Response by The Royal Academy of Engineering to the DTI consultation document:

A Carbon Abatement Technologies Strategy for Fossil Fuel Power Generation

October 2004

1. Introduction

The Consultation Document sought views on the content of a Carbon Abatement Technology Strategy being developed by the DTI. That strategy is based on the expectation that beyond 2020 there will be a significant reliance on fossil fuels to meet our energy needs. It is believed that new technologies will have to be developed but in parallel there is a need to consider improvements in the efficiency/conversion technologies that offer carbon dioxide reductions and which are near market.

A consultation amongst Fellows of the Royal Academy of Engineering has indicated that, given the pattern of energy supply at the present time, the lower than expected impact of wind power, and reductions in nuclear power, then it is clear that fossil fuels will have to make a major contribution to the UK energy-mix up to and well beyond 2020. It is unlikely that control of non-CO_2 Greenhouse Gas emission would be able to compensate adequately or make a major contribution to enable the target of a 60% reduction in carbon dioxide set by the Government to be met.

Consequently it is possible that Carbon Abatement Technologies (CATs) will play an important part in the future of the UK energy supply. In such a situation the draft objective would form a reasonable basis to achieve the objectives of the Energy White Paper.

2. The Technologies

There needs to be clear Government stimuli, in respect of clear messages, leadership and funding to accelerate the development and demonstration of CATs. The current electricity trading arrangements have provided a distressed market place for electricity wholesalers and merchant generators and have acted to stifle investment in new generation plant.

It is clear that gas figures prominently in Government thinking as an integral part of the solution package, and thus coal has not received the backing that it has in other large, mature countries notably USA, Germany, Japan and Australia. This being the case, there is an understandable reticence for owners of coal plant to invest in any longer term technologies that target significant reductions in CO_2. This situation is compounded by the likely impact of the Large Combustion Plants Directive (LCPD) on coal plant which has resulted in a large capacity of coal plant being ‘opted out’ of a programme to reduce NO_x and SO_x levels to the more stringent levels expected.

CATs are traditionally viewed as necessary to maintain a role for coal in the medium to long term, but it is perhaps not realised that treatment of gas plant will also be needed at some stage. If coal’s position was made more secure by its re-emergence as a major fuel for power generation, or if it was decided to clean-up emissions from gas plant, then the development of CATs and the addressing of related issues would gain greater prominence. In any event, the development and demonstration of CATs should be carried out with eventual application to both coal and gas plant in mind.

Two groups of technological areas can be considered (1) evolutionary developments of existing power generation technologies and (2) the development of carbon dioxide capture and storage technologies. The UK can contribute to both approaches with a number of industries contributing to evolutionary developments and carbon dioxide capture but policy decisions have to be made by a number of major companies about their involvement in the storage technologies. The development of these technologies would be generally advantageous to UK companies and should be supported by appropriate levels of R & D.

The UK has developed or maintained considerable strengths in design and manufacturing capabilities in supercritical boiler technology, biomass co-firing, gas and steam turbines, CFD modelling, project management, sophisticated control systems and materials, to name a few areas. The oil and gas industry in the North Sea has also allowed the UK to develop geological, engineering, logistics and PR skills that would be useful in CO_2 sequestration issues. Future development of CATs should trade on these skills, rather than trying to replicate those that may exist in other countries, to ensure that an optimal position is reached in respect of both meeting the UK's national requirements effectively and without excessive cost and exploiting overseas export potential.

Involvement with pilot or commercial scale demonstrations of relevant technologies must form part of the future strategy. This should be complementary to continuation of R&D into underpinning sciences, for which the UK is rightly respected, in a vertically integrated partnership between industry and academia.

At the present time the engineering capabilities can be applied to gas-fired, coal-fired plant or indeed biomass-fired or cofired power stations. In these cases the cost of generating electricity with respect to carbon dioxide emission costs has been examined by The Royal Academy of Engineering [1] and a Table based on figures quoted in that Report showing these for different technologies is given below. This calculation is based on a cost of £30 per tonne for carbon dioxide. The lower efficiency of coal fired plant compared with natural gas means that the gap between Combined Cycle Gas Turbine (CCGT) plant and coal based technologies will widen as the cost of CO_2 increases. These factors, together with the influence of emissions trading, will determine the approach taken by industry.

Table 1

Cost of generating electricity (p/kWh) with respect to carbon dioxide emission costs (Zero to £30 per tonne)

Technology	Zero cost	£30 per tonne
Coal fired pulverised fuel	2.5 p/kWh	5.0 p/kWh
Coal fired circulating fluidised bed	2.6 p/kWh	5.1 p/kWh
Coal fired integrated gasification combined cycle	3.2 p/kWh	5.2 p/kWh
Gas fired open-cycle gas turbine (OCGT)	3.1 p/kWh	4.8 p/kWh
Gas fired combined-cycle gas turbine (CCGT)	2.2 p/kWh	3.3 p/kWh

2.1 Evolutionary Developments

A number of developments could take place and these are summarised below:
Natural Gas.
In the case of natural gas used in CCGT units there will be increasing efficiencies in the operation of gas turbines and electricity generation. These result from the use of improved thermodynamic cycles and plant optimisation including improved cooling tower technology. The increase in plant efficiency is estimated to be about 5-10 %.
Coal Combustion
In the case of current plant there are small gains in efficiency (several percent) that can be made in combustion processes and control and NOx/SOx/particulate emission abatement. In the case of new plant, there would be a considerable decrease in carbon emissions if a supercritical unit were built, of about 5-10%.
Biomass Co-Combustion
One of the easiest and most rapid options is use co-firing of coal and biomass [2] but there can be difficulties in the fuel supply. At present biomass fuels used in UK power plant are mainly imported and this does not provide a satisfactory secure supply. The provision of a UK market for biofuels of all types is essential and this would include both bio-residues and specially grown biofuel crops. In order to achieve this, the present Regulatory arrangements should be changed with advantage and some incentive/direction needs to be given to the biofuel/agricultural industries.
It is clear that the reductions of carbon emissions resulting from such evolutionary developments are limited.

2.2 Carbon Dioxide Capture and Storage

In principle natural gas offers some significant advantages in that CCGT plant can be readily refitted because of the clean flue gas but it is partially offset by the reduced carbon dioxide concentration in the flue gases.

With the recent volatility of the coal and gas prices set to become a more common occurrence, it is important that measures are considered to maximise the yield of the UK's natural resources on the continental shelf. Recent reviews of the potential role of CO_2 in enhanced oil recovery have questioned its economic viability, but this was against the context of a much more stable and lower oil price. If there is a window of opportunity over the next ten years to extend the UK's self sufficiency in respect of gas and oil while simultaneously conserving stocks in other geographical regions, it should be exploited.

The capture of CO_2 from existing, possibly upgraded, plant would seem to be the most expeditious route given the lack of commercial experience with a fully integrated advanced power generation/CO_2 capture technology. In this respect, retrofitting a post combustion carbon capture technology onto a CCGT power station could represent the least costly, least risky and quickest option. It would enable scale-up of currently applied carbon capture technology to be tested against all of the operational requirements previously mentioned whilst potentially reducing the requirement for government/host site funding because of the potential value of the

CO_2 being produced. Short-term application to a coal fired plant is much less attractive because of the additional costs and significant reduction in efficiency from an already lower base figure. However, continual involvement in the development and demonstration of higher efficiency, ultra-supercritical conventional coal combustion technology might enable the combination with carbon capture to be considered within the 15 year timeframe.

Pre-combustion carbon capture combined with integrated gasifier combined cycle GT (IGCC) technology is likely to emerge as the eventual coal fuelled option that may be sustainable in a carbon constrained world. This is recognised by the aspirational US Department of Energy FutureGen programme and the newer European equivalent (Hypogen), both of which make significant advances towards a hydrogen economy. However, the technology is at least 15 years away in respect of commercial viability and so interim or additional technologies will be required to help fulfil the growth in demand in the developing world and the replacement plant that will be required in more mature markets. Two possible options, both of which could be produced in a carbon-capture-ready arrangement are IGCC and (ultra) supercritical pulverised fuel technologies. Both provide a significant incremental increase in efficiency, and hence reduction in CO_2 emissions, are nearer market coal based options, and are the subject of current engineering studies supported under the DTI Cleaner Coal programme. The UK should retain an involvement in both technologies as they represent shorter-term options for consideration within the context of the UK's energy needs and for possible export potential.

The pace of developments in both CO_2 capture and CO_2 sequestration must be consistent otherwise the overall drive will be held back. The sequestration of carbon dioxide presents a number of challenges. Apart from issues concerned with the regulatory framework, legal liability, intergenerational equity and public perception there are many substantive technical issues. For instance, it is difficult to model with confidence the fate of injected CO_2 with the host formation over time periods that are relevant for sequestration projects.

3. Views on Specific Points Listed on p 13/14 of the Consultation Document

i/ii. We consider that the critical technologies lie in both areas set out in 2.1.and 2.2 above. Therefore we conclude that a two-track strategy needs to be applied supporting incremental improvements to fossil fuel combustion technologies as well as Carbon Dioxide capture and storage.

iii. Much can be done in the short term by incremental evolutionary changes leading to say 10% reduction in carbon emissions. Significantly greater reductions can be achieved without resorting to completely new plant through a combination of energy efficiency modifications and retrofitted carbon capture equipment. For larger reductions new plant has to be constructed especially designed for sequestration. This could lead to 90% reduction in carbon from the plants thus fitted.

iv. Certain aspects can be carried out on a UK basis but larger projects will have to be undertaken on an international basis. The UK should neither act independently nor leave it to others to develop CATs. The cost and benefits of rivalling established CAT programmes around the world are very difficult to justify but, by the same token, the specific drivers, skill base and geographical/economic factors that characterise the UK suggest that to simply import technologies in an uninformed way would be a sub-optimal strategy. There is no doubt that the UK should take a proactive stance in respect of carbon abatement but pool its resources with other countries and take advantage of the multi-national nature of the energy sector to participate in large scale demonstrations of relevant technologies. UK Government should allocate sufficient funds to ensure that the UK is able to participate in demonstration projects by stimulating the involvement of UK based companies.

It is important, however, that the collaboration of the UK in international projects should be more than a financial contribution, it should include the active participation of engineers from industry and academia in the work itself. Otherwise UK industry will not be able to compete on equal terms in the supply of the developed technology in the developing markets. Opportunities should be sought for the UK to take the lead in international projects, which would lead to the maximum benefit for UK exploitation.

v. The classification of CATs given in Annex A is supported. This entails a very wide spectrum of activity and should be integrated with other research programmes including those of the Research Councils and the Carbon Trust.

vi. The present mechanisms for the interaction of Academic and Industrial research programmes are extremely limited and need to be extended to cover all aspects of CAT technologies.

vii. There would be problems in attempting to obtain funding for a large-scale sequestration unit for a coal-fired plant. A possible approach in the UK would be to consider a demonstration plant with a single gas-fired CCGT unit, but probably the best approach is on an international or European basis as discussed above.

viii. A balanced approach to CAT technologies and issues associated with CO_2 storage is required within the strategy. The emphasis must be to facilitate involvement in international programmes at a significant level, perhaps including the opportunity to host an internationally funded demonstration within the UK. The European Framework Programmes and equivalent activity in the US and Canada, for example, provide an ideal opportunity to pool resources to mutual benefit and without undue compromise on the UK's export position. There is little to be gained in replicating demonstrations in the UK of technologies that are already at an advanced stage of assessment elsewhere.

ix. The UK Government should develop a CAT strategy that establishes the UK as a major player in efforts to reduce CO_2 emissions It should not be looking to develop and demonstrate CATs in isolation from efforts in progress or planned in the rest of the world, but it should be able to make a significant contribution to international efforts. The Government should concentrate at least a proportion of its efforts on bi-lateral initiatives, or cooperation with smaller groups of countries. The DTI involvement in the European Commission financed Fossil Energy Coalition (FENCO) is sending the right signals, but at the end of the day this has to be backed up with financial commitment to facilitate UK involvement at a significant level. A fresh impetus on enhanced oil recovery might be appropriate and this may enable the UK to complement current work on CO_2 capture, transportation and storage. Parallel activity on the technologies that might provide incremental improvements in efficiency and the longer term bulk production of hydrogen is also appropriate but with the emphasis on collaboration.

x. The key issues are agreed with.

xi. If it was totally up to the market to decide on the economic viability of CATs then their introduction is likely to be slow and patchy at best. The unpredictability of the cost of CO_2 within fledgling trading markets, the lack of a clear signal from government on the future energy mix in the UK and the unproven performance and reliability of CATs act as a disincentive for power generators to invest. The government must provide some confidence to the sector that it is clear on the role of fossil fuels in the energy mix through appropriate financial instruments. At present, there is no certainty in the volume and therefore value of CO_2 permits beyond the next few years. Market stability needs to be established over much longer timescales to allow industry to invest.

xii. The Royal Academy of Engineering would be pleased to facilitate an informed public debate.

xiii. The Technology Transfer and Exports Promotion activities could be retained with advantage.

xiv. If the proper incentives are in place to allow strong consideration of the application of CATs, then there are some key aspects of their application that require further investigation. From an operational perspective the safety, efficiency, reliability, through life cost and flexibility of capture technologies would need quantifying whereas the sequestration of CO_2 still has the major issues of legality, long term stability, public perception and monitoring and evaluation to resolve.

xv. At present no additional steps need to be taken.

4. Concluding Remarks

Fossil fuels will continue to make a major contribution beyond 2020 and action will have to taken to reduce or eliminate the resultant carbon dioxide emissions. Thus it is not a question of small incremental efficiency improvements versus innovative technological step changes such as sequestration, but in the time scale envisaged here both are required.

Having a strong presence in the development and demonstration of CATs would enable the UK to minimise the cost of commercial application of appropriate technologies by reducing the risk of investing in an inappropriate strategy. It would also allow UK manufacturers to be able to develop certain components of CATs and therefore reduce the import burden and increase export opportunities. UK universities could provide the scientific underpinning for the development and ensure that the role of the research led universities as a source of both creative people and ideas was sustained.

There are many other industrial sectors that would benefit by a CAT programme than just power generation. Enhanced recovery of gas and oil from the gradually depleting North Sea reserves is one example and carbon reduction in many process industries eg cement, metals, paper, petrochemicals must also be addressed because of their significant impact on CO_2 emissions.

References

1. The Cost of Generating Electricity. A Study carried out by PB Power for The Royal Academy of Engineering, March 2004

2. Biomass as a Renewable Energy Source. Royal Commission on Environmental Pollution, May 2004

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