options for early deployment and demonstration.

Systems Modelling Results

This work involved a scenario modelling approach to examine a range of possible future development paths for the UK economy and energy system. The deployment of technology options for reducing carbon dioxide emissions from the energy system was investigated across a range of scenarios. This work focused on the size and timing for the deployment of the technology options, the spread of actions between supply and demand sides of the economy, and the overall costs to the energy element of the UK economy. The model also provided a facility for undertaking a range of sensitivity analyses of critical assumptions. Some of these yield particularly useful insights and are included in the results that follow.

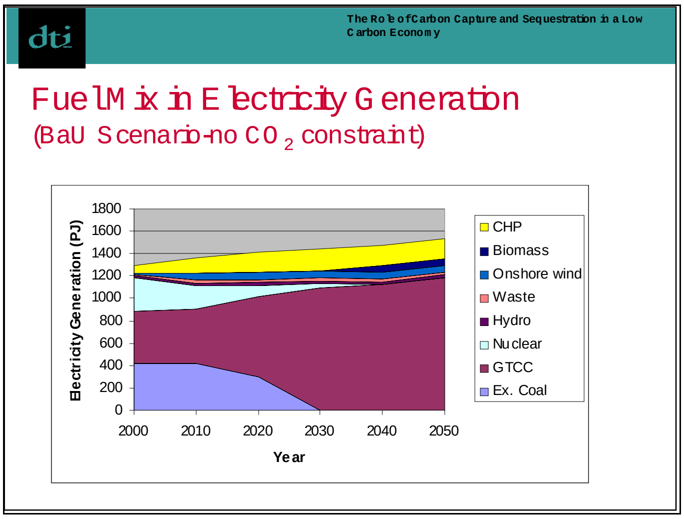




This slide shows the projected CO_2 emissions for all three scenarios.

Note that emissions are projected to fall in all cases. This is due mainly to an expected increased rate of improvement in energy efficiency across the whole economy.

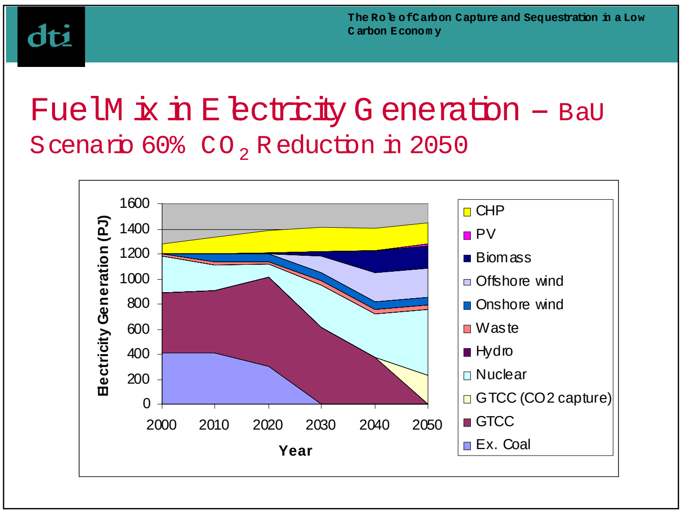
Even so a further substantial reduction is needed to get to the 60% reduction target by 2050.



This slide shows the projected fuel mix for electricity generation without any CO_2 constraint. Note:

- the phase out of both coal and nuclear power,
- the large expansion of natural gas fired generation.

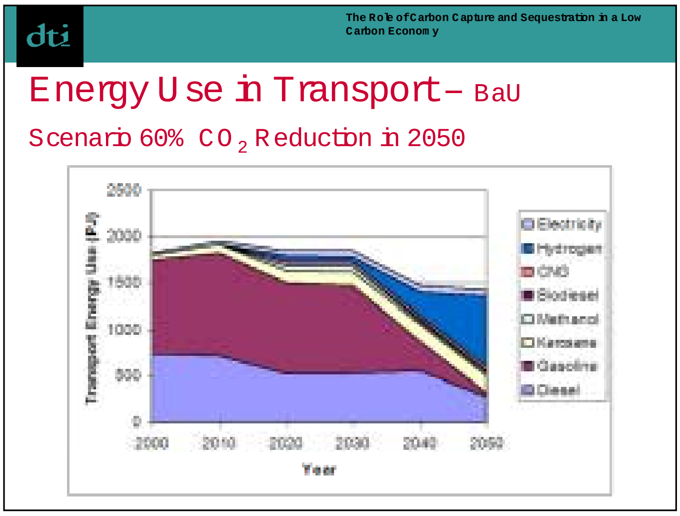
These trends were also produced with the other scenarios



This slide shows the fuel mix for electricity generation with a 60% CO_2 emission reduction by 2050.

Main points to note here are:

- The coal phase out occurs as for the case without CO_2 constraints.
- New nuclear is deployed from 2020.
- There is an expansion in the deployment of wind energy and later biomass.
- CCS is deployed from 2040 on natural gas fired GTCC plant.



This slide examines the mix of fuels used in road transport when CO_2 emissions are reduced by 60%.

Up to 2030 the fuel mix is about the same as for the unconstrained result. This is because CO_2 abatement is expensive in road transport and consequently the model takes up lower cost options in other sectors first. However, after 2030 it has to take action in transport, and this is done by deploying hydrogen in combination with fuel cell vehicles.

The important point in the context of this presentation is that the hydrogen is produced from natural gas with CCS.

The Role of Carbon Capture and Sequestration in a Low Carbon Economy

Annual cost of reducing emissions ($Bn/yr)

Theme	2020	2030	2040	2050
BaU	0	2	8	16
BaU - Limited EE	2	13	27	61
BaU - Limited Innovation	2	10	30	67

This slide shows the annual cost of reducing CO_2 emissions on a path to a 60% reduction by 2050. The cost increases significantly in later decades as the reductions become more challenging. Note that the cost increases substantially if the rate of improvement in energy efficiency is limited to the average rate of the last 30 years (BaU – Limited EE) Also the cost of abatement is higher if it is assumed that innovation in both supply and energy utilisation technologies is limited (BaU – Limited Innovation). This particular result was obtained with a crude representation of limited innovation, based on freezing technology cost and performance at the 2010 levels.

The key messages to take from this work are:

- CCS has the potential to form a major element of a low carbon economy. This is particularly so if there is no further deployment of nuclear power.
- CCS technology is likely to be needed between 2020 and 2030.The date is sensitive to scenario assumptions for economic growth and growth in the demand for energy services, as well as the success of other measures such as energy efficiency.
- CCS is important to the transport sector as well as electricity generation.
- In the UK context CCS is applied first to natural gas plant. However, this is sensitive to fuel price assumptions and the representation of deployment options in the model.

Early Deployment Opportunities

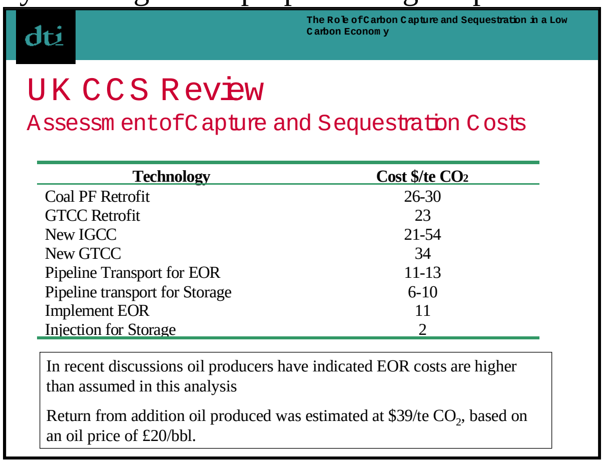
The second part of this paper is concerned with early deployment opportunities for CCS. These are important for demonstrating the technology and increasing confidence in its performance and reliability. This applies both to capture, and perhaps more importantly to storage of CO_2. In the UK the following were identified as the leading options for early deployment/demonstration:

With regard to storage most of our storage capacity is located offshore. In the longer term aquifer storage has the largest capacity, but in the near term two alternatives exist which take advantage of existing operations in the North Sea.

•Enhanced oil recovery – this has the attraction of offering a financial return from the additional oil recovered.

•Injection into a depleted gas reservoir - this does not give any financial return but involves less capital investment than EOR, which requires significant modification to production facilities.

With regard to capture this could be done by retrofitting to an existing power plant or by building a new purpose designed plant.



The Role of Carbon Capture and Sequestration in a Low Carbon Economy

UK CCS Review

Assessment of Capture and Sequestration Costs

Technology	Cost \$/te CO_2
Coal PF Retrofit	26-30
GTCC Retrofit	23
New IGCC	21-54
New GTCC	34
Pipeline Transport for EOR	11-13
Pipeline transport for Storage	6-10
Implement EOR	11
Injection for Storage	2

In recent discussions oil producers have indicated EOR costs are higher than assumed in this analysis

Return from addition oil produced was estimated at \$39/te CO_2, based on an oil price of £20/bbl.

The UK's review of the feasibility of CO_2 capture and storage made an initial economic assessment of these early deployment options.

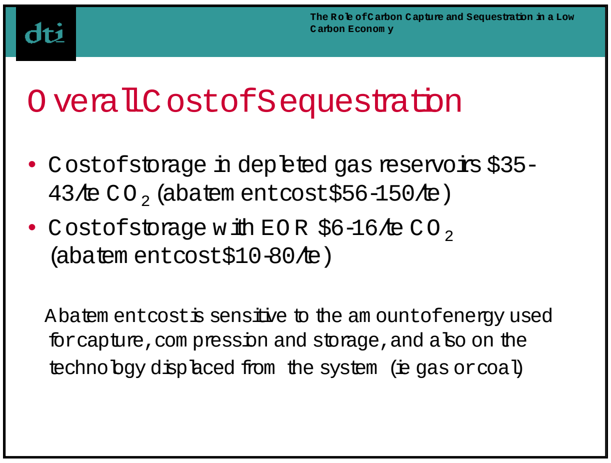
This table breaks down the cost of capture, transportation and storage of CO_2.

Note the higher cost for EOR storage compared to injection into a depleted gas reservoir.

Also the pipeline costs for EOR are higher because the oil fields are generally located further offshore than the gas fields in the North Sea.

Overall it was found that storage through EOR was cheaper than injection into a depleted natural gas field because of the financial return from the additional oil recovered.

However, this financial return was not sufficient to make EOR viable commercially, there is still an "economic gap".



Drawing the data in the previous slide together we can estimate two factors:
•The cost of CO_2 storage
•The cost of CO_2 abated
These factors are not the same because a tonne of CO_2 placed in storage is not necessarily a tonne of CO_2 emission abated.
This is because:
•Additional energy is used to capture, compress and inject the CO_2•The level of abatement depends on what emission source is displaced by the CCS plant. For example if a coal fired CCS plant displaces a natural gas fired plant the abatement is less than if it displaced another coal fired plant that did not have CCS fitted.

At present the UK is considering what options are available for bridging this economic gap. If this were to be done by price support to the power generation plant where the CO_2 is captured, support of the order of $3-16/MWh would be needed for EOR. This would enable the power station operator to supply CO_2 at a price acceptable to the oil producers, taking account of transport costs. The price support for injection into a depleted natural gas reservoir is higher of the order of $16-37/MWh. The wide ranges on these values reflect uncertainties concerning the location of the power plant relative to the oil/gas field, as well as the cost of the technologies.

Another option for supporting CCS is the EU Emission Trading Scheme, which begins in 2005. The key factor here is the price of emission permits. Current estimates suggest this will not be high enough, at least initially, to bridge the full economic gap for CCS.

It may be that a combination of measures could be drawn together to provide financial support, but it is too soon to form a view on this.

Non-Economic Factors

Finally it is important to stress that, while the economics of CCS are central to the commercialisation of the technology, there are other issues that need to be resolved for the technology to be successful.

•Authorisation and regulatory standards – CCS will need to satisfy environmental and safety standards both during the operational phase and after closure of the storage site.
•Compliance with legal frameworks it particularly important to the UK because most of our offshore storage capacity falls under the London and Ospar Treaties controlling disposal into and under the North Sea.
•Monitoring/verification standards and inventory/accounting frameworks are important if CCS is to be included within an emission trading scheme.

•Long term ownership issues need to be resolved since the commitment to monitoring and possible remediation measures will go on well beyond the usual lifetime of private organisations.
•Finally public acceptance will be paramount to successful deployment.