The North East CCS Cluster

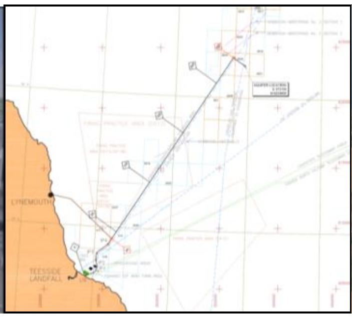
The proposed North East CCS Cluster is in the heartland of the UK's heavy process and chemical industries. Design and pre-FEED engineering has been undertaken for all elements of the CCS chain and key arrangements put in place to support a project plan which aims for first operation before the end of 2015.

Captured CO_2 will transported in a new pipeline for storage, and potential EOR, in an oil field in the Central North Sea. The pipeline is routed to also allow storage in a saline aquifer with a CO_2 storage capacity in excess of 1bte providing risk management to the storage element and allowing storage in a large saline aquifer to be demonstrated. The offshore pipeline has been sized to accommodate additional CO_2 from Teesside and the wider North East.

Development work has been undertaken on two substantial anchor CO_2 capture sources either or both of which could underpin the commercial development of the network, as well as provide demonstration of pre-combustion capture at a scale of at least 400MWe. The facility at Teesside will be a new build syngas plant which generates decarbonised hydrogen from coal for conversion to power in a CCGT (ie operating as an IGCC) as well as for use by Industry in the area. At Lynemouth, configuring the existing coal power station with pre-combustion capture provides demonstration of an IGCC retrofit with capture to an existing coal power station. Each facility would capture in excess of 2.5million tonnes of CO_2 per annum.

The region has numerous substantial emitters of carbon dioxide who will be able to link into the core CO_2 infrastructure, either via capture from their existing facilities, or by the use of decarbonised feedstock and fuel. Specific existing industrial players are actively pursing the decarbonisation options that CO_2 infrastructure would offer. Furthermore the network will enable inward investment into the UK by other high carbon emitters from around Europe for whom the unique storage opportunities afforded by the North Sea enables decarbonisation of their industry.

Eston Grange IGCC, Teesside



Offshore Infrastructure

Lynemouth Power Plant

[redacted], *Progressive Energy,* [redacted]

The need and timescale for CCS in the UK

In the short term CCS is needed in the UK to enable coal generation to be maintained in the energy mix, strengthening security of supply by avoiding overdependence on imported gas. New generating capacity is required from 2015 onward and there is an incentive to either extend the life of existing coal stations by fitting CCS or build new stations to begin operation on this timescale.

In the longer term it is expected that gas generation will also need to be decarbonised in order to reach emission reduction targets in 2030 and beyond. However the higher specific CO_2 emissions and more urgent need associated with coal generation indicate that the policy of focussing on coal and supporting 4 coal fired CCS projects in the first instance is appropriate.

UK industry will become exposed to increased costs from the Emissions Trading Scheme from 2013. Many industrial sources are smaller than those associated with power generation but nevertheless the emissions cost can have a significant effect on profitability. There is concern in Teesside, which has one of the highest concentration of energy intensive and process industries in the UK, that the increased costs may cause significant business contraction and job losses.

By themselves most industrial emitters are unable to support the full capital costs of transport and storage as well as capture. The availability of CO_2 transport and storage infrastructure is needed to support decarbonisation of these industries, some of which of have very low capture costs but no means of disposing of the captured CO_2. For some industries other decarbonisation strategies may be appropriate including, as is proposed at Teesside, using decarbonised feedstock from a dedicated plant producing decarbonised syngas for industrial as well as power industry use.

Certainly for Teesside it is crucially important that, at the least, CO_2 transport and storage infrastructure is put in place as soon as possible to allow industries who become exposed to the ETS in 2013 to consider investment in capture plant or use of decarbonised syngas to mitigate the risk to their business. The marginal cost of sizing the spine pipeline from the first capture project to CO_2 store to accommodate CO_2 from additional geographically clustered, capture projects is low. Right sizing of the pipeline against anticipated future need provides real benefits to UK plc by providing a framework for investment decisions for industry and other power station owners to decarbonise their own operations.

The UK oil province is mature and annual production is falling rapidly. CO_2 injection into mature oil fields is an established technique for recovering otherwise unrecoverable oil. Durham University have estimated that the use of CO_2 to enhance oil recovery has the potential to recover >3b barrels of oil from the North Sea if applied soon. The network which has been designed to transport CO_2 from Teesside and the wider North East takes CO_2 to the central North Sea where it is available for commercial EOR use. The spine pipeline has been sized to transport c15mteCO_2/yr. If applied for EOR this could produce c1b barrels of otherwise unrecoverable oil extending the life of existing oil fields for up to 20 years.

The status of CCS & the role of the UK Demonstration Programme

The operation of the CCS chain has already been, and continues to be, demonstrated at 3Mte CO_2/yr by the Dakota Synfuels plant which has 10 years experience of operation of the full chain. The Synfuels plant consists essentially of a syngas production unit which uses pre-combustion capture to produce a decarbonised hydrogen rich syngas which at Dakota is used in the manufacture of synthetic natural gas. In the power generation application, which is technically more straight-forward than synthetic natural gas production, decarbonised syngas is combusted in a Combined Cycle Gas Turbine to produce electricity – 3Mte/yr of captured CO_2 equates to a power plant of ~500MWe underlining that there no scale issues associated with use of this capture technology and hence full scale commercial projects can be constructed now[1,2]. However there are no clear reference plants for such Integrated Gasification Combined Cycle Power Stations with capture. This first of-a-kind risk makes the attraction of debt into early projects challenging.

There *are* examples of CO_2 storage in gas fields, oil fields and saline aquifers across the world, including North Sea experience, although most injections are less than 1mte CO_2/yr. This area has higher uncertainties than the capture element and requires demonstration at large scale in the North Sea environment for the different reservoir types available.

Hence technology exists, and whilst there are clearly substantial uncertainties, the challenge is for the most developed options to move from the RD&D phase to early market applications. This is primarily an issue of putting in place the appropriate commercial framework to enable the first of a kind risks and uncertainties to be managed. Pre-combustion capture projects at say 400-800 MWe are possible now. The captured CO_2 can be stored, with the uncertainty being the scale of injection irrespective of reservoir type. The UK has offshore oil fields, gas fields and saline aquifers which may be used for storage. Storage in oil fields holds the prospect of providing the greatest value added as CO_2 injection can be used to recover otherwise unrecoverable oil – this is an established technique on-shore with c25-30mte CO_2 injected annually in oil fields in the USA for this purpose. However offshore experience is minimal at present.

The Programme therefore needs to address the real first-of-kind uncertainties in the early CCS projects even where the technology exists, notably full CCS chain reliability and large scale storage. It needs to be on a basis which makes CCS a credible investment decision alongside renewables and gas CCGT. Investment capital is limited for all candidate investors – including the major utilities and so the demonstration programme needs to be structured to enable debt to be secured, and such that the widest possible range of investors can be involved, as has been achieved for renewables.

In combination, the state of readiness of the technology and the opportunities for value creation support a policy which seeks to introduce and deploy CCS in the UK as soon as possible. Clearly the current financial environment limits what is affordable by consumers. However, even these first capture projects will require less support than many other low carbon options.The overriding objective from this tranche of 4 CCS projects is not the demonstration of individual capture technologies, but must be to demonstrate how to introduce CCS into the country's economy to create long term value.

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[1] In contrast other capture technologies suitable for power generation (post combustion and oxyfuel) have only operated at small scale and do require substantial scale up.

[2] Pre-combustion capture can also be used to repower existing coal power stations to utilise cost effectively existing assets with enhanced output compared with alternative refit options such as post-combustion.

Technology Strategy Board, Carbon Abatement Technologies

BR009A - Feasibility Study to Re-power 140MW Pulverised Fuel Boiler to have Lower CO_2 Emissions (FS4PF boiler)

Final Report to the Technology Strategy Board

1 Introduction

Greenhouse gas emissions from conventional coal fired power stations are a major contributor to increased CO_2 levels. However coal is plentiful and these coal stations are expected to continue to provide a major contribution to electricity generation worldwide. Cost effective strategies are required for reducing CO_2 emissions for existing coal power stations. In many cases power station owners are seeking increased generating capacity and are attracted to strategies which produce increased generation with low carbon emissions.

This study has considered the feasibility of repowering an existing coal fired station to create an Integrated Gasification Combined Cycle (IGCC) power plant incorporating pre-combustion CO_2 capture. Wide-spread application of this concept has the potential to provide a cost-effective, energy efficient solution to reduce carbon emissions from a significant portion of the existing fleet of coal-fired plant world-wide.

The study was undertaken by Progressive Energy Limited (Progressive Energy) in collaboration with Alcan Aluminium UK Limited (Alcan) and examined the repowering concept at a specific coal plant in North East England. Consideration was given to the wider applicability of the results

The Feasibility Study was part funded by the Technology Strategy Board (TSB) under the Carbon Abatement Technologies initiative. This Final Report to TSB provides a summary of the study including the objectives, activities undertaken and the corresponding outcomes and deliverables. The report describes the proposed "next steps" to exploit the findings of the study.

2 Background & Study Objectives

Alcan, part of Rio Tinto Alcan, own and operate the Lynemouth Aluminium Smelter and the associated Power Station located just south of the village of Lynemouth in Northumberland. The 420MW power station is a conventional coal fired plant with pulverised fuel (pf) boilers comprising three generating units, each with an output of 140MW. The plant was commissioned in 1972 and is the most efficient coal fired plant operating in the UK.

Lynemouth Power Station, in common with other coal-fired plant in the UK and worldwide is facing ever tightening environmental legislation to reduce emissions as well as the economic imperative of managing carbon (CO_2) emissions. However, unlike most other coal fired power stations Lynemouth has the additional requirement to provide an economic and secure supply of power to underpin the operation of the Smelter. Recognising these drivers, a previous study by Progressive Energy identified the concept of repowering as an IGCC plant as potentially the most attractive solution which merited further investigation.

The concept is innovative in achieving CO_2 reductions on an existing coal plant insofar as it applies pre-combustion capture technology. Unlike post-combustion capture, which significantly reduces the net power output of an existing plant, repowering as an IGCC retro-fit increases the net power output of the host plant. Moreover, it enables the simultaneous reduction of other emissions such as NOx, SOx and particulates whilst producing less and more usable by-products compared with post-combustion technology.

The aim of the TSB Feasibility Study was to develop a technology application which was generally applicable by using the Lynemouth plant as a project exemplar. The Feasibility Study was to investigate the technical and commercial feasibility of this form of repowering and to evaluate the generality of applying advanced gasification and associated carbon capture technologies to the worldwide fleet of existing pulverised coal-fired plant. This has the potential to provide a cost effective, energy efficient solution to CO_2 reductions with a worldwide market. Furthermore, deployment could enhance security of supply by maintaining existing coal generation which gives diversity of fuel supply with low carbon electricity.

3 Details of the Study

The technical evaluation of the concept comprised three main activities: process flow-scheme modelling, a constraints review and a plant status review. Process flow-scheme modelling was used to simulate and develop a viable process flow scheme for the concept and to evaluate the performance of the repowered unit. The constraints review examined the limitations of the Lynemouth site and the requirements for utility and offsite services in the context of a repowered unit. The plant status review evaluated the suitability of the existing plant for re-use within a repowering project.

A chemical flow scheme model of the entire process was constructed utilising the proprietary software packages ProMax and CHEMCAD . This model was underpinned by utilising information on key plant items or systems obtained from the Original Equipment Manufacturer (OEM) or technology provider for e.g. for the gasifier, gas turbine, acid gas removal (AGR) plant. The flow-scheme model was developed on a step by step basis in accordance with a pre-determined modelling strategy. At each stage of development the outputs were evaluated and, wherever possible, validated against independent data. Where necessary the flow-scheme was re-optimised prior to proceeding to the next stage. Throughout the modelling process, a dialogue was maintained with OEMs and technology providers to inform the modelling activity and to establish candidate plant and equipment for the repowered unit.

The constraints review examined the limitations of the Lynemouth site and the utility and offsite requirements in the context of the IGCC plant configuration and the required process inputs and outputs. The site issues considered included plant footprint requirements, the availability of land for construction and the needs of plant integration. In addition, the requirements and constraints for utilities and off-site services were established for key services e.g. cooling and process water, natural gas supply and grid connection. To increase the generality of the study the constraints were considered for two different scenarios both of which assumed the repowering of just a single unit. In the first case the two remaining generating units were assumed to be shut down whereas in the second case these other units were assumed to remain in operation.

The objective of the plant status review was to establish which plant, equipment and infra-structure from the existing power station asset base could be incorporated within a plant repowered as an IGCC. This was based upon the technical and economic viability including consideration of a number of factors such as the existing plant performance and capability, plant condition, remnant life and the opportunities for plant life extension including estimated cost.

Analysis of the outputs from the flow scheme modelling and the constraints review were used to identify shortfalls in the provision of utilities and the requirements for additional off-site infrastructure. Options for fulfilling these requirements were identified and estimated costs and timelines established.

Outputs from the flow scheme modelling were also utilised to establish indicative equipment sizing information and to prepare preliminary plot layouts within the constraints of the site. Based on these a main plant equipment list was prepared and budget prices for key items were obtained from OEMs and other sources. These data, along with other information on the norms applicable to process industry and power generation construction, was used to establish an indicative capital cost for a repowering project.

A financial model was developed to evaluate the cost of power generation for the repowering project including the costs for carbon capture. Following validation of the model it was used to evaluate the commercial viability of the repowering concept. This included calculation of the levelised cost of power generation for the plant based on capital and operating cost data (capex & opex) and estimates of plant performance obtained from the study. Sensitivity studies were performed, including the impact of different market price scenarios and the effect of different candidate fiscal support mechanisms which are being proposed for CCS projects.

4 Study Outcome & Deliverables

The key outcome of the study is the demonstration of the technical viability of the concept. In particular the flow-scheme modelling has demonstrated it is possible to incorporate an existing steam turbine in a viable IGCC flow-scheme and has illustrated the extent to which other plant, equipment and systems from the existing asset base can be utilised.

There will be some mismatch between the steam conditions required by an existing steam turbine as used in pf stations and that required to make best use of the process heat and residual heat from combined cycle gas turbine operation. However for the Lynemouth plant and for many other conventional coal plants supplementary firing can be used to ensure efficient utilisation of the available plant assets without significant reduction in overall plant efficiency. Careful choice of equipment in terms of technology, sizing and battery limit conditions can be used to optimise the configuration.

Pre-combustion capture of CO_2 is inherently an efficient process compared to the flue gas, post combustion, CO_2 capture techniques as it ensures low carbon generation is produced with relatively high efficiency.

The inclusion of a gas turbine results in a net increase in generation, a requirement sought by many power station owners. Fuel flexibility is increased by allowing the use of high sulphur and other coals, petcoke and biomass as feedstock to the gasification plant and natural gas for combustion in the gas turbine.

The approach is particularly cost effective in cases where FGD and SCR have not already been fitted as the technique obviates the need for such plant to reduce acid gas emissions from the existing boilers.

Applications will be favoured where, like at Lynemouth, the steam turbine in particular but also other plant has been maintained to a high standard with advantage being taken of upgrades to improve efficiency and remnant life.

The constraints on repowering will vary on a site by site basis. The gasification plant can be sited remote from the existing power station but efficiency is compromised if the gas turbine and heat recovery are not close to the existing team turbine. Site specific constraints associated with electricity export capacity, water supply and coal import arrangements may be relevant.

The cost of generation from a coal power station repowered in this way is lower than that from a new build IGCC power station with CO_2 capture provided an efficient design can be configured In general terms as generation efficiency is 33%+ on an LHV basis the specific cost of generation will also be lower than the alternative of fitting post combustion capture particularly at high fuel prices. The overall economic justification clearly depends on the value ascribed to the avoidance of CO_2 emissions including the level of support which may be provided to encourage deployment of carbon capture and storage projects.

The overall conclusion from this study is that this approach provides a viable means for repowering existing coal fired power stations to produce decarbonised electricity with low acid gas emissions.

Key deliverables from the study include a suite of reports on the main activities specifically relating to the Lynemouth project exemplar. These include reporting of each of the main activities which can be utilised either to provide specific information which would underpin any further development at Lynemouth or to provide general guidelines for exploitation of the concept more generally.

5 Next Steps

Repowering of a unit of the Lynemouth Power Station would provide a practical demonstration of achieving decarbonised electricity with increased generation capacity using this approach. This will be considered by the plant owners in the context of demonstrator programmes available from the EC and the UK Government which aim to provide financial support to encourage the deployment of carbon capture and storage projects.

The know-how and intellectual property developed in the UK as a result of carrying out the Feasibility Study has significant potential. Progressive Energy is already discussing similar initiatives with other owners of conventional power plant with considerable interest being shown. Further applications will be sought both in the UK and Europe in particular where these could benefit from market support mechanisms for the deployment of carbon capture and storage projects.

TSB Project title: High Efficiency Electricity Generation and CO_2 Capture from Blast Furnace Gas

Project lead: Progressive Energy Ltd

Project summary:

Steel-making produces significant CO_2 emissions, and accounts for approximately 3-4% of UK CO_2 emissions. Measures have already been introduced to reduce these, but the limit of incremental improvements is expected to be reached in 2020, after which a step change will be needed. Efficiency improvements can no longer reduce CO_2 emissions without wholesale investment in new equipment, which is unattractive in the current financial climate. This project investigated a concept with the potential to deliver just such a step change.

Technology transfer from the process chemical and advanced gasification industries is used, applying them in an innovative way to the steelmaking industry. The concept is to process Blast Furnace Gas (BFG) such that a significant amount (up to 90%) of the CO_2 can be removed. The BFG would be cleaned of particulate, processed and separated. The remaining gas (mostly hydrogen mixed with nitrogen) can be used as a fuel in a CCGT.

The objective of the project was to produce a proposal that could lead to a demonstration plant being built in the UK in the 2012/2013 time frame. A full-size demonstration could follow in 2015/2016 and full commercial exploitation from 2018. Wide implementation could preserve jobs in steelmaking and associated industries in Europe and result in a significant reduction in CO_2 and other emissions.

Blast Furnaces at Corus' Scunthorpe Steelworks

(Image courtesy of Corus Ltd)

Key results

- The project team evaluated the concept and concluded that, based on flowscheme modelling, it was viable.
- Potential manufacturers for key items of equipment were identified. No product development beyond already proven designs would be required.
- The efficiency of the concept was calculated and shown to be higher than the currently available alternative methods of removing CO_2 from BFG.
- A proposal was made to take the concept forward and develop a Demonstration Plant.