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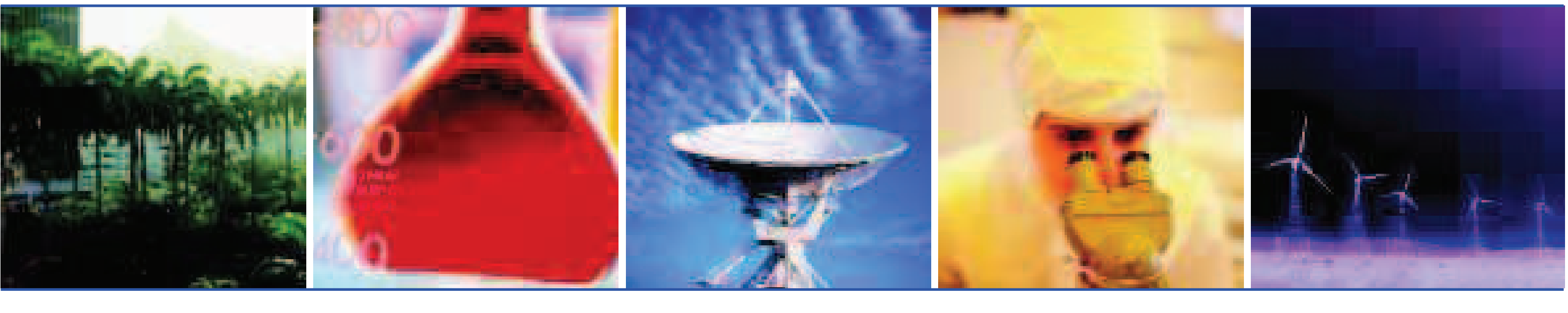

Assessment of the CCR Compliance of the Proposed Gateway Energy Centre

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Executive Summary

Imperial College Consultants have reviewed a document provided by Siemens discussing the plant layout for the Gateway Energy Centre's CCS scheme to evaluate whether the proposed plans are compliant with the UK DECC's Carbon Capture Readiness (CCR) Guidance as amended by the Imperial College Assessment (Florin and Fennell, 2010).

The evaluation also refers to additional information presented in the 'Gateway Energy Centre CCR Feasibility Study' (Parsons Brinckerhoff, 2010).

Specifically, Florin and Fennell (2010) noted that the guide for approximate minimum land footprint requirements for a 500 MWe CCGT plant prior to post-combustion capture retrofit was transcribed from a previous set of estimates for a 785 MWe plant (also prior to the addition of capture) and that the assumptions made in this original estimate in terms of equipment were likely very conservative and out-of-date. These observations were supported by consultation with engineering companies.

On this basis, Florin and Fennell (2010) recommended that the approximate minimum land footprint requirements for a 500 MW CCGT power plant with post-combustion capture retrofit should be reduced by 36% from the DECC CCR Guidance. Therefore, this equates to a requirement of 24,000 m^2 for a 500 MW CCGT power plant with post-combustion capture retrofit.

In addition, Florin and Fennell (2010) also noted additional scope for a total reduction by 50% from the DECC CCR Guidance (including the above 36%) taking into account technology advances and layout optimisation. Therefore, this equates to a requirement of 18,750 m^2 for a 500 MW CCGT power plant with post-combustion capture retrofit.

Therefore, in line with Florin and Fennell (2010), the approximate minimum land footprint requirement for the Gateway Energy Centre CCS scheme (i.e. for a 1250 MW CCGT power plant with post-combustion capture retrofit) is 46,875 m^2 (based on a total reduction of 50%). The land available at site for the Gateway Energy Centre CCS scheme is 47,100 m^2. Therefore, the land available at site for the Gateway Energy Centre CCS scheme is sufficient to meet the approximate minimum land footprint requirement.

It is further observed that the technical maturity of the proposed CO_2 capture system described in the document provided by Siemens appears sufficient to carry out the engineering calculations necessary to underpin the preliminary design work associated with the preparation of the proposed CO_2 capture plant layout for Gateway Energy Centre's CCS scheme. This is evidenced by the range of pilot studies conducted by Siemens.

Thus, considering the assumed equipment list for the proposed CO_2 capture plant, as well as the proposed CO_2 capture plant layout, **the authors consider that the proposed CCR plans are compliant with the UK DECC's Carbon Capture Readiness (CCR) Guidance as amended by the Imperial College Assessment (Florin and Fennell, 2010) and that the land available at site for the Gateway Energy Centre CCS scheme is sufficient to meet the approximate minimum land footprint requirement.**

Introduction

Imperial College Consultants was engaged by the Gateway Energy Centre Limited to offer an opinion as to whether its future CO_2 capture plans (and therefore current CO_2 capture readiness plans) are compliant with the guidance offered for the UK, in particular with the original guidelines for Section 36 approval (including the update from Imperial College regarding such guidance).

The previous advice given by Imperial College Consultants in this regard (Approximate minimum land footprint for some types of CO_2 capture plant provided as a guide to the Environment Agency assessment of Carbon Capture Readiness in DECC's CCR Guide for Applications under Section 36 of the Electricity Act 1989) has been used to inform the opinion given.

As noted in (Florin and Fennell 2010) "In the contentious case of post-combustion retrofit of CCGT plants, it appears that the original space requirements estimated in the IEA report (2005/1)) for a 785 MWe power station (pre-retrofit) have been directly transcribed into the Guidance which assumes a 500 MWe power station (later clarified by Mott MacDonald to be with CO_2 capture, i.e., post retrofit), without adjustment for the different basis. It is also relevant to note that the original study (IEA, 2005) assumed two GTs with eight trains of CO_2 capture equipment, which was conservative with respect to column sizing and may now be outdated."

Documents Reviewed By Imperial Consultants

Imperial Consultants were provided with a document produced by Siemens (2014) which included discussion and a potential plant layout for the Gateway Energy Centre's CCS scheme. We have also briefly reviewed the Environmental Statement / CCR Feasibility study provided by Parsons Brinkerhoff in 2010 in support of the original section 36 application (Parsons Brinkerhoff 2010), and were later provided with the water balance for the plant.

Basic Calculations

It is instructive to make some initial order-of-magnitude calculations, before discussing the detailed plant layout which has been provided by Siemens.

Florin and Fennell (2010) made a set of basic recommendations with regards to space requirements. Having reviewed the original literature, it was noted that the recommendations for a 500 MWe power station (prior to the addition of CCS) were highly conservative, appearing to be transcribed from those in a previous set of recommendations for a 785 MWe plant (prior to the addition of capture).

250 x 150 m^2 was originally recommended by Jacobs for a 785 MWe CCGT(IEA GHG, 2005).

Based on linear scaling from the original Jacobs report (which is very conservative), this would require ~ 60,000 m^2 for the 1250 MWe plant. However, our original report suggested that a further reduction of ~ 20 % was reasonable (to an overall reduction of 50 %), based on progress in CO_2 capture technology and arguments presented by a number of engineering firms, together with our own assessment of the literature.

The total land available in the Gateway Power scheme is 47,100 m^2. We have calculated approximate minimum land footprint requirement for the Gateway Energy Centre CCS scheme to be 46,875 m^2.

On this basis, the land available at site for the Gateway Energy Centre CCS scheme is sufficient to meet the approximate minimum land footprint requirement.

Detailed Plant Layout Provided by Siemens

Here, we note that Siemens has developed a CCS technology ("Siemens PostCap^{TM} CO_2 Capture Technology" (Siemens 2014) – provided in a report to Imperial Consultants). This report contains a brief overview of the pilot studies conducted by Siemens to validate the technology, based on Amino-Acid Salts, and progress since 2009. The technology appears to have been validated to a sufficient degree that calculations of rates of absorption and desorption, etc., should be sufficient for Siemens to conduct basic engineering layout calculations of the types shown in their report (though, for the avoidance of doubt, Imperial Consultants have not conducted detailed engineering analysis or validation of the technology).

Key Changes to Original Report by Parsons Brinkerhoff

Given that the CCR plant has been demonstrated above to fit within the amended approximate guidelines (Florin and Fennell 2010), it is only necessary to discuss a small number of changes which have been made to the layout for the sake of efficiency, and to consider their reasonableness.

Demineralised Water Production

In the original CCR report from (Parsons Brinkerhoff, 2010), the provision of demineralised water was included within the envelope of the CCS plant:

"6.2.68 The provision of space for the increased water treatment capability is included in

Figure 3-A at Item 13."

In the new CCR report, this has been moved to be within the envelope of the power plant. The water requirement has been estimated as approximately 1 m^3 / hr based on Siemens' improved technology (as opposed to approximately 1.8 m^3 / hr in the original PB report).

Imperial Consultants has been provided with the water balance for the power plant, have noted that the future flow to the CCS plant is included, and that 1 m^3 / hr is small compared to the 16 m^3 / hr capacity of the demineralisation plant. There is also a 1000 m^3 buffer tank included in the system, so that the demineralisation plant can run, if necessary, continuously to make up for losses during operation. We have been assured that the marginal capacity of the plant is sufficient to make up for this small extra water usage.

Wastewater Treatment

The choice of an Amino-Acid Salt (AAS) is important in this regard. Interestingly, though the Siemens report states that the AAS has negligible vapour pressure, the MSDS provided as part of the report states a vapour pressure of 16 mbar at 20^{o}C, somewhat higher than that for MEA (approximately 0.25 mbar at 20^{o}C). Of course, the vapour pressure exerted by the AAS will be significantly different to this when diluted with H_2O.

The wastewater treatment area has been moved from the CCS area to the power plant area. Since there is a low flow of water anticipated to the CCS area, the return flow of water should be similarly low (though this should be shown in the water balance). Given Siemens' significant pilot experience with AAS, the company should be in a position to confirm that there are no significant issues anticipated with waste water treatment.

Administration Buildings / Control

It is reasonable that the control systems and administration are moved to be within the footprint of the power plant. Modern plant control / monitoring is increasingly non local.

Overall Plant Layout

One key message from the work of Florin and Fennell (2010) was that a detailed plant layout design should be provided to demonstrate that the plant is carbon capture ready.

From the guidance "To avoid ambiguity and facilitate comparison, minimum land footprint estimates must specify all of the assumed equipment, including: generation system (incl. use of auxiliary supply, steam supply), CO_2 capture equipment (incl. column sizing for absorber and stripper, number of trains), cooling systems, CO_2 dehydration and compression (incl. number of compressors per train), additional flue gas treatment (incl. scope to incorporate within existing facilities), solvent/sorbent storage, CO_2 transport details (incl. pipelines), space for construction, appropriate space for health and safety".

These are all appropriately dealt with within the Siemens study, though with a few minor caveats: "space for construction, laydown etc" (Intergen have identified land nearby which can be rented for this, though this has not been identified in the plans Imperial College have reviewed).

Imperial College have not checked that the layout complies with minimum safe distances required, though assume that Siemens have done so.

There is no discussion of additional flue-gas treatment required, though since Siemens have tested their AAS solvents for a number of years, and have stated in their report (p. 3) that they have "good solvent stability against various degradation mechanisms" it is reasonable to believe that they will be able to treat the flue gases coming from a CCGT, which is inherently extremely clean burning.

On this basis, the authors consider that the CCR plan, as described in the report by Siemens is compliant with the CCR requirements.

Solvent Storage for Optimal Plant Profitability (extension)

Chalmers et al (2011) has conducted a study of solvent requirements to allow flexible operation via storage and regeneration during off-peak times. An order of magnitude additional volume of solvent required is 10,000 m^3 for each hour of ('flexible') operation, for an 825 MWe coal-fired plant. Accounting for differences in CO2 intensity (~ 469 g / kWh vs 1000 g / kWh) and scaling up to 1250 MW yields ~ 7000 m^3 per hour of operation, with 2 – 4 hours of storage suggested. This means that were this strategy to be employed, 4 extra tanks around 22m high and 20m in diameter would be employed onsite.

Examination of the plant layout with which Imperial College has been provided demonstrates that with appropriate optimisation of the plant layout these could be accommodated on the site.

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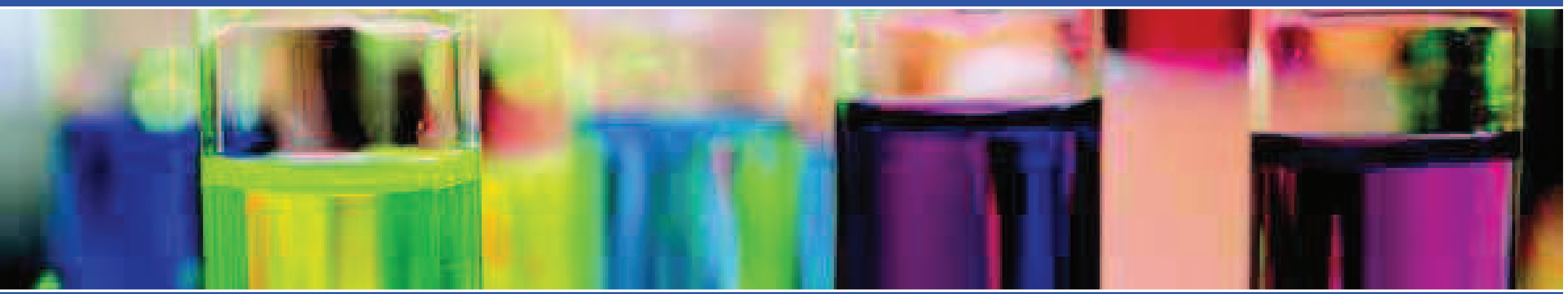

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