



## **SURVEY OF POWER STATION CONTRACTORS**

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## EXECUTIVE SUMMARY

Coal can continue to have a significant role within the UK energy portfolio providing that it can meet the ever tightening environmental regulations. This includes the need to be able to capture CO<sub>2</sub> for secure storage. In that regard, since there will be a need to order new power plant in the very near future, and if coal is to be considered, then the concept of the capture ready power plant, such that the capture process can be added at a later time, will have to be adopted. This will only happen if there are contractors who will be willing to bid to establish such concepts. Accordingly, this survey has been undertaken to determine whether they are prepared to take forward one or more of the four capture ready options proposed. Therefore it provides a valuable insight into the UK prospects for establishing such a strategic position. The key findings from this survey of ten UK based contractors are set out below.

All contractors had some reservations regarding the terms of reference inasmuch that any decision to bid in practice will be dependent on many factors prevalent at the time, such as client, scope and interface definition, availability of resources, number of bidders, commercial terms and conditions and associated risks. In particular, the idea that any new power station would be built on a full turnkey contract basis, with guarantees against financial liabilities for capital cost, completion time, and overall performance, as has been the general practice in the industry, was not necessarily seen as the most appropriate mechanism for the capture ready approach. Many contractors noted that their clients now advocate an initial reimbursable route, with an incentivised approach, that can be fully or partly converted to a lump sum basis at an appropriate stage within the project cycle.

There are contractors that would be prepared to bid to construct each of the four options of capture ready power plant identified within the study. However, in all cases, while contractors could be found to provide guarantees for each power plant option, all pointed out that no guarantees could be provided for the performance of any subsequent CO<sub>2</sub> capture phase nor for any adverse performance that would occur once the capture ready option was implemented.

Notwithstanding, the fact that there should be contractors available to take forward the construction of capture ready clean coal power plants within the UK, all expressed some concerns with the capture ready concept. Within the UK power sector framework, the introduction of the capture ready plant design for all four options would introduce significant additional costs to be borne by the end-user power company that places the order. This is not just a case of allowing space in the overall layout for the subsequent introduction of additional equipment but could also include significant engineering work if the end-user is to avoid much greater costs at the capture implementation stage. Unless the capture ready concept is recognised and supported in some way within the framework of the UK power sector then it is difficult to envisage any power generator willing to incur such significant upfront costs.

That said, the option of establishing a PF power plant, with a supercritical steam cycle, to which could be added, in due course, some form of back-end CO<sub>2</sub> scrubber was considered, in principle, to be a relatively low risk approach by all the contractors that include the provision of such combustion based technology within their business

portfolio. However, all noted that before the capture ready option could actually be implemented there would need to be a meaningful demonstration of the scrubber technology in advance of its implementation at this commercial scale.

The option of establishing an IGCC power plant that could subsequently be converted to allow for pre-combustion decarbonisation and the production of a very hydrogen rich fuel gas provoked a more mixed response. Those contractors who either do not have a gasification-based track record and/or who do not include such technology within their business portfolio, were not convinced of the maturity of the basic IGCC for use within the UK power system. In contrast, those contractors that have been active in the chemical processing sector and in IGCC refinery activities were far more positive although they acknowledged the difficulty in establishing coal based IGCC at an overall cost acceptable within the UK power sector compared to combustion based alternatives. However, the need to make such a system capture ready was not seen as overly problematical from a technical and engineering perspective since this approach has been established at a meaningful scale within non-power operations.

The oxyfuel option, i.e. the option of establishing a PF power plant, with a supercritical steam cycle, capable of modification in due course to allow for oxygen based combustion with CO<sub>2</sub> recycle in order to produce a concentrated stream of CO<sub>2</sub> and water vapour for subsequent separation of the CO<sub>2</sub>, received another mixed response. The combustion based equipment developers were very supportive of this approach as they see it as being a potentially important route forward for PF plant to achieve cost effective CO<sub>2</sub> capture. They recognised that the technology is not yet proven for power plant operation but believed that ongoing R&D will be successful. In contrast, many of the other contractors, which are not involved in such R&D activities, were not convinced of its merits and had concerns that its relative immaturity would preclude their involvement since its market potential cannot yet be determined. In effect, should they be asked to bid, there would be a need for such an extensive risk analysis and cost benefit analysis that it might not be worth their companies becoming involved.

The option for the provision of a standalone coal based gasifier system to provide a syngas for use within an existing combined cycle plant that previously had been fired on natural gas, was seen as a much lower risk approach than the full IGCC option. The engineering required would be simpler since there would be a lack of detailed integration. However, several contractors expressed concerns that the lack of integration may lead to a low economic benefit.

It was also intended that the outcome from this survey might provide guidance for the direction of future UK DTI support for clean coal R,D&D. It is evident that, while capture ready clean coal power plants could be established now, there is a need for a considerable amount of work to establish the capture technologies themselves such that they can be ready for implementation in the medium term future. Support will be required for both combustion and gasification based technology options. Thus, R&D issues remain with all the capture ready options above and beyond the overall need in each case to improve availability, efficiency and environmental performance.

There remains merit in trying to improve the efficiency of the CO<sub>2</sub> scrubber process appropriate to the range of conditions likely to be found at existing coal fired UK power plants. However, it must be said that the major need with this scrubber technology must

be to establish some form of meaningful demonstration. At the same time, several contractors noted that there is a strong driver to improve the performance of PF plant through the establishment of advanced steam conditions, together with changes in the overall design to limit increases in capital costs due to the need to use very expensive super-alloys for the higher pressure and temperature steam components. There are various major R&D programmes underway on this topic. At present the inclusion of a CO<sub>2</sub> scrubber within these new designs is not a high priority but it will need to become so in due course so that the next generation of PF plant can be specified and designed to be capture ready as well as the current generation

The need remains to prove coal based IGCC technology as a competitive alternative to PF plant and the establishment of such a capture ready plant in the UK would be a significant step forward. With regard to R&D issues, although it was recognised that that the gas turbine combustors could be modified to accept and utilise a very hydrogen rich fuel gas rather than syngas if the capture ready mode was implemented, several contractors identified this as an area where they believe that further work is necessary. This would ensure that the gas turbine combustors can readily and effectively accept the full range of syngases likely to be encountered, including very hydrogen rich mixtures with much lower levels of dilution from nitrogen than would be needed at present. .

The oxyfuel variant is only at the pre-competitive R&D stage and so work needs to be taken forward at least until meaningful comparisons with more established alternatives can be undertaken.

Finally, the option to establish a gasifier to supply syngas to a combined cycle power plant is probably the only option where R&D is not needed. However, studies are needed to determine the conditions under which such an approach is economically justifiable compared to alternatives.

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## 1. INTRODUCTION

### Background

Within the UK, in order to meet expected power demand, it is generally accepted that a major new build of power stations will be needed shortly to replace both coal fired and nuclear plant that will be shut down at the end of their operating life. The Energy White Paper of 2003 assumed a fallback situation of increased imports of natural gas for power station fuel to balance national demand for electricity, after new contributions from renewable energy had been taken into account. However, it is recognised that this could result in an imbalance of energy supply sources, and attention is now focusing on the issues associated with maintaining a viable, diverse energy supply portfolio.

This has focused attention on alternatives to natural gas such as maintaining the current proportion of nuclear power through the building of replacement plants. A further option is to also replace existing coal-fired power stations, with “clean coal” versions. “Clean coal” is defined as discharging only small quantities of SO<sub>x</sub>, NO<sub>x</sub>, particulates and CO<sub>2</sub> into the atmosphere. When CO<sub>2</sub> emissions are considered, the ultimate aim of future clean coal power stations will be to capture CO<sub>2</sub> for secure storage. However, at present, the inclusion of a technology for CO<sub>2</sub> capture is not either a realistic or commercial proposition since the capture stage is not yet proven while no authorised and monitored CO<sub>2</sub> storage facilities yet exist. Therefore, for the likely timescales when new clean coal power plants must be ordered and built, these will have to be “capture ready” units such that the capture stage can be added at a later time.

There are four types of clean coal power stations that could be considered for application in the UK. All are in various states of development and none have yet been built in either the UK or outside of the UK. For realisation of any of these power station concepts, turnkey contractors (TCs) have to be available to bid. It is anticipated that any new power station would be built on a turnkey contract basis, with guarantees against financial liabilities for capital cost, completion time, and overall performance including atmospheric discharges. Because of the continuous development of the technologies, and the dispersed nature of data and information on their progress and benefits, it is possible that TCs may either prefer to build one rather than another option, or wait for further development work to be in place before considering bidding.

At the same time, UK Government funding for development continues to be invested in all four options as there is no clear-cut “best” technology. This spreading of limited available funding between four options dilutes its effect, and another means of demarcation would be useful in addition to the paper estimates of cost, time to build, and performance.

Accordingly, the Energy Conversion Technology Subject Group (ECTSG) representing the Institution of Chemical Engineers (IChemE), together with the United Kingdom Department of Trade and Industry (DTI) have jointly funded this survey of suitably qualified UK contractors prepared to bid for the turnkey supply of a CO<sub>2</sub> capture ready clean coal power station. The objective is to determine the status of UK Turnkey Contractors as to their preparedness to undertake clean coal power station turnkey bidding and, where appropriate, what additional development, both technical and commercial, would facilitate such preparedness.

It is recognised that, under EU bidding rules, mainland companies would also be entitled to bid for the supply of new power stations in the UK. However, it is stressed that this survey was not intended to be a form of pre-selection in any way. Its purpose was to determine the state of the market to support new clean coal build, and to help identify the most appropriate areas of development investment that would in due course encourage more contractors to bid. Consequently, the TC companies that have been contacted are all UK based.

This report provides a review of the study and the implications arising. On the basis of the contents, the IChemE will produce an input to the DTI "carbon abatement technology road map", due to be completed during April 2006.

### Scope

The Survey comprised a Preliminary Inquiry followed by a more detailed Confirmation of each TC company position.

The Preliminary Inquiry has determined whether the TC would be interested in bidding turnkey for "capture ready" clean coal power stations, which include an option from which at least 90% of the carbon in the feed is to be removed in the form of high purity CO<sub>2</sub> gas. The intention would be, if and when the option is commissioned, to dry and compress the captured CO<sub>2</sub> for export from the power station to storage. In order for the TCs to have a rational specification, against which to consider bidding for "capture ready" power stations, a definition was provided, as set out in Appendix A.

The power station was deemed to be a commercial unit feeding electricity to the National Grid and with multi-streaming as necessary to achieve a competitive availability. The following four process schemes were considered:

Pulverised coal burning with flue gas scrubbing of CO<sub>2</sub>

Integrated Gasification Combined Cycle with pre-combustion capture of CO<sub>2</sub>

Oxyburn combustion in a pulverised coal fired unit

An upstream gasification module contracted separately to an existing downstream Combined Cycle Unit that previously had been fired on natural gas

It is noted that circulating fluidised bed combustion (CFBC) has not been specifically considered as a technology variant for Options A and C, given that the current UK coal fired power plant stock is all based on pulverised fuel combustion and that it is understood that this comparative position is unlikely to change in the foreseeable future. However, it should be noted that, in general terms, the issues raised below for Options A and C would also be applicable to CFBC.

## **2. METHOD OF WORKING**

The UK contractors that were contacted to establish whether each was agreeable to participate in the Survey are given in Appendix B. Of the ten contacted originally, nine expressed a positive and proactive interest in participating in this survey.

The Preliminary Inquiry document was prepared and issued to those selected UK contractors that had agreed to participate, as summarised in Appendix C. This was designed to clarify and confirm the details of the Objectives, Scope and the Method of Working.

The completed responses from the UK contractors were collated and tabulated, as given in non-attributable form in Appendix D.

Subsequent discussions were held with each UK contractor to determine their views on the issues that will influence their willingness to bid for the provision of each of the four options set out above. A non-attributable summary of those discussions is given in Section 4 of the main body of this report. From this, the implications for the UK to establish capture ready power plant are also considered, as given in Section 5.

## **3. RESULTS**

The results from the preliminary enquiry are given in Appendix D. This shows that, of the UK contractors that participated, at least one was prepared to bid, either as a turn-key contractor or as the leader of a consortium, for the supply of a capture ready power plant based on each of the four options listed.

## **4. DISCUSSION**

### **4.1 Overview of the companies' profiles**

All nine companies that participated have extensive track records within the power sector. Of these, Aker Kvaerner, AMEC, Fluor, Foster Wheeler and Stone & Webster can be viewed as 'traditional' contractors, encompassing all phases of project execution including feasibility studies, optimisation and integration studies, front-end engineering design (FEED), and full engineering-procurement-construction (EPC). The others can offer a similar range of services but also offer a selection of their own technologies that are appropriate for use in the current coal fired power sector. Of these Alstom offer an extensive range including the boiler island, steam and gas turbines. Mitsui Babcock offer the boiler island and combustion related technologies, Siemens offer both steam and gas turbine based components while GE Energy has access to gasifier island and gas turbine technologies via their parent company.

Finally, looking towards the eventual need for CO<sub>2</sub> capture, Fluor can offer its own removal technology for recovering CO<sub>2</sub> from flue gas.

## 4.2 Criteria for bidding by the contractors

The decision to actually bid and the basis of such a bid depends on many factors such as client, scope and interface definition, availability of resources, number of bidders, commercial terms and conditions and associated risks. Two options put forward were:

Full lump sum turnkey (LSTK), with the contractor taking full responsibility for meeting all plant performance guarantees and completion within a specified timescale against defined financial penalties for non-achievement of contractual terms. Inevitably, under such an arrangement, the contractor needs to include significant financial contingencies within his bid to allow for the unexpected. At the same time, this approach may not best lend itself to any form of development project, of the sort considered within this study.

Reimbursable contract with the contractor working alongside the client to address the areas of uncertainty on a target based incentivised approach. This can subsequently be converted to a lump sum basis at an agreed stage in the overall process. Many of the contractors noted that the market is driving this change in contract strategy due to the current uncertainty regarding equipment/material supply and the contingency required to compensate for this. Consequently, their clients are increasingly seeing the value of going the reimbursable /conversion route since ultimately it offers lower risk and in the current climate can be more cost effective. They also noted that while a client may use different contractors for different project phases, a client may retain the services of a particular contractor throughout the project cycle via a number of contracts as this will minimise the time associated with competitive bidding.

In the context of this study, the advantages and disadvantages of both approaches were noted, with the engineering procurement contractors, who did not own technology themselves, being in favour of working on a reimbursable basis within an incentivised approach. As noted above, this can be converted to a lump sum contract at an appropriate point, which most determined would be within the design-engineering phase.

With regard to the decision to bid either as a single contractor or as the leader of a consortium bid, this like all commercial responses would be both value and risk driven. Certain companies noted that they have risk-averse procedures in place that are likely to preclude them offering a single bid. However, under the right circumstances, they would be prepared to lead a consortium bid.

In addition, under the terms of this study, many of the contractors have identified that they could lead bids in principle, as noted in their responses. However, in practice, they might not since the foreseen value might be too low to merit serious interest (e.g. Option D where the value will be dominated by the provision of the gasifier-based component). As such the responses given in Appendix D must be treated with caution.

### 4.3 Overview of findings

Comments are made for each of the four options outlined above, based on the views put forward during the discussions held with each of the nine contractors.

Option A (Provision of a supercritical PF fired power plant to be engineered for the later inclusion of some form of back-end CO<sub>2</sub> scrubber)

The prevailing view was that this could be undertaken immediately and that this option was now ready for market exploitation. Thus all the eight contractors that are in the business of offering combustion based plant are ready now to offer a capture ready design for the subsequent installation of a back end flue gas scrubber for CO<sub>2</sub> removal. Of these, four would be prepared to offer single bids while eight would be prepared to lead consortia bids. That said, they would offer 'commercial guarantees' for the performance of the PF plant (this being state of the art technology) but would not offer commercial guarantees either for the performance of the scrubber itself or for any overall adverse impact on plant efficiency and availability, should it be added at a later date.

All noted very strongly that to date such scrubbers have been used only at modest scales, for a flue gas throughput arising from natural gas combustion equivalent to some tens of MWs. There is not yet evidence that such scrubbers are commercially proven at the scale appropriate for the power sector where the flue gas throughput equivalent to some 500 MWs would have to be treated. Another key issue is the adverse impact on the regenerability of the amine-based solvent arising from the coal-derived impurities in the flue gas. Thus they believe that further work is required to improve and optimise the flue gas scrubber system in order for such a system to be economically viable in the current market. As such, six of the eight have indicated that more development work is needed. However all noted that, in principle, there is every likelihood that CO<sub>2</sub> scrubber development and demonstration at a meaningful scale can be proven over the next few years. Of course, this requires some organisation to take the lead in such a technology demonstration and given the uncertainty in the UK power market it is difficult to determine a possible UK technology champion in the absence of some form of financial support to alleviate commercial risk. However, it is stressed that the need for such development and demonstration of the scrubber would not impact on their capability to offer a capture ready plant at the present time.

Such a design could be for either a retrofit or a new build option. However, in the UK, given the age of the power plants, a retrofit is likely to represent almost a complete rebuild (i.e. boiler island plus steam turbine and generators) within the existing site. As such a new build on an existing site is probably a more likely option.

For the contractor that also has a scrubber technology of its own, their view was that they would prefer to offer the scrubber now rather than go to a capture ready design as, in their view, there is a danger of significant over-engineering in the capture ready approach with associated cost considerations either for the contractor and/or the end-user client. It was noted that this approach would in effect become a first power plant scale demonstration of technology and as such it is recognised that there would need to be certain financial safeguards on all sides to mitigate risk.

The other concern raised, applicable to all options, was the economic feasibility of the capture ready concept. Within the UK power sector framework, the introduction of the capture ready plant design for all four options will introduce significant additional costs to be borne by the end-user power company that places the order. This is not just a case of allowing space in the overall layout for the subsequent introduction of additional equipment but can also include significant engineering work and additional plant components if the end-user is to avoid much greater costs at the capture implementation stage. Unless the capture ready concept is recognised and supported in some way within the framework of the UK power sector then it is difficult to envisage any power generator willing to incur such significant upfront costs

Option B Integrated Gasification Combined Cycle to be engineered for the later inclusion of pre-combustion capture of CO<sub>2</sub>

Two contractors would be prepared to offer single bids while eight (i.e. these two and six others) would be prepared to lead consortia bids. They believe that their consortia could offer performance guarantees now for the capture ready IGCC. However, as for the other options, they could not offer such guarantees for the implementation of the capture ready step.

There was a greater divergence of views on this option compared to Option A. Thus the contractors with a combustion-based portfolio were doubtful that the basic technology could currently be offered with commercial guarantees, leaving aside the issues for a capture ready option. They cited the need to establish a commercial gasifier power plant system that can meet the operability/reliability criteria demanded by UK utilities. In contrast, those contractors either offering their own technology or who have considerable experience of contracting gasification systems outside of the coal fired power sector, were far more positive. They stated that they could offer commercial guarantees at present on the IGCC, although it would not be possible to offer such guarantees for the implementation of the capture ready option unless the exact decarbonised fuel composition could be defined. They noted that since the USA and EU coal gasification demonstration plants were established, considerable experience had been gained particularly in the refinery sector. As such, the approach that would now be adopted would reflect a range of improvements determined from the performance of these various plants such that the power sector end-user needs could be achieved. Indeed they believe that they can exceed those needs if they meet state of the art non-power sector availability requirements, although there are capital costs considerations with this approach.

The choices included the installation of spare gasification capacity together with some form of buffer gas storage system. However, such availability comes at the expense of an increased capital expenditure (capex) requirement, which is higher than for alternative PF power generation system expectations. Since the power sector has always been driven by a low capex/KW approach, this is a difference that needs to be addressed. To put this in context, with regard to availability of IGCC, several contractors noted that for the UK situation, there are some five strong generating companies, with a diversified portfolio of power plants. As such, it would be possible for such companies to establish an IGCC on the balance sheet and so take an evaluated risk with unexpected IGCC outages being covered through use of spare capacity. In contrast, independent power producers would not be in a position to adopt this approach and as such may be viewed by the Banks as too high a risk to support for IGCC. That said, unless a UK

utility takes a strategic position to establish an IGCC system it might be difficult to establish such a technology in the UK.

With regard to making such a gasification based system capture ready, this was not seen as overly problematical from an engineering perspective, irrespective of gasifier choice. The preferred approach would be to include the shift reactor in the original design while leaving space for the additional CO<sub>2</sub> removal equipment that would be required when the CO<sub>2</sub> capture approach was subsequently implemented. The decision on whether to then use that reactor and to what extent would be driven by operational economic issues. If the reactor should be utilised in non-capture mode then the syngas would be a mixture of CO<sub>2</sub> and H<sub>2</sub>. This can be accommodated in various gas turbine combustors, albeit with an impact on cost and efficiency. If the CO<sub>2</sub> capture stage should be implemented, thereby removing the CO<sub>2</sub>, then the hydrogen rich fuel gas would be need to be diluted with nitrogen and/or steam, depending to some extent on the allowable NO<sub>x</sub> emissions.

That said, all noted areas for development to ensure that such a gasification power system could operate effectively if the capture ready option should be implemented. Thus with regard to gasifier choice, there would be some site-specific issues to consider, of which the element of moisturisation within the gasifier process is important. They believe that the status of each individual component is adequate although there would be clear benefit in improving each component performance to enhance the overall cycle efficiency. For example, there would be benefit in developing a better understanding of the fluid dynamics and thermo/chemical dynamics within the gasifier vessels at the physical sizes now envisaged, It would be valuable to improve the energy efficiency of the CO<sub>2</sub> sorbing/desorbing system. Most importantly, the contractors that supply gas turbines noted that while the acceptable combustion of very hydrogen rich fuel gas can be achieved by dilution with nitrogen and/or steam there is a need to continue the development of fuel flexible concepts capable of achieving acceptable environmental standards with less use of diluents. There is also the issue of making the gas turbine combustion system dual-fired so that either natural gas or gas oil can be used when hydrogen rich syngas is not available for any reason. It is possible that higher capex investment on the gasification system to ensure very high availability (as in the Kodak Eastman approach in USA) would negate the need for the expensive dual fuel capability.

The other point to be considered is the relative lack of contractors prepared to make single bids to establish this capture ready option. As noted above, many organisations see the turnkey bid as inappropriate for this type of project. Others noted that it would seem to need the former CEGB approach where the end-user manages the project and places contracts as necessary with suppliers, design and engineering consultants and so on.

Option C Provision of a supercritical PF fired power plant to be engineered for the later inclusion of oxyburn combustion

In total, three contractors would be prepared to offer single bids while six (those three and three others) would be prepared to lead consortium bids. It was noticeable that this option was championed primarily by two contractors, each with an extensive combustion/boiler equipment portfolio, and both of whom have major R&D projects underway. This also reflects the widespread interest from end-users due to the

perceived potential advantage that the technology would be a modification of the 'tried and trusted' PF package. In all cases, it was felt that it should be possible to engineer the 'standard' PF package such that later it could be adapted for oxyfuel operation. That said, this option appeared to be the one for which the modifications that would be necessary to implement a capture ready approach were least well identified. As such six contractors stated that this technology is not yet proven at power plant scale and that there was a need for extensive technology development.

In overall terms, this option was seen to be the least proven on technical grounds. If an order should be placed now, then to take this option forward would require a greater level of upfront feasibility work. At the same time, to an extent, this was seen as an option for which a market niche is the least certain, which links back to the current uncertainties regarding the establishment of a technology approach on a cost-effective basis that can offer advantages over alternative options.

Option D An upstream gasification module contracted separately to an existing downstream Combined Cycle Unit that previously had been fired on natural gas. This option was seen as possibly the least problematical on technical grounds. Thus at this time four contractors would offer single bids and eight in principle would offer consortia bids for the provision of a system that is capable of providing syngas to fuel a gas turbine with the necessary availability to meet a power generator end-user needs.

The contractors see this as an evolutionary development option, which will allow for the retrofit of existing combined cycle power plants through the provision of a syngas supply to replace a natural gas supply. It is viewed as a relatively straightforward engineering challenge, due to the lack of detailed integration that would otherwise be found with the IGCC Option B. However, it was also noted that the lack of integration could lead to poor economics and so in practice it would be essential to determine whether a cost-benefit analysis of this option would be positive. Thus all eight contractors that might lead a consortium stated that they could proceed without further development work although five noted that the attractiveness of the technology could be improved through further R,D&D. The approach would be similar to that for Option B. Thus the shift reactor would need to be included and the decision on whether to then use that reactor and to what extent would be driven by operational economic issues, including whether the gas turbine supplier was comfortable with the syngas composition to be fired. As for Option B, the major commercial requirement would be to agree contractual terms for meeting power plant availability issues.

The value for such a retrofit contract would be in the provision of the gasifier. The other main input would be to modify the gas turbine combustor system to accept and utilise effectively syngas rather than natural gas. It is possible that the gas turbine modification would be dealt with as a subcontract separate from the contract for the provision of the gasifier source. Thus, some contractors doubt there would be sufficient value in practice to justify their involvement.

#### 4.4 Other issues arising

It was noted that the recent energy bill in the USA includes measures to motivate investment in the market. In particular, there is provision for the USA Government to mitigate the risk to underwriters for IGCC projects such that projects can proceed more readily. In the past there have been some very successful gasification projects in the USA (e.g. Great Plains) but these had required heavy Government subsidy to get them established. They noted that the lack of such support is likely to make the introduction of IGCC and indeed other advanced clean coal combustion technologies more difficult in the UK.

Although not strictly within the terms of reference, it was noted that if carbon capture from clean coal plants is to be introduced extensively within the UK, then there will need to be established an extensive CO<sub>2</sub> transmission pipeline and associated infrastructure. It would be prohibitively expensive for the first CCS project to pay for such an infrastructure and they suggest that the Government would need to underwrite this in the national interest. As it is possible that the first CCS projects in the UK might be linked to enhanced oil recovery, perhaps the Government could use tax credits on the extra oil production to pay for such a national infrastructure.

#### 4.5 Summary of future development needs

In the context of the study terms of reference, contractors were prepared to build clean coal capture ready power plants without the need for further technology development. For the contractors that also have their own technology portfolio, their position reflects their belief that ongoing R, D&D activities are likely to be successful by the time that any capture ready options need to be implemented. For the other contractors their position reflects that they will impose a contractual onus on the suppliers to ensure that their technology meets the performance guarantees.

Within this context, the majority of contractors therefore identified that in each case there was a need to take forward the development of the capture processes in order that these can be ready for subsequent implementation. This will then allow the capture ready options to be fully implemented once CO<sub>2</sub> removal is required. The R&D that is needed includes establishing better efficiency and environmental performance for individual components together with better system integration to ensure acceptable availability. In some cases this applies to the capture unit while for others it also applies to the base technology.

It is worth noting that within the European Commission the carbon capture and storage R, D&D programme is expected to follow a twin track approach with support being provided for both combustion and gasification based technology options since it is not felt possible to identify a single technology winner. Thus the introduction of back-end scrubbers for combustion plant, is seen as having merit as is the gasification based pre-combustion decarbonisation approach. The latter is especially relevant when the need to establish a poly-generation system that can produce both electricity and significant quantities of hydrogen is taken into account. The development of an oxyfuel based technology is receiving significant support at the pre-competitive R&D stage, while recognising that as this development progresses it will then be possible to then make

some meaningful cost-benefit analyses compared to the alternatives that are currently better developed.

Within the UK context, it is evident that the same R&D issues remain for the first three capture ready options considered in this study, above and beyond the overall need in each case to improve availability, efficiency and environmental performance.

Thus for Option A, there remains merit in trying to improve the efficiency of the CO<sub>2</sub> scrubber process appropriate to the range of conditions likely to be found at UK coal fired power plants. However, it must be said that the major need with this scrubber technology must be to establish some form of meaningful demonstration of the technology so that subsequently it can be offered with commercial guarantees. At the same time, several contractors noted that there is a strong driver to improve the performance of PF plant through the establishment of advanced steam conditions, together with changes in the overall design to limit increases in capital costs through the need to use very expensive super-alloys for the higher pressure and temperature steam components. There are various major R&D programmes on this topic. At present the inclusion of a CO<sub>2</sub> scrubber within these new designs is not a high priority but it will need to become so in due course so that the next generation of PF plant can be designed to be capture ready as well as the current generation

For Option B, two of the gas turbine providers stated strongly that there is a need to optimise gas turbine combustor performance to cover the full range of syngas likely to be encountered in capture and non-capture mode. With this provision and with regard to the implementation of the overall IGCC design concept, the general feeling was that there is now a considerable wealth of experience for each component in various applications and that it should now be possible to put this altogether such that a capture ready coal fuelled IGCC could be established in the UK.

For Option C, this technology variant is at the pre-competitive R&D stage. Thus work needs to be taken forward at least until meaningful comparisons with more established alternatives can be undertaken. If this option then shows technical and economic promise against the alternative approaches then there will be justification to move forward towards a technology demonstration.

Finally, Option D is probably the only option where R&D is not needed to establish a gasifier system to supply syngas to an existing combined cycle unit. Whether such an approach is economically justifiable compared to alternatives needs to be determined.

## 5. CONCLUSIONS

Coal will continue to have a significant role within the UK energy portfolio providing that it can meet the ever-tightening environmental regulations. This includes the need to be able to capture CO<sub>2</sub> for secure storage. In that regard, since there will be a need to order new power plant in the very near future, if coal is to be considered, the concept of the capture ready power plant, such that the capture stage can be added at a later time, will have to be adopted. This will only happen if there are contractors who will be willing to bid to establish such concepts. The nine UK contractors that took an active part in this survey to determine whether they are prepared to take forward one or more of the four capture ready options proposed have therefore provided a valuable insight into the UK prospects for establishing such a strategic position. The conclusions from this survey are as follows:

All contractors had some reservations regarding the terms of reference inasmuch that any decision to bid in practice will be dependent on many factors such as client, scope and interface definition, availability of resources, number of bidders and commercial terms and conditions and associated risks.

In particular, the idea that any new power station would be built on a full turnkey contract basis, with guarantees against financial liabilities for capital cost, completion time, and overall performance, was not necessarily seen as the most appropriate mechanism for the capture ready approach. Many contractors stated that their clients now advocated an initial reimbursable route, with an incentivised approach, that can be fully or partly converted to a lump sum basis at an appropriate stage within the project cycle.

There are contractors that would be prepared to bid to construct each of the four options of capture ready power plant identified within the study

In all cases, while contractors could be found to provide guarantees for each power plant option, all pointed out that no guarantees could be provided for the performance of any subsequent CO<sub>2</sub> capture phase nor for any adverse performance that would occur once the capture ready option was implemented.

Notwithstanding, the fact that there should be contractors available to take forward the construction of capture ready clean coal power plants within the UK, all expressed some concerns with the capture ready concept. Within the UK power sector framework, the introduction of the capture ready plant design for all four options will introduce significant additional costs to be borne by the end-user power company that places the order. This is not just a case of allowing space in the overall layout for the subsequent introduction of additional equipment but can also include significant engineering work if the end-user is to avoid much greater costs at the capture implementation stage. Unless the capture ready concept is recognised and supported in some way within the framework of the UK power sector then it is difficult to envisage any power generator willing to incur such significant upfront costs

With regard to the tighter focus of UK DTI R&D funds when the capture ready options are considered, this is less easily answered. The fact that contractors would be prepared to bid for each option on a capture ready basis while identifying that further R&D is needed to improve the attractiveness of each option confirms that this range of R&D activities must be maintained.

## **APPENDIX A**

### **DEFINITION OF THE CAPTURE READY POWER STATION**

The phrase “capture ready” is used loosely in the field of Carbon Capture and Storage (CCS).

Insomuch as all fossil fuel power stations discharge a flue gas which contains essentially all the by-product CO<sub>2</sub> which could be scrubbed to capture that CO<sub>2</sub>, then in the strictest sense, all power station designs could be defined as capture ready.

It has been suggested that certification of new build power stations as having capture ready status should be issued by the DTI as part of the normal Section 36 consent procedure.

To qualify for this status, the applicant would have to submit additional information for examination and approval. This would not entail any minimum build requirement in order to be ready for capture, but instead requires the applicant to provide the following information for a future conversion of the plant to a minimum 90% capture mode of operation:

Estimated down-time between shut down and completion of recommissioning with capture

Evidence that adequate land space is available

Anticipated new output and generating efficiency

Evidence that the technologies intended to be employed are commercially proven

Completion of an environmental impact appraisal for the change to capture operation.

This would enable the DTI to judge if the proposed plant could be certified as capture ready.

A more precise definition of what constitutes a “capture ready” plant may be the subject of a future study, but for the purposes of the Contractor Survey, the above definition is to be used.

## **APPENDIX B**

### LIST OF UK CONTRACTORS INVITED TO PARTICIPATE IN THE SURVEY

Aker Kvaerner  
Alstom  
AMEC  
Bechtel  
Fluor  
Foster Wheeler  
GE Energy  
Mitsui Babcock  
Siemens  
Stone & Webster

## APPENDIX C

### SALIENT DETAILS FROM THE ENQUIRY DOCUMENT

The Survey comprises a Preliminary Inquiry followed by a more detailed Confirmation of each TC company position.

#### Preliminary Inquiry

This Preliminary Inquiry will determine whether the TC would be interested in bidding turnkey for “capture ready” clean coal power stations, which include an option from which at least 90% of the carbon in the feed is to be removed in the form of high purity CO<sub>2</sub> gas. The intention would be, if and when the option is commissioned, to dry and compress the captured CO<sub>2</sub> for export from the power station to storage.

The power station is to be a commercial unit feeding electricity to the National Grid and with multi-streaming as necessary to achieve a competitive availability. Any one of the following process schemes could be applicable:

Coal burning with flue gas scrubbing of CO<sub>2</sub>

Integrated Gasification Combined Cycle with pre-combustion capture of CO<sub>2</sub>

Oxyburn

An upstream gasification module contracted separately to an existing Combined Cycle Unit that was fired previously on natural gas

It is stressed that responses are being sought from single source/single name TCs. If it is felt that a consortium would be appropriate, then the TC should answer as if representing the total consortium as leader. Interest in being a member of a consortium led by others could be claimed by all contractors. Therefore a single source answer is required.

The preliminary inquiry is intended to be a screening exercise to identify those who wish to be considered as potential turnkey contractors for capture-ready clean coal power stations. It is appreciated that responses will necessarily relate to today's circumstances and state-of-the-art technology.

A positive response for any of the four options will mean that the TC is content with the current status of the available technology.

Negative responses for any of the four options may mean that further development is required in order to make a positive response possible.

A negative response to all three questions for any of the four options will mean the TC is not interested in bidding at this time for that particular option.

No other information or qualification will be required at this stage of the Survey.

The TC is requested to complete the simple table set out below.

Table 1 - Interest in Bidding

Name of TC				
Scheme	A	B	C	D
Single TC Bid	Yes/No	Yes/No	Yes/No	Yes/No
Leader of Consortium Bid	Yes/No	Yes/No	Yes/No	Yes/No
More Development Needed	Yes/No	Yes/No	Yes/No	Yes/No

Please note that a 'Maybe intention to bid' should be entered as "No", which should be complemented by a "Yes" for "More Development Needed". This will be taken to signify that the TC would consider bidding once more development had been completed on that option. The development requirements will then be considered in the follow-up discussions.

Provision of additional information for those options identified where more development is needed

Following the initial response, the TC will be contacted again by the Contractor/Consultant in order to determine a description of the technical and/commercial development(s) considered necessary by the TCs under "More Development Needed" before reconsidering bidding.

## APPENDIX D

### THE NON-ATTRIBUTABLE PRELIMINARY ENQUIRY RESPONSES

Name of TC				
Scheme	A	B	C	D
Single TC Bid	No	No	No	No
Leader of Consortium Bid	Yes	Yes	Yes	Yes
More Development Needed	Yes	Yes	Yes	Yes

Name of TC				
Scheme	A	B	C	D
Single TC Bid	Yes	No	Yes	No
Leader of Consortium Bid	Yes	Yes	Yes	Yes
More Development Needed	Yes	Yes	Yes	Yes

Name of TC				
Scheme	A	B	C	D
Single TC Bid	No	No	No	No
Leader of Consortium Bid	Yes	Yes	Yes	Yes
More Development Needed	No	No	No	No

Name of TC				
Scheme	A	B	C	D
Single TC Bid	Yes	Yes	Yes	Yes
Leader of Consortium Bid	Yes	Yes	Yes	Yes
More Development Needed	No	No	No	No

Name of TC				
Scheme	A	B	C	D
Single TC Bid	No	No	No	No
Leader of Consortium Bid	Yes	Yes	Yes	Yes
More Development Needed	Yes	Yes	Yes	Yes

Name of TC				
Scheme	A	B	C	D
Single TC Bid	No	No	No	Yes
Leader of Consortium Bid	No	Yes	No	Yes
More Development Needed	No	Yes	No	No

Name of TC				
Scheme	A	B	C	D
Single TC Bid	Yes	No	Yes	No
Leader of Consortium Bid	Yes	No	Yes	No
More Development Needed	Yes	Yes	Yes	Yes

Name of TC				
Scheme	A	B	C	D
Single TC Bid	Yes	No	No	Yes
Leader of Consortium Bid	Yes	Yes	No	Yes
More Development Needed	Yes	Yes	Yes	Yes

Name of TC				
Scheme	A	B	C	D
Single TC Bid	No	Yes	No	Yes
Leader of Consortium Bid	Yes	Yes	No	Yes
More Development Needed	Yes	No	Yes	No