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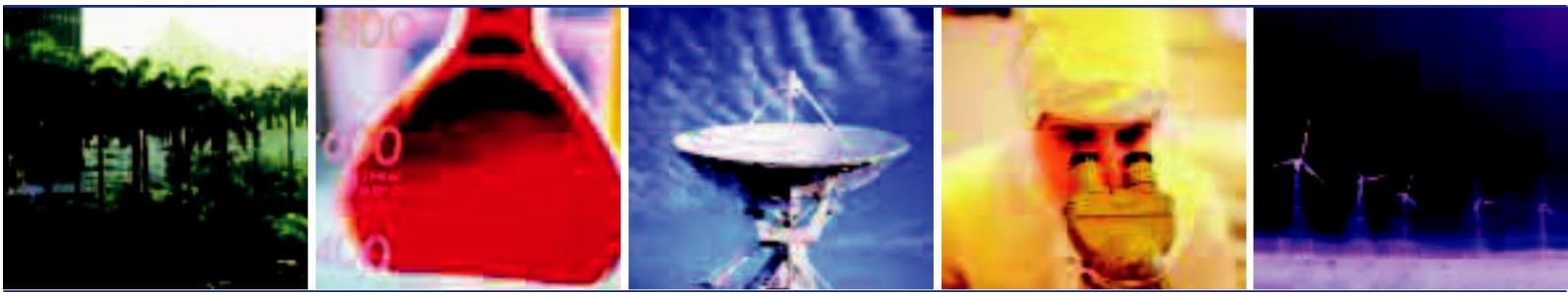

Assessment of the CCR Compliance of the Tees Combined Cycle Power Plant Project

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This report contains an opinion concerning the potential for retrofit of carbon dioxide (CO_2) capture equipment to Sembcorp Utilities (UK) Limited's planned Tees Combined Cycle Power Plant project. Neither Imperial College Consultants, nor the authors, accept any liability whatsoever to any third party for any loss or damage arising from any interpretation or use of the information contained in this report, or reliance on any views expressed therein.

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Executive Summary

Imperial College Consultants have reviewed a document provided by AECOM Consultants discussing the plant layout and equipment lists for potential carbon capture and storage (CCS) options for Sembcorp Utilities (UK) Limited's Tees Combined Cycle Power Plant Project to evaluate whether the proposed plans are compliant with the UK DECC (now BEIS)'s Carbon Capture Readiness (CCR) Guidance as amended by the Imperial College Assessment (Florin and Fennell, 2010).

In our original review, 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and that the assumptions made in this original estimate in terms of equipment were likely very conservative and out-of-date.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. Florin and Fennell (2010) updated the guidance to yield (for example) a requirement of 18,750 m^2 for a 500 MW CCGT power plant with post-combustion capture retrofit, *i.e.*, 37.5 m^2/MW_e, but stated that a detailed layout should also be provided to demonstrate CCR compliance, rather than a simple linear scaling of this value.

Therefore, in line with Florin and Fennell (2010), the approximate minimum land footprint requirement for the Tees Combined Cycle Power Plant Project (*i.e.*, for the most stringent of the options examined, case number 2) was calculated to be 54,900 m^2 based on a power output of 1,520 MW_e. The land available at site for the project is 57,000 m^2 which is sufficient to meet the approximate minimum land footprint requirement.

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 Tees Combined Cycle Power Plant CCS scheme is sufficient to meet the approximate minimum land footprint requirement.**

Introduction

Imperial College Consultants was engaged by AECOM consultants to offer an opinion as to whether the future CO_2 capture plans for Sembcorp Utilities (UK) Limited's Tees Combined Cycle plant are compliant with the guidance offered for the UK and 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, alongside a consideration of the plant layout proposed and the route to the storage sites proposed.

Documents Reviewed by Imperial Consultants

Imperial Consultants were provided with a document produced by AECOM which examined the sizing of potential CCS configurations on the available land allocated by Sembcorp Utilities (UK) Limited.

Basic Calculations

Sembcorp Utilities (UK) Limited requested AECOM to model three options for CCS. These options were distinguished from each other based on their net power output (Case number 0: 1290 MWe, Case number 1: 1385 MWe, Case number 2: 1520 MWe) using Version 27 of the THERMOFLOW suite of programmes. The plant performance was generated using sea level standard conditions assumptions run at ISO conditions. Although the exact power output was not modelled, the gas turbines modelled by AECOM were considered sufficiently close to the desired output power (Case number 0: 1269 MWe, Case number 1: 1335 MWe, Case number 2: 1528 MWe).

Florin and Fennell (2010) made a set of basic recommendations with regards to space requirements. The total land available in the Tees Combined Cycle Project are 48,400 m^2, 52,000 m^2 and 57,000 m^2, respectively for the three case numbers. AECOM have calculated plant areas, based on the desired power outputs, of 4.79 ha, 5.08 ha and 5.49 ha, respectively (see Table 1). This equates to specific areas of 37.7, 38.1 and 36 m^2/MWe. The final value, corresponding to case 2, is below the recommended specific area of 37.5 m^2/MWe mentioned by Florin and Fennell (2010) and at first glance may be considered inadequate. However, when the difference in plant output between the modelled and the actual desired output is taken into account, the 37.5 m^2/MWe figure is achieved.

Table 1: Data taken from AECOM's sizing study.

Case Number	0	1	2
GT model	GE9HA01 (#652)	Siemens 8000H (#654)	GE9HA02 (#653)
Target Net Power Output/MWe	1290	1385	1520
As modelled Net Power Output/MWe	1269	1335	1527
Required plant area for modelled output/ha	4.79	5.08	5.49
As modelled specific area/ m^2/MWe based on modelled power	37.7	38.1	36.0
Available area on site /ha	4.84	5.20	5.70
Available specific area/ m^2/MWe based on target power	37.5	37.5	37.5

On this basis, the land available at site for the Tees Combined Cycle Project is sufficient to accommodate any of the three layouts, based on the actual (not modelled) area requirement.

Detailed Plant Layout Provided by AECOM

We have previously found that the technology has been validated to a sufficient degree that calculations of rates of absorption and desorption, etc., should be sufficient for AECOM 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).

Points of Interest within the Layout Provided

Given that the CCR plant has been demonstrated above to fit within the amended approximate guidelines (Florin and Fennell 2010), it is necessary only to discuss whether the proposed layout is sensible, since it also **includes everything required** within the CCR guidance, with the minor exception of laydown for construction, discussed below.

Laydown
Discussions with the client have identified a strategy for laydown, and this appears to be reasonable.

CO_2 transport and storage
The documents reviewed by Imperial College do not discuss available transport and storage options.

Cooling
The project plant layout is based on a "worst case scenario" estimate which assumes all heat exchangers will be air cooled. If hybrid cooling is used, the footprint of the plant should decrease.

Demineralised Water Production
The use of demineralised water from the CCGT for the CCS plant has previously been discussed in by Imperial College in the context of other applications. There is sufficient space onsite for an extra demineralisation plant if required.

Wastewater Treatment
Given the global pilot and demonstration plant experience with amine scrubbing 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.

Electrical Efficiency of CCGTs
Based on the turbine efficiency study carried out by AECOM, it is clear that class H turbines are required to fit the CCGTs to the allocated area. If class F and E turbines were used, the required specific area will increase to 51.3 and 63.3 m^2/MWe, respectively.

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 this study, with the exception of laydown, which is to be identified in the future.

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

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