



Programme Area: Carbon Capture and Storage

**Project:** Thermal Power with CCS

Title: Design Optimisations Technical Note

#### Abstract:

Following completion of the main body of work, some opportunities for design optimisation were explored. These were: combining two trains of CCGT into one capture unit, reducing the assumed reboiler duty on the stripper, reducing the specification of the amine thermal recovery unit and reducing compression requirements. This Technical Note describes the outcome of these in terms of the impact of design, performance and cost.

#### Context:

The ETI's whole energy system modelling work has shown that CCS is one of the most cost effective technologies to help the UK meet its 2050 CO2 reduction targets. Without it the energy system cost in 2050 could be £30bn per annum higher. Consequently, ETI invested £650,000 in a nine month project to support the creation of a business case for a large scale gas with CCS power plant, to include an outline scheme and a 'template' power plant design (Combined Cycle Gas Turbine with post combustion capture), identify potential sites in key UK industrial hubs and build a credible cost base for such a scheme, benchmarked as far as possible against actual project data and as-built plant. The ETI appointed engineering and construction group SNC-Lavalin to deliver the project working with global infrastructure services firm AECOM and the University of Sheffield's Energy 2050 Institute.

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#### **TECHNICAL NOTE**

To: The ETI Document No.: 181869-0001-T-EM-TNT-AAA-

00-01008 - ETI ref D7.1

From: Matt Wills Date: 20-December-2017

Project: Thermal Power with CCS Project No.: 181869

**Subject:** Design Optimisations to the Generic Business Case

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## 3 Introduction

The UK Government retains the belief that CCS could play a crucial role in the future energy system. The ETI's analysis has shown that the best route to reliable, cost-effective and investable CCS in the UK is to build one or more power with CCS schemes, using best-proven technologies in the most beneficial locations at size which maximises the benefits of scale. However, stakeholders in CCS would need compelling evidence of the business case for a power with CCS project. Therefore the ETI has identified a need to develop a clear vision of what a cost-effective gas power with CCS scheme might look like and provide a clear and credible performance and cost information for such a scheme. To achieve this, the Generic Business Case project involved developing an outline scheme and 'template' power plant design (Combined Cycle Gas Turbine (CCGT) with post combustion capture) and identifying how this might be built and operated at selected sites around the UK.

SNC-Lavalin has developed a template plant design, a capital cost estimate, and an operating cost model for a large scale deployment of CCGT + CCS for the UK. SNC-Lavalin has been supported by AECOM who have identified potential site locations for such a plant and the University of Sheffield who have supported the project with technical and policy expertise.

The GBC project reviewed and compared 5 separate regions in the UK for the deployment of CCGT + CCS and analysed the scale of such a scheme for 1 to 5 trains<sup>1</sup> of CCGT + CCS.

The Power Generation Units for the GBC project use the largest credible Combined Cycle Gas Turbine (CCGT) Power Blocks available today. The Generic Business Case aims to capture around 10 million tonnes of CO<sub>2</sub> per annum from Combined Cycle Gas Turbines (CCGT). An engineered best in class amine has been selected for the plant in order to generate an optimised performance for the plant. The benchmark amine solvent (MEA) has a high energy penalty. Using engineered amines reduces this penalty, thereby maximising the power output from the CCGT.

The best in class amine technology is licensed by the owners of the technology: the performance of the technology is confidential. Unable to publish a licensed technology design SNC-Lavalin have made use of publicly available information regards post combustion carbon capture from the Key Knowledge Documents published regarding the Shell Peterhead project in order to develop a design sized for the gas turbines of the Generic Business Case.

The ETI have asked SNC-Lavalin to provide a number of optimisations to the Generic Business Case Design in order to explore the feasibility, performance impact, and a reduction in cost of the project.

## 3.1 Options

The base case for the Study is the Generic Business Case design. Improvements resulting from the optimisations in this document are in comparison with this base case.

The following options have been identified for investigation:

#### Optimisation:

Consider a single carbon capture unit for two trains of CCGT.

<sup>&</sup>lt;sup>1</sup> A 'train' in this context means a single gas turbine with a heat recovery steam generator (and steam turbine), a single capture unit with one absorber vessel and one stripper and a single compressor. Multiple trains then feed into a single CO<sub>2</sub> export pipeline.



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### Sensitivity Study:

- Use of brochure efficiency for the carbon capture plant / reboiler.
- 150 barg compression as opposed to higher pressures used for Endurance in the Generic Business Case (GBC).
- One solvent recovery unit as opposed to a single TRU per carbon capture unit.

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Combination of the three sensitivity cases above.



## 4 Requirement for Options

### 4.1 Two into One Design

Preliminary work undertaken by the ETI with support from SNC-Lavalin shows a shallow cost increase gradient for the increase in cost for a double size DCC and Absorber slip form tower: this indicated a significant economy of scale advantage to feed a single carbon capture unit with two class H/J CCGT trains.

A limitation of this approach is that the scale of plants can only increase in pairs.

The approach selected does not include a common steam system and steam turbine within the CCGT<sup>2</sup>: this is further potential optimisation in order to get a lowest possible CAPEX: but at the cost of overall scheme flexibility and reliability.

## 4.2 Brochure Efficiency for Plant / Reboiler

The performance of the Generic Business Case Carbon Capture Units was based on the Shell Peterhead CCS Key Knowledge Documents published by DECC (now BEIS). The performance of the Amine circuit was higher than the published performance (GJ/tonne CO<sub>2</sub>) for Shell Cansolv solvents. Using only publicly available sources it is assumed that the energy efficiency of the Shell Peterhead CCS amine circuit included a margin in order to provide commercial protection against a performance guarantee (i.e. this is what the author would do in the same circumstances). The interest in this option is what would the energy consumption of the circuit be if a brochure efficiency were utilised instead of a conservative performance guarantee number.

A brochure efficiency would reduce the amount of LP steam to be extracted from the steam turbine of the CCGT which would in turn result in an increase in the power which could be generated and exported. In addition, the reboilers and LP steam mains are significant cost items which could be optimised by using a lower amount of LP steam.

## 4.3 150 barg Compression

The SNC-Lavalin approach to the GBC was conservative in the area of pipelines and storage. This scenario is to look at a lower pressure requirement to supply CO<sub>2</sub> to Endurance.

A lower 150 barg compression would reduce the compression power required (and potentially the reduction in one stage of compression with an equipment saving). The reduced design pressure of the pipeline would reduce the pipeline thickness and hence the amount of material / cost.

The scope agreed with the ETI is to end the analysis of this case at the battery limit of the onshore plant; therefore downstream savings have not been considered.

## 4.4 Single Thermal Recovery Unit (TRU)

The data for the TRU was provided by the Licensor and therefore had to be used directly from the KKDs so as not to impinge Licensor IP, nor to give any impression that the project was using any IP. The GBC design therefore has one TRU per CC train in keeping with the Shell Peterhead CCS design published by DECC (now BEIS).

The TRU is a significant cost per train. It is assumed that there is a cost efficiency to having a single TRU serving multiple trains.

<sup>&</sup>lt;sup>2</sup> This would be a 2 + 1 CCGT which is a common arrangement and was the basis of the 1<sup>st</sup> work done by the power group for the Thermal Power with CCS project (PEACE estimate Λ = f4 7m).





#### 4.5 Combination

UK Government policy published on 12<sup>th</sup> October 2017 requires a reduction in CCS costs against a back drop of significantly realised cost efficiencies in the Offshore Wind Industry (which was reflected in CfD strike prices).<sup>3</sup>

All three above scenarios combined in order to see what is the cumulative effect of the above optimisations.

## 4.6 Common Philosophy

The optimisation studies are looking to challenge boundaries of performance and costing. Therefore, the philosophy will be to accept technically feasible solutions as opposed to being limited to technology with suitable references for application; this is a similar philosophy used to optimise cost in the offshore wind industry.

It was agreed with the ETI that the general philosophy should be to leave the CCGT design alone and concentrate efforts on the CCC unit. The general philosophy being that the 1+1 CCGT design allows independence between CCGT trains ensuring the maximum robustness, flexibility, and availability of the Power Generation Plant.

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<sup>&</sup>lt;sup>3</sup> UK Government's Clean Growth Strategy (<a href="https://www.gov.uk/government/publications/clean-growth-strategy/clean-growth-strategy-executive-summary">https://www.gov.uk/government/publications/clean-growth-strategy/clean-growth-strategy-executive-summary</a>). Offshore wind CfD strike price (<a href="https://www.4coffshore.com/windfarms/cfd-round-two-results-are-in%2C-offshore-wind-cheaper-than-gas-and-nuclear-pid6373.html">https://www.4coffshore.com/windfarms/cfd-round-two-results-are-in%2C-offshore-wind-cheaper-than-gas-and-nuclear-pid6373.html</a>).



## 5 Methodology

## 5.1 Single CC Unit for Two CCGTs

- Concept design for the Single CC Unit for Two CCGTs resulting in a Block Diagram of scheme and discussion on the conceptual design decisions.
- Rough size and scale of equipment in an equipment list. Judgment call based on experience or discussions with Vendors
  as to whether the duty is performed by a single piece of equipment or multiple units.
- Quick check of layout to ascertain impact on layout of plant.
- Adjust Teesside CAPEX for latest equipment list size.
- Assess impact on bulks
- Adjust generic OPEX model
- Report outcome and conclusions to the ETI in a technical note

## 5.2 Sensitivity Studies

- Concept design for each scenario resulting in a Block Diagram of scheme and discussion on the conceptual design decisions.
- Process design for change and technical sizing of affected equipment.
- Update to the equipment list and heat & mass balance (H&MB).
- Identify impact to performance.
- Adjust Teesside CAPEX for latest equipment list size.
- Assess impact on bulks
- Adjust generic OPEX model
- Report outcome and conclusions to the ETI in a technical note

## 5.3 Reporting

Document Description		
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## 6 One CC Unit for Two CCGT Trains

## 6.1 Conceptual Design

The design has been developed form that used for the Plant Performance and Cost Estimate Report, 181869-0001-T-EM-REP-AAA-00-00004, ETI Ref: D4.1.

In the current GBC design each CCGT is served by a CCC unit to remove  $CO_2$  from the turbine exhaust gases and compress the  $CO_2$  for offshore storage. The design of the plant has been optimised for this case so that two CCGT trains will feed into one CCC unit to deliver an economy of scale benefit to the overall plant.

The concept can be seen in Attachment 1.1 – Block Diagram.

Where ever possible larger single equipment selections have been used through the Carbon Capture and Compression plant as opposed to retaining the number of equipment items used for 2 trains of CCC in the GBC.

## 6.2 Design Decisions

#### **Assumptions**

The main assumptions are as per the Plant Performance and Cost Estimate Report, 181869-0001-T-EM-REP-AAA-00-00004, ETI Ref: D4.1.

Duct and pipe sizes were increased for the flow, keeping pressure drop constant, resulting in a doubling of duty and power per duty.

It was assumed that there was no impact on utilities from merging 2 CC trains into 1: the energy, cooling, etc consumption is going to be approximately the same because the process duty requirement is the same (albeit performed in one train not 2). As the same amount of work is required for the process systems it is assumed that the parasitic loads are unchanged compared to 2 x CCC units for the GBC.

#### **CCGT Trains**

The design of the CCGT trains will be generally be unchanged for the 2 into 1 optimisation. The steam extraction from both trains may need to increase in case one of the trains is not in operation. Whilst the carbon capture unit load would reduce at turndown to one train, it is not expected that the reduction would be linear because the equipment size is much larger as a consequence of being for 2 trains, and the TRU load would remain constant during its operation regardless of the number of CCGTs feeding.

The opportunity to save capital costs and possibly increase efficiency by combining the steam outputs from two HRSG units into one large steam turbine was considered and rejected. The flexibility around shutdowns and the desire to keep a single unit operating competitively was viewed as marginally more important for a second generation CCS plant.

With reference to the experience of Boundary Dam SNC-Lavalin believes that there is no reason why the steam extraction from two steam turbines would not be functionally able to supply one carbon capture unit; however, the control arrangements for the extraction would have to be carefully studied with the Steam Turbine manufacturer.



It is assumed that the slight oversizing of the LP and MP steam extraction would probably not make much difference to cost and would not affect peak performance.

#### **Blowers**

Due to the potential for different turbine outlet pressures each CCGT will need to be served by its own blower. The sensitivity of gas turbines when they start may give rise to nuisance trips if both CCGTs were served by a common fan.

#### **Gas-Gas Heat Exchanger**

Gas-Gas Heat Exchangers are used for large thermal power plants and therefore they can be sized larger than the combined duty for the carbon capture plant.

Since a single unit is selected, and it serves a single DCC and Absorber, it follows that the Gas-Gas Heat Exchanger will take the entire flue gas supply and return as single streams.

Work has been undertaken with Howden to confirm that it is feasible to provide a single Rotary Heat Exchanger to serve 2 x class H/J turbine exhausts.

#### DCC and Absorber

The DCC and Absorber are volume flow devices and therefore the cross section area of these towers has been scaled up in proportion to the increase in flow. The height of the devices is unchanged (as confirmed with internals vendors during the GBC). The length and width dimensions have been optimised to allow a common wall between the DCC and Absorber which would save schedule, material, and cost.

Whilst the combined DCC and Absorber are a large structure it is fabricated from slip form concrete – much larger slip form concrete structures have been built and therefore the size is not a concern.

The dimensions are large and references do not exist for CO<sub>2</sub> service devices at this size: however, the design is considered to be feasible. The project team for execution would have to work with internals vendors, flow/CFD modellers, and 3D flow reviews of the design to ensure the technical functionality.

#### Stack(s)

The generic business case had a single stack serving each CCGT. There was a single damper serving the stack of similar design to dampers in CCGT bypass stacks: either flowing to the blower, or the stack, or manoeuvring between the two.

A dynamic simulation would be required in detailed design to show whether a gas turbine in the generic business case design would be back pressured following a trip of a blower or whether the damper would respond rapidly enough to redirect sufficient flow up the stack to prevent a build up of pressure beyond the exhaust hi hi trip of the gas turbine.

Gas turbines are very expensive capital cost items and design / protection is required to prevent damage through exhaust back pressure.

The design of the 2 CCGT x 1 CC needs to conceptually avoid one train potentially back pressuring a second at start-up, during normal operation, or during reasonably expected excursions.

Options	Thoughts
Single stack design of GBC serving both	If one CCGT is operating and a second is not then there is a risk of back flow of hot
CCGTs	gas through shut down Gas Turbine resulting in equipment damage.



Options	Thoughts		
- Options	THOMBITO .		
	HAZOP would pick up risk of natural gas from non-operating set and heat from operating exhaust causing explosion. The action would need positive isolation unless proved that both sets purged.		
	Don't want complicated system of dampers separating both sets as HAZOP would pick up potential non / mal operation leading to back pressure on turbine and equipment damage (the very thing trying to avoid).		
	This option is not technically feasible.		
Exhaust flue per CCGT	The advantage of an exhaust flue per turbine is that there is no way of hot exhaust from 1 turbine directly back flowing to non-operating machine.		
	There is commonality of flow through the DCC and absorber requiring a split before returning to the individual CCGT flues. The GBC design means that the split flow will return to both turbine flues and will draw a draft in the non-operating set flue which would act to continue the purge of the non operating turbine.		
Gas Turbine Exhaust Carbon Capture Unit Capt	There will be a potential for the flow of gases to non operating set: however, the heat / buoyancy in gases should result in flow up flow.  FLUE 1  CCGT Operating  To Carbon Capture Plant		
	Flue Gas Flow Path		
Exhaust and outlet flue per CCGT	Installing an exhaust and outlet flue per CCGT eliminates risk of back flow from operating set to the non-operating set.		
	This is the most expensive solution as requires 4 flues for the 2 CCGTs.		
	Having a separate flue per CCGT allows any combination of abated / non-abated / off operation.		
	Since all four flues would probably run up the same stack the flue dampers can be mechanically interlinked per CCGT to ensure that it is not possible to have both dampers closed resulting in a close in back pressure to the turbine: there still remains the risk of back pressure due to the pressure drop across the carbon capture plant.		



Options	Thoughts
	Splitting exhaust after carbon capture will give better buoyancy in the operating flue
	if only one CCGT in operation, assuming the other flue is closed by a damper.
Exhaust flue per CCGT with a common	A lower cost alternative to the above option would be to have three flues up the
outlet flue per carbon capture	same stack, an exhaust flue per CCGT for start-up, shut down, and unabated
	operation: and a common outlet flue from carbon capture unit.
	Would need to check by calculation that there is sufficient buoyancy to provide
	dispersion with only 1 train in operation.
	The buoyancy in the common outlet flow after carbon capture will not be so great if
	only one CCGT is in operation at turndown: will this be sufficient to meet emissions
	dispersion?
	Preferred solution without calculation.

The recommended arrangement for the flues would be for all the different flues to go up the same stack from both CCGTs: this will deliver some cost saving compared to multiple stacks; however, the primary reason would be for the aesthetics and emissions benefit when submitted for planning approvals.

#### **Exchangers**

Generally the exchangers have been increased in size for the larger sized CC unit.

The Lean / Rich exchangers and Stripper Reboilers were already at a size limit for the duty and therefore the number of compact design heat exchangers has been doubled.

The Overhead Condenser, Wash Water Cooler, and Lean Amine Cooler are dimensionally smaller than the equipment items designed for the GBC: this is because an alternative vendor plate design (with better U values) has been utilised for this case.

The sizes of the other exchangers is within the experience range for plate exchangers and therefore the surface area has been increased proportionately within the same number of exchangers.

#### **Stripper Column**

The preliminary sizing results in a diameter of the wider central section of 13.6m.

- KNM have a limit of φ13m.
- Geldof reference 55148 is for a similar size vacuum tower (same shape) with φ15.4m, T-T 37.2m, and overall length 60.6m.

As a vessel of similar size and design has been fabricated in the past it is considered a feasible design. Heavy lift will be required to manoeuvre the stripper from the fabrication yard onto a barge, and then from the barge, to shore, to the installation location. The heavy haul route from shoreside to the Redcar site at Teesside included within the analysis for the GBC (4% saving) would need to be beefed up and significant cranage would be required.

The installation of a shop fabricated Stripper is only feasible for shoreline / quayside sites (e.g. Redcar, Longannet): this approach would not be feasible for inland sites where a site fabricated column would be required.

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#### Vessels, Tanks, and Filters

Vessels, Tanks, and Filters have been increased in size for the larger sized CC unit.

#### **Pumps**

In general, larger centrifugal pumps are available to perform the duties required for the double throughput carbon capture unit. However, this may not be the most cost effective solution (i.e. 2 large x 100% pumps). The sparing philosophy requires a standby pump for machinery service. It is probably more cost and energy efficient at MW duties to go to 3 x 50% pumps as opposed to 2 x 100% pumps. A smaller duty sized pump will also be beneficial for the electrical stability of the plant as there will be lower starting currents for each of the drives compared to a 100% duty unit.

#### Philosophy followed:

- Low Voltage Pumps double in size (2 x 100%)
- Medium Voltage Pumps size for multiple units (3 x 50%, 4 x 33%)

#### **Dehydration Package - Adsoption**

The Peterhead design used a 2 column approach designed for 24 hours adsoption on the working column with a 12 hour regeneration cycle for the non-working column followed by 12 hour standby.

An optimal solution for a double sized carbon capture would be to go for a 3 column adsorption system where 2 columns are absorping whilst 1 is regenerating. As the Peterhead, and scale up to GBC designs, use a 2 column system with 12 hour regeneration and 12 hour standby there is scope to use the 12 hour standby for a further regeneration cycle without having to increase the amount of adsorptent.

This allows a single additional GBC sized column to be added as opposed to adding 2 columns or expanding the size of the GBC columns.

#### **Amine Treatment Packages**

The Amine Treatment Packages have been scaled up to provide a single set of packages for the two CC units.

#### Compression

Largest known reference for  $CO_2$  compression is 28 MW. MAN Diesel and Turbo has a frame size of integrally geared machine up to 60 MW which would accommodate the duty for 2 trains. MAN Diesel and Turbo have provided a selection of an RG140-8 with 6 interstage coolers as can be seen on the figure below with an absorbed shaft power for the duty of 48 MW.



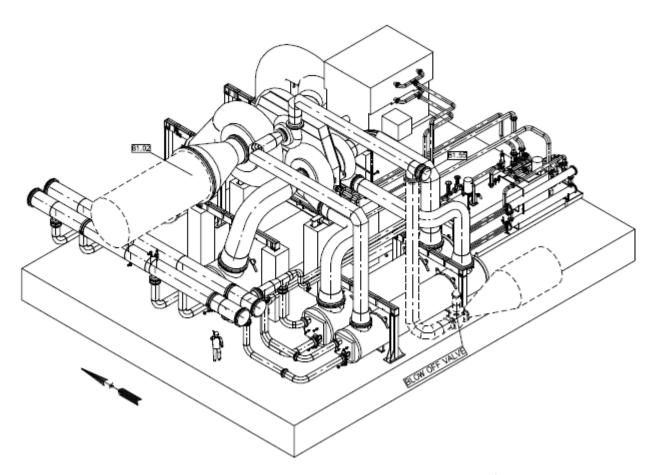


Figure 2 - MAN Diesel and Turbo Frame Size RG140<sup>4</sup>

The image also shows the sheer scale of the compression package (the operator can be seen in the bottom left of the isometric view.

#### **Control System**

A rough signal count showed that the I/O for the double size CC unit was around 75% of the combined total of 2 trains: not all drives and equipment have been reduced to a single unit instead of multiple units: this also has a knock on for valves and instrumentation. In addition, larger equipment items need more instrumentation coverage.

#### **Duct Work**

Indicative size of ductwork is 16m x 8m rectangular or  $\phi$ 12.5m circular. The circular size, whilst being inherently stiffer, would be difficult to fabricate at this size and transport to site (or around site). See the constructability section for further discussion.

## 6.3 Outcome of Design / Cost Estimating

#### **Operation and Turndown**

What is the expected turndown of the unit? Amine sweetening systems for natural gas can turndown as low as 20%<sup>5</sup> Typical engineering practice is that below 50% turndown absorbers tend to see lower recoveries: perhaps turndown limit to 40% design but with 50% amine circulation.

<sup>&</sup>lt;sup>4</sup> The machine shown has less stages than that proposed. Permission given by MAN Diesel & Turbo to share image – email of 8<sup>th</sup> November 2017.

<sup>&</sup>lt;sup>5</sup> Successful Operation of Selective Amine Unit at low gas turndown, Gauthier Perdu, Clément Salais, Stéphanie Pons, PROSERNAT, Salim Azzi, Jing Zhao, Claire Weiss, Total SA, PAPER PRESENTED AT SOGAT 2014 Abu Dhabi, 23rd - 27th March 2014.





The 'Turndown' case for Shell Peterhead CCS corresponded to the operating scenario where the CO2 output of the CO2 compressor equated to the minimum injection flow rate for the wells. This is approximately 70% of the gas volume rate. 6

The expected turndown of the double sized CC Unit is 50% as this is within operating experience which would allow continued operation with 1 CCGT being out of service. The main issue limiting turndown is gas-side mal-distribution. The problem gets worse with lower gas flows and bigger absorbers. This being said, it should be possible to design the absorber with gas distributors (Schoepentoeter, a Shell\* proprietary feed inlet vane device commonly used for introducing gas-liquid mixtures into distillation columns or gas-liquid separators).

#### Layout

The layout was studied in relation to the new equipment sizing.

Flue Gas Ducting - As can be seen from the layout below the layout was considered feasible. The exhaust from the gas-gas rotary heat exchanger and the exhausts from the Gas Turbines has been ducted to the new combined stack. A matched arrangement of the blowers was better for the layout and equalising pressure drop than a handed arrangement. The ducting is combined before feeding into the gas-gas rotary heat exchanger, the layout and dimensions of which were provided by Howden. An optimised arrangement against Peterhead CCS has been developed for the approach and return to the DCC and Absorber towers. The ductwork size is approximately 16 x 8 m - the rectangular dimension being used to reduce footprint versus height on the basis that there is a lot of height available considering the ductwork needs to exit the DCC and Absorber above 65m. The maximum height is roughly 90m from grade allowing for duct bends and supports. The optimised arrangement should result in shorter duct lengths and thus reduced cost / pressure drop.

Carbon Capture - the Carbon Capture unit dimensions have been scaled up from the GBC and significant additional items of equipment added. Including the new duct arrangement the resulting layout uses the majority of the plot available for 2 trains the limits in the following graphic are shown by the road to the right, the HRSGs at the bottom, the pipe rack at the top and the 3<sup>rd</sup> train to the left. Dead space is allowed in the layout below the electrical substation. The other space within the plot (e.g. above the stripper column 21 or left of gas gas rotary exchanger 32 is allotted to maintenance access for pumps, exchangers, and large valves.

<sup>&</sup>lt;sup>6</sup> Basis of Design for the CCS Chain, PCCS-00-PT-AA-7704-00001, revision K06, © Shell U.K. Limited 2015. Any recipient of this document is hereby licensed under Shell U.K. Limited's copyright to use, modify, reproduce, publish, adapt and enhance this document.



### Interconnections Piperack SUBSTATION D 亩 **—** ₫ (21) **Jan** Ħ **—** - | (50 P-6 18 19 (32) 32 Access Road 61

Figure 3 - Layout of 2 into 1 Scheme

The larger compressor dimensions offered by MAN Diesel and Turbo have been included in the Compression area in the following figure. The lay down for the compressor would need to be moved to the opposite end of the compression area: the former location would be blocked by the very large inlet pipe work. The machinery and scaled equipment appears to fit within the plot allocation, although as mentioned in the constructability subsection, the compression may need to move up the plot 10m to allow for a wider heavy haul route.



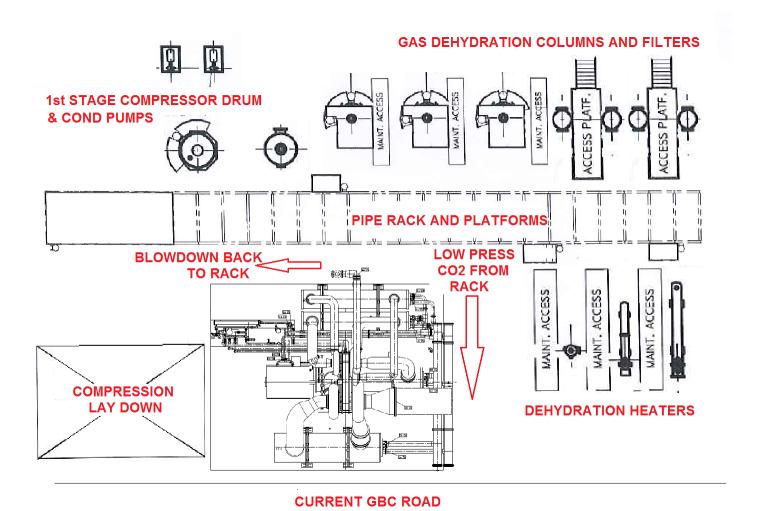


Figure 4 – Layout of the 2 into 1 Compressor and Dehydration

The CCGT area is not covered by the layout for this case: however, there would be an opportunity to reduce cost further by combining the Steam Turbine Generators of the two CCGT trains into a single turbine hall.

#### **Constructability Aspects**

The following constructability aspects were considered in the constructability review held on 3<sup>rd</sup> November 2017:

Aspect	Finding	
Slip Form Concrete DCC and	The construction speed is likely to be similar for the larger perimeter for the same height:	
Absorber	there would be more resources required and approximately 10% increase in schedule in	
	order to pour a greater size tower (66 weeks total).	
	<ul> <li>Foundations likely to be deeper as a higher wind load (same load per area over greater area)</li> </ul>	
	Central wall likely to be thicker because of the risk of shear at the DCC to Absorber	
	junction (remember DCC not as tall as the Absorber).	
Ductwork	Duct work dimensions of ~ 16m x 8m are huge scale. Concern over damage or deformation	
	in transport. What will be additional weight of temporary steels to maintain dimensions	
	until installed and support?	
	It is concluded that ductwork at this site would have to be fabricated in situ in plate form.	



Aspect	Finding
Heavy Lift	The larger size equipment for the 2 into 1 will need heavy lift cranes to install. These would have to be booked at the start of the EPC phase of the project to be available on site for the heavy lifts (e.g. Stripper Column, Compressor, Large Package Modules).
	A 20m wide heavy haul route is required for the 2 into 1 case. Current haul route is lower width – may need to extend layout 10m beyond current compression area fenceline to increase width between compressors and piperack.
	Larger but fewer heavy activities increases overall project risk – i.e. 1 failure wipes out CCC for 2 x CCGT not just one train.
Congestion	The intensity of the 2 into 1 site will result in further congestion. Further modularisation is recommended over that proposed for the GBC Teesside and Scotland Regions <sup>7</sup> in order to minimise on site labour, congestion, site costs, and to improve safe working. Further opportunities for modularisation:  • Gas-Gas Rotary Heat Exchanger and steelwork support tower: 20m x 20m x 40m
	<ul><li>module</li><li>Exchanger Towers</li><li>Thermal Recovery Unit</li></ul>
Stack	Would design stack so that it helps to support the tower crane installing the stack. Tower crane would then be available to help installation in the stack area.  The stack would go in early so as to eliminate the risk of collapse / topple damage onto high
	value Gas and Steam Turbines.
Tower Cranes	Tower Cranes would offer an advantage over mobile cranes in that they take less plot space. EPC Contractor would hire / buy tower cranes and deploy on site: sub-contractors would use tower cranes for their work (better than each sub-contractor mobilising and demobilising cranage).
Temporary Works	Time and money spent on temporary works may be 30% for a project of this size. The larger scale of the works would need more temporary works than 2 trains: e.g. double duct size would need larger temporary bracing since the temporary bracing for 2 x small sets of ductwork could be reused for each train in turn. Consideration would need to be given in execution as to whether a design could eliminate the temporary works to remove cost, or can save cost of removal by leaving in place?
Concrete	Volume of concrete for the 2 into 1 DCC and Absorber would justify a concrete batching plant to be located on site. There is space on the plot created by the 2 into 1 case for a suitable batching plant. Concrete would be pumped to the slip form concrete team.
Man Power	Savings on smaller items of equipment – not seeing savings in other areas because were at the limits of the equipment sizing and therefore need a greater amount of equipment and labour to install.
	Whilst there is less pipe work to install for the 2 into 1 case, any savings are diluted by the increased size of the 2 into 1 layout (more spread out) and by increased diameter of pipe work. The same applies to cables.
DCC and Absorber Internals	The Vendor estimate (confidential) for the Peterhead project was 210 days (working

<sup>&</sup>lt;sup>7</sup> Reference 181869-0001-T-EM-TNT-AAA-00-01003, Technical Note – Constructability.



Aspect	Finding		
	continuous shifts 24 hrs a day, 7 days per week) to install internals. Scaling this estimate per		
	area would result in 697 days (nearly 2 years). This is a big impact to the schedule as the		
	work could be done in parallel for 2 absorbers in the GBC case.		
	To make the schedule for the project practical there would have to be an earlier start on the		
	slip form work for the Absorber and DCC. This work cannot start on day 1 of an EPC Contract		
	as the contractor would have to take possession of the site, secure the site, and carry out		
	site enabling works. The preferred site for Teesside would need decontamination works		
	completed before the slip form sub-contractor could begin construction: potentially 6		
	months after EPC Contract award.		
General	The general conclusion of the Constructability review was that whilst feasible, the 2 into 1		
	project was maybe not practical to construct as the construction risks are increased, the		
	critical path running through the absorbers runs to 4 years just to have the tower available		
	(before any pre-commissioning has begun).		
	In addition the condensed plant for the larger pieces of equipment increases construction		
	congestion: which if not alleviated by increased modularisation, would impact productivity,		
	and therefore increase the project duration.		

#### **Cost Estimating**

The design of the combined carbon capture unit for two CCGT trains resulted in a reduced cost for major equipment in the CCC unit of approximately £69 million. Although savings are not seen in major capital items, such as the internals for the absorber and DCC towers, and the large heat exchangers, savings on reduced duplication of vessels, tanks, pumps, and amine treatment equipment results in the overall equipment and labour cost savings.

The internals for the Absorber have not resulted in scaling savings. The same area of internals is required for the 2 into 1 tower. Additional steels are required for internal supports over the wider spans; however, there is a minor saving on engineering and management.

There is an increase in ducting cost, as the ducting increases to  $16m \times 8m$  and requires significant additional supports and internal bracing. In this instance, the rise in ducting cost negates cost improvements made in scaling the CCC components for the 2 + 1 design. The subcontract for ducting could increase as much as £50 million for the 2 + 1 design.

The layout has not resulted in significant savings within the plot space: the routings for pipe work and cable are longer than for the equivalent single unit. Therefore, even though there should be a saving in the interconnections, the longer length and larger diameter, has not delivered the saving expected.

#### **OPEX Cost Estimation**

The design of the One CC Unit for Two CCGT Trains case results in a reduced number of equipment items in the CCC unit for two trains of CCGT. Compared to two trains within the GBC this results in:

- A reduction of 10% in the number of operating and maintenance personnel as a benefit of a smaller number of
  equipment items, instrumentation, devices, valves, and pipe work. Control will only be required for one, not two, trains
  of CCC.
- The CO<sub>2</sub> compressors are a significant maintenance routine item and cost within the GBC. The maintenance routing will
  be reduced for this case as there is only one larger compressor. It is assumed that the same maintenance schedule is
  required for one larger compressor as for two smaller compressors, for a savings of £1 million annually.

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#### **TECHNICAL NOTE**

- There will also be a reduction in the spares for carbon capture of 30% compared to the 2 train CC option because significant equipment items within the CCC unit have been reduced from 2 items to 1.
- Average annual OPEX (over 25 years) reduces by £2.2 million or 0.4%.

#### 6.4 Conclusion

The two CCGT into one CC unit has been shown to be technically feasible. The equipment selection shows improvement in that a single equipment item can cover the main equipment items:

- Gas-Gas Rotary Heat Exchangers
- DCC and Absorber
- Stripper
- CO<sub>2</sub> Compressor

The assumption was that the economy of scale within the Carbon Capture unit would deliver a significant saving. This was demonstrated with the slip form concrete towers for the DCC and Absorber. Unfortunately the economy of scale did not work well with other areas of the carbon capture unit resulting in a smaller improvement than expected.

It is concluded that, contrary to what SNC-Lavalin expected, whilst the two into one case is technically feasible it is not practical and therefore does not yield the cost saving expected.



## 7 Brochure Efficiency Reboiler

### 7.1 Conceptual Design

The design has been developed form that used for the Plant Performance and Cost Estimate Report, 181869-0001-T-EM-REP-AAA-00-00004, ETI Ref: D4.1.

 $CO_2$  is absorbed from the Exhaust Gases of the Gas Turbine in the Absorber Tower. The absorbed  $CO_2$  is separated from the Amine Solvent in a reboiler using heat. The heating is provided by LP steam extracted from a Steam Turbine. The Stripper Reboiler duty has been reduced assuming a more efficient solvent and therefore requires less LP Steam extraction from the Steam Turbine Generation set. The reduction in the heat input to the Carbon Capture Amine Circuit will result in a reduction in the heat that has to be removed from the Carbon Capture Unit, and will result in more steam available to generate electrical power to export to the grid.

The concept can be seen in Attachment 1.2 – Block Diagram.

## 7.2 Design Decisions

#### **Assumptions**

Main assumptions are as per the Plant Performance and Cost Estimate Report, 181869-0001-T-EM-REP-AAA-00-00004, ETI Ref: D4.1.

A key assumption for this work is that the GJ/tonne figure used for the Shell Peterhead CCS project, and hence the GBC project, is a performance guarantee number, in which there is a commercial margin between actual performance and guarantee, which will degrade the published performance for the overall GBC scheme.

The "brochure" efficiency for capture plant / reboiler (GJ/tonne  $CO_2$ ) is to be agreed with ETI before proceeding with design work. The range of proposed thermal input performance benchmarks are referenced in Benchmarking Data, 181869-0001-T-PC-CAL-AAA-00-00001, revision A03, which can be seen in the following table.

Solvent	GJ/tonne CO <sub>2</sub>	Reference	
KS1 CDR	2.8	CO <sub>2</sub> Separation Post Combustion Capture, David Campbell, from IMechE Carbon Capture and Storage Making It Happen Seminar Proceedings, 28-29 October	
KSI CBN	2.0	2017.	
		CO <sub>2</sub> Separation Post Combustion Capture, David Campbell, from IMechE Carbon	
Ecoamine FG+	2.8	Capture and Storage Making It Happen Seminar Proceedings, 28-29 October	
		2017.	
Best in Class Amine	2.5	SaskPower Boundary Dam 3 Project Update & some Lessons Learned, Philippe	
		Micone, March 2013, Cansolv Technologies Inc, http://7bf847d11d127c20fa70-	
(Cansolv)		cd6cb913bb8b30d5bcc03e5d889b94ba.r34.cf1.rackcdn.com/philippemicone.pdf	
	2.4	Recent Developments of Hitachi's Advanced Solvent Technology for Post-	
		combustion CO <sub>2</sub> Capture, Sandhya Eswaran Song Wu, Hirofumi Kikkawa Eiji	
Best in Class Amine		Miyamoto, Frank Morton,	
(MHI)		http://www.psa.mhps.com/supportingdocs/forbus/hpsa/technical_papers/Recen	
		t%20Developments%20of%20Hitachi's%20Advanced%20Solvent%20Technology%	
		20for%20Post-Combustion%20CO2%20Capture.pdf	

Table 1 - Brochure Efficiencies for Reboiler Duties



Two cases were reviewed for the study:

- An efficiency of 2.7 GJ/tonneCO<sub>2</sub> was selected to provide a best gas fired CCS efficiency.
- An efficiency of 2.4 GJ/tonneCO<sub>2</sub> was analysed in order to push the performance of the post combustion carbon capture as hard as technically feasible in accordance with the philosophy for the optimisation cases. This efficiency is a stretch because the cited reference is for coal, where the CO<sub>2</sub> concentration is the flue gas is much higher than from a gas turbine, which reduces the physical size / cost of flue gas and carbon capture ductwork and equipment, and has a lower energy penalty to transport lower volumes of flue gas for the same power output. The higher CO<sub>2</sub> concentration for coal fired plant (~12%) also results in a higher loaded solvent with less energy required to release the CO<sub>2</sub> in the stripper. Such an efficiency is, to the knowledge of the authors, unproven for CCGT applications.

The engineered amine solvent circulation rate is to be maintained from the Shell Peterhead CCS basis as per the information from the publicly available KKDs published by DECC, but with technical sizing for equipment

If less energy is input to the Carbon Capture Unit it is assumed that less energy will be needed to be taken out (i.e. lower cooling load).

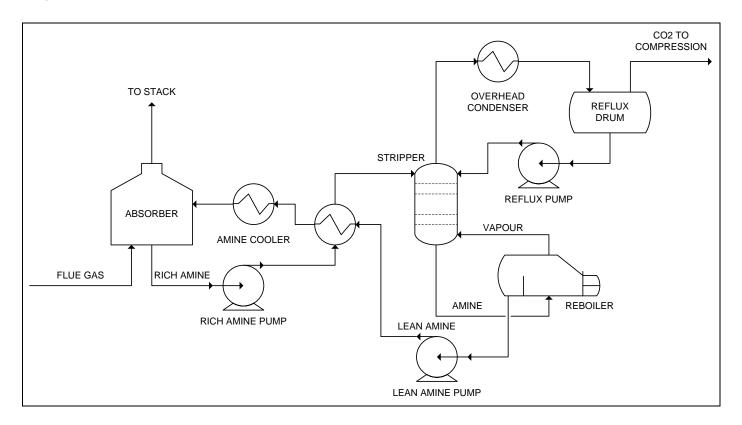


Figure 5 - Amine Circuit

The improvement in efficiency comes from the amine solvent formulation reducing the unit heat of sorbent regeneration. Theoretically, the heat of reaction that needs to be supplied in order to reverse the absorption reaction between  $CO_2$  and MEA is about 1.9 GJ/tonne $CO_2$ . The actual amount of heat required for regeneration of the solvent is much higher mainly because of the large amount of specific and latent heat taken up by the dilution water in the solvent. The better formulations of engineered amine solvent bring this down to 2.7 GJ/tonne $CO_2$  (or potentially down to 2.4 GJ/tonne $CO_2$ ).

The reduced heat input to the amine will result in a lower operating temperature to the stripper, resulting in lower Lean Amine and CO<sub>2</sub> stream temperatures leaving the stripper. Assuming that if less heat is entered into the amine circuit less heat needs to



be taken out in order to retain a thermal balance, the cooling duty of the Overhead Condenser (E-111) and Lean Amine Cooler (E-113) have been reduced (in proportion to their thermal duties). This will also result in a reduction to the cooling supplied to the Amine Circuit, however, for thermal balance, this will also increase the amount of cooling required for the CCGTs: i.e. no overall change.

A lower steam requirement will reduce the steam extraction from the steam turbine. This will result in a reduction in the size of the LP steam infrastructure and an increase in the performance of the steam turbine.

Pipe sizes to be altered for the altered LP Steam and Cooling Flows, keeping pressure drop constant.

## 7.3 Outcome of Design / Cost Estimating

#### **Process Design**

The following steps were followed to identified the H&MB streams, equipments and LP steam rate affect by reduce the GJ/tonne CO₂ratio from 2.99 to lower ratio.

- 1. 2.7 (GJ/tonne CO<sub>2</sub>) ratio is selected to determine the maximum steam reduction rate.
- 2. The reduced steam rate has been calculated for a range of (GJ/tonne CO<sub>2</sub>) ratio. Both the Peterhead and GBC steam rate were calculated based on heating rate to validate the calculation method.
- 3. The streams and equipment which were affected by the reduction in the GJ/tonne CO<sub>2</sub> ratio are identified as shown in the sketches below:

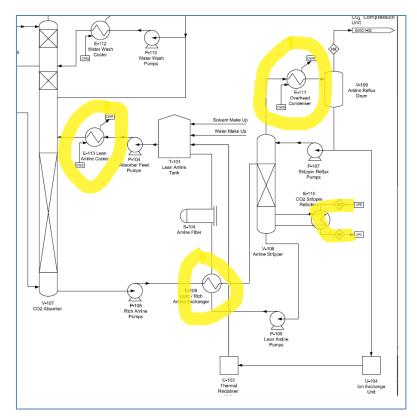


Figure 6 - Equipment Affected by Brochure Efficiency Reboiler Case



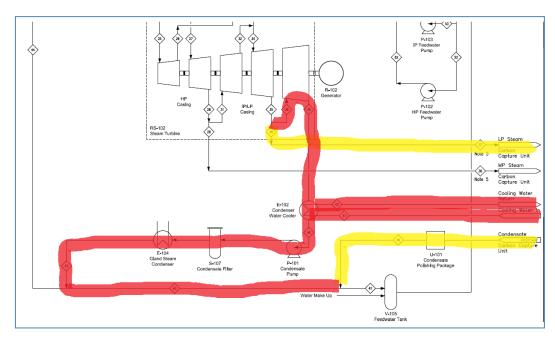


Figure 7 - Streams Affected by the Brochure Efficiency Reboiler Case

- 4. The yellow highlighted streams and equipment are reducing in duty due to lower GJ/tonne CO<sub>2</sub> ratio. The red highlighted streams and equipment are increasing in duty due to lower GJ/tonne CO<sub>2</sub> ratio.
- 5. The streams affected by the change are shown in red text in the Heat and Mass Balance (please refer to Attachment 3.2).
- 6. For the 2.7 GJ/tonne CO<sub>2</sub> selected ratio, the steam usage has reduced to 278.607 te/hr with a reduction of 21.297te/hr.
- 7. With the 2.7 GJ/tonne CO<sub>2</sub> selected ratio the CO<sub>2</sub>Stripper Reboilers E-110 duty and steam rate has been reduced by 7.1%.
- 8. As the CO<sub>2</sub> Stripper Reboilers Duty has been reduced the amount of energy in the Stripper column is also reduced; therefore the Overhead Condenser E-111 is expected to be reduced as well due to the Reboilers duty reduction.
- 9. As the CO<sub>2</sub> Stripper Reboilers Duty reduced, this will have an impact on the lean Amine loadings so that equipments in the Lean Amine loop such as Lean / Rich Amine Exchanger E-109 and Lean Amine Cooler E-113 will be impacted due to Reboilers duty reduction. As these equipment were designed by the Licensor for the selected engineered amine solvent on Shell Peterhead CCS and therefore it is difficult to predict the heat exchanger reduced duty: an assumption is made that the Stripper temperature is reduced therefore reducing the thermal duty of the overhead condenser and the Lean Amine Cooler.
- 10. As the LP Steam rate has been reduced as per stream 36 the LP Steam to LP Casing stream 38 has been increased and hence Condensate from Turbine stream 39 to Condenser Water Cooler E-102 has also been increased.
- 11. The H&MB in Attachment 3.2 has been updated for the Brochure Efficiency with all streams affected by this case shown in red text.

The utility schedule has been updated for the changes to the steam consumption and condensate generation, as can be seen in Attachment 6.1.



#### Layout

The change to the size of the heat exchangers will actually have no perceivable impact on the overall conceptual layout of the plant. The local change would be to the reboilers around the stripper which would be slightly repositioned as per the following sketch – distance from reboiler 'ring' to stripper can be slightly reduced due to slightly smaller reboiler size (graphic should be treated in confidence as uses Vendor supplied dimensions).

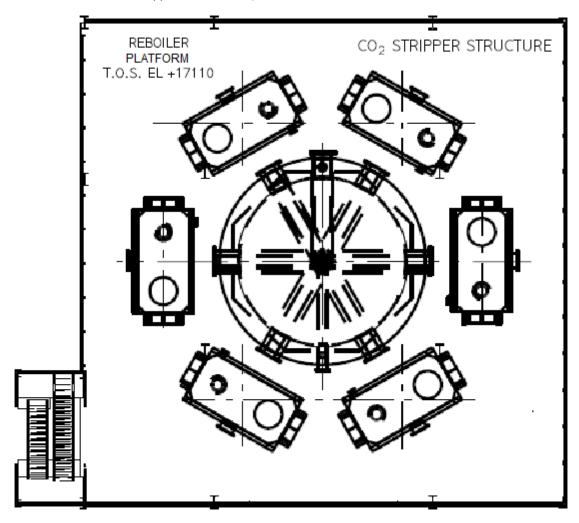


Figure 8 - Revised Layout for the Reboilers Around the Stripper

#### Equipment

The heat exchanger sizing of the Stripper Reboilers, Lean Amine Cooler, and the Stripper Overhead Reboiler has been adjusted to suit the reduced process duty as described above. The equipment pricing has been adjusted based on the reduction in heat transfer surface.

The amount of condensate being returned has been reduced (as less steam is supplied). The Condensate Return Pumps have been resized for this case and the cost of the pumps reduced in the cost estimate.

#### **Piping**

There is a significant proportion of the piping cost attributed to the cost of the steam header (due to the fact that this is a large line). It is estimated that the size of the steam header will reduce from the Generic Business Case = 46" down to 24" for this case. Although the actual piping cost is split between the Power Generation Unit and the Carbon Capture Unit the whole estimated reduction has been applied only to the Carbon Capture Unit.



#### **Overall Performance**

The overall performance of the plant has been improved by reducing the amount of steam directed to the reboilers from the steam turbine extraction. The change in performance has been shown in the table used at the front of the main reports:

Power Generation − 2.7 GJ/tonneCO <sub>2</sub> Case			
Item	Per Train	5 Train Plant	
Gross	732 MW	3.66 GW	
Efficiency @ Generator Terminals	62.0% (LHV)		
Net (Gross minus Parasitic Loads)	715 MW	3.58 GW	
Efficiency Net	60.6% (LHV)		
Steam Abated (Gross Power with Abatement Steam Extracted)	693 MW	3.47 GW	
CCGT Parasitic Electrical Load	17 MW	0.09 GW	
CC Parasitic Electrical Load	52 MW	0.26 GW	
Net Abated (Steam Abated minus CCGT & CC Parasitic Loads)	625 MW	3.13 GW	
Efficiency Net (abated)	52.9% (LHV)		
Efficiency Loss for CC	-7.7 percentage points (LHV)		

Carbon Capture & Compression			
Item	Per Train	5 Train Plant	
CO <sub>2</sub> Purity (Volume Basis)	98%	98%	
CO <sub>2</sub> Mass Flow	221 T/hr	1103 T/hr	
(@ 100% availability)	1.93 MT/annum	9.66 MT/annum	
Reboiler Service	2.70 GJ/tonneCO₂		
Compressor Service	0.38 GJ/tonneCO₂		

Table 2 - Performance Improvement from Brochure Efficiency Reboiler

Power Generation − 2.4 GJ/tonneCO <sub>2</sub> Case			
Item	Per Train	5 Train Plant	
Gross	732 MW	3.66 GW	
Efficiency @ Generator Terminals	62.0% (LHV)		
Net (Gross minus Parasitic Loads)	715 MW	3.58 GW	
Efficiency Net	60.6% (LHV)		
Steam Abated (Gross Power with Abatement Steam Extracted)	697 MW	3.49 GW	
CCGT Parasitic Electrical Load	17 MW	0.09 GW	
CC Parasitic Electrical Load	52 MW	0.26 GW	
Net Abated (Steam Abated minus CCGT & CC Parasitic Loads)	628 MW	3.14 GW	
Efficiency Net (abated)	53.2% (LHV)		
Efficiency Loss for CC	-7.4 percentage points (LHV)		

Carbon Capture & Compression			
Item	Per Train	5 Train Plant	
CO <sub>2</sub> Purity (Volume Basis)	98%	98%	
CO <sub>2</sub> Mass Flow	221 T/hr	1103 T/hr	
(@ 100% availability)	1.93 MT/annum	9.66 MT/annum	
Reboiler Service	2.40 GJ/tonneCO <sub>2</sub>		
Compressor Service	0.38 GJ/tonneCO <sub>2</sub>		

Table 3 - Performance Improvement from Brochure Efficiency Reboiler

#### **Cost Estimating**

The design of the Brochure Efficiency Reboiler 2.7 GJ/tonne  $CO_2$  Case has a modest impact on overall CAPEX, showing an improvement in cost of approximately £3 million per unit as a result of the resized heat exchangers and condensate pumps which includes a decrease in piping costs of £627k per train.

The impact on overall CAPEX for the 2.4 GJ/tonne  $CO_2$  Case shows a cost improvement of £3.7 million per train, based on the resizing of the heat exchangers and piping decrease.

#### **OPEX Cost Estimation**

The design of the Brochure Efficiency Reboiler case results in a reduction in the parasitic steam load which increases the available power generation. Whilst this does not affect the OPEX costs it does reduce/improve the OPEX per kW cost.

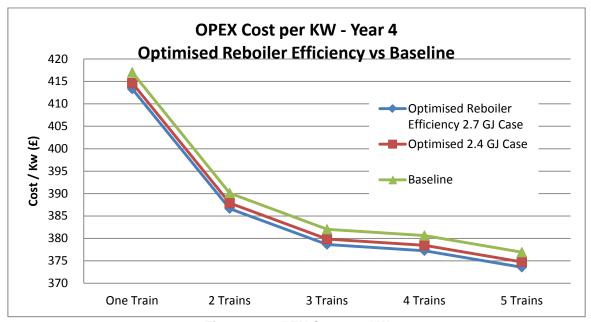


Figure 9 - OPEX Cost per kW

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## 7.4 Conclusion

The increase in reboiler efficiency from the GBC to 2.7 and 2.4 GJ/tonneCO<sub>2</sub> provides an increase in efficiency, an increase in electrical generation, and a decrease in the OPEX per kW.



## 8 Lower Discharge Pressure Compression

## 8.1 Conceptual Design

The design has been developed form that used for the Plant Performance and Cost Estimate Report, 181869-0001-T-EM-REP-AAA-00-00004, ETI Ref: D4.1.

The discharge pressure of the CO<sub>2</sub> Compressor has been reduced to 150 barg. This will reduce the sizing of the compressor, potentially affect the downstream equipment selection, and reduce the design pressures for the downstream equipment.

The concept can be seen in Attachment 1.3 – Block Diagram.

### 8.2 Design Decisions

#### **Assumptions**

Main assumptions are as per the Plant Performance and Cost Estimate Report, 181869-0001-T-EM-REP-AAA-00-00004, ETI Ref: D4.1.

It is assumed that the 150 barg is set at the battery limit of the plant (PFD / HYSYS stream 240).

#### Compression

The reduction in outlet pressure results in the removal of a stage of compression and less work done over the dry CO<sub>2</sub> section of the compressor<sup>8</sup>. The removal of a stage of the machine, a smaller motor size, and a smaller VFD will result in a reduction of the compressor package sizing.

<sup>&</sup>lt;sup>8</sup> For this discussion a compression stage is one wheel of the integrally geared compression and a section is a series of wheels with intercooling and knock out between an inlet to compression and an outlet from compression.



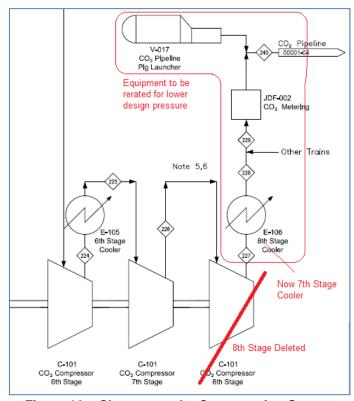


Figure 10 - Changes to the Compression System

#### **Exchangers**

There is cooling required at the outlet of the compressor to control the phase of the  $CO_2$ . Therefore, the  $8^{th}$  stage cooler will be retained but will now follow the final  $7^{th}$  stage.

The duties of the 6<sup>th</sup> and renamed 7<sup>th</sup> stage coolers have been revised based on the HYSYS simulation work.

#### **Static Equipment**

Equipment downstream of the compressors has been redesigned for the lower design pressure (1.1 \* 150 barg = 165 barg). The equipment downstream of the compressors will be manufactured from pipe (metering loops, etc). Although the design pressure has reduced it is still within the range of the same piping material class used for the GBC and therefore the piping components, pressure thickness, weight, and cost will remain the same.

#### **Pipelines & Offshore Platform**

It was agreed at the meeting on 20<sup>th</sup> October that the design does not need to consider the impact downstream of the CCGT + CCC plant. The following impacts could be considered:

- The pipeline design pressure will be reduced which should result in a lower pressure thickness (subject to checks on crushing, buckling, etc in subsea section). The reduction in material over a long distance will make a reduction to the cost of pipelines.<sup>9</sup>
- The topsides CO<sub>2</sub> equipment will also reduce in weight due to the reduction in the design pressure.
- The topsides structure and the platform jacket design weights will reduce as a result in the reduction in the equipment weight, which would result in a cost saving.

<sup>9</sup> An indication of the sa ving due to a reduction in pipeline pressure thickness would be £29m for the Teesside to Endurance pipeline.



## 8.3 Outcome of Design / Cost Estimating

#### **Process Design**

The HYSYS model has been updated for the new compressor discharge condition (please refer to Attachment 3.3 and 7.2).

#### Layout

The change to the size of the compressors will actually have no perceivable impact on the layout of the plant.

#### **Overall Performance**

The overall performance of the plant has been improved by reducing the amount of parasitic load taken by the compressor. The change in performance has been shown in the table used at the front of the main reports:

Power Generation			
Item	Per Train	5 Train Plant	
Gross	732 MW	3.66 GW	
Efficiency @ Generator Terminals	62.0% (LHV)		
Net (Gross minus Parasitic Loads)	715 MW	3.58 GW	
Efficiency Net	60.6% (LHV)		
Steam Abated (Gross Power with Abatement Steam Extracted)	691 MW	3.45 GW	
CCGT Parasitic Electrical Load	17 MW	0.09 GW	
CC Parasitic Electrical Load	51 MW	0.26 GW	
Net Abated (Steam Abated minus CCGT & CC Parasitic Loads)	623 MW	3.12 GW	
Efficiency Net (abated)	52.8% (LHV)		
Efficiency Loss for CC	-7.8 percentage points (LHV)		

Carbon Capture & Compression			
Item	Per Train	5 Train Plant	
CO <sub>2</sub> Purity (Volume Basis)	98%	98%	
CO <sub>2</sub> Mass Flow	221 T/hr	1103 T/hr	
(@ 100% availability)	1.93 MT/annum	9.66 MT/annum	
Reboiler Service	2.99 GJ/tonneCO <sub>2</sub>		
Compressor Service	0.37 GJ/tonneCO <sub>2</sub>		

Table 4 - Performance Improvement from the Reduced Compressor Discharge Pressure

#### **Cost Estimating**

The change in design to accommodate the 150 barg Compressor had a minor cost impact on the overall project CAPEX. The reduced compressor size lowered CAPEX cost by approximately £950,000 per train, or £4.7 million for 5 trains due to lower equipment and installation costs.

#### **OPEX Cost Estimation**

The design of the 150 barg Compressor Discharge case results in a reduction in the parasitic load which increases the available power generation. Whilst this does not affect the OPEX costs it does reduce/improve the OPEX per kW cost.

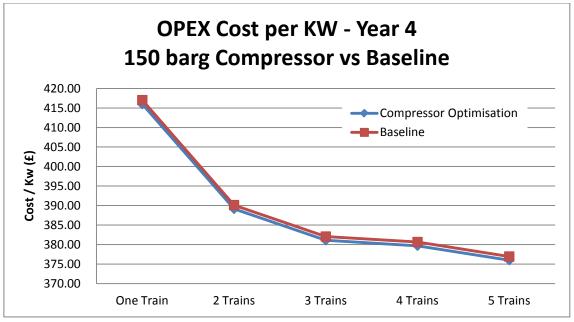


Figure 11 - OPEX per kW - 150 barg Compressor

#### 8.4 Conclusion

The reduction in the compression discharge pressure has improved the overall plant efficiency, an increase in electrical generation, and a decrease in the OPEX per kW.

## 9 Combined Solvent Recovery Unit

## 9.1 Conceptual Design

The design has been developed form that used for the Plant Performance and Cost Estimate Report, 181869-0001-T-EM-REP-AAA-00-00004, ETI Ref: D4.1.

Each train in the GBC design has a solvent recovery unit. These are a large capital cost item. The solvent recovery operations for an entire multi train plant have been consolidated for this sensitivity case and relocated to a central point on the plant.

The concept can be seen in Attachment 1.4 – Block Diagram.

### 9.2 Design Decisions

#### **Assumptions**

Main assumptions are as per the Plant Performance and Cost Estimate Report, 181869-0001-T-EM-REP-AAA-00-00004, ETI Ref: D4.1.

As the amine treatment is a batch process it is assumed that it is OK to feed the amine treatment from each train in turn. Amine would be supplied, treated, and then returned. This does introduce a risk of cross contamination between trains as it is assumed that it would not be practical to clean amine treatment facilities between batches (Peterhead design was 2.5 hours per batch allowing approximately 2 batches per day for each of 5 trains within the largest scale Generic Business Case plant).

It is assumed that larger equipment sizes are required for higher flow rates allowing for each batch to process more volume so that the volumetric treatment for each train remains the same (there are fewer but larger batches for each train). It is assumed that this has no impact on the performance of the carbon capture of the affected train during treatment. The slip stream would be 13% of the flow.

#### **Process Scheme**

The engineered amine solvent used for the Generic Business Case (GBC) will become contaminated by insoluble contaminants like dust from the volume of flue gas running through the absorber towers and contacting with the amine. The insolubles will be removed by side stream filtration on each train (maintained on each train as will be needed for commissioning, whereas the amine circuits can be run for a number of weeks without the need for amine treatment as it will take time for contamination to build up).

The amine solvent contacts the flue gas and contaminants in the absorber. The amine circuit also operates in the stripper at elevated temperatures. These two parts of the process give rise to the formation of ionic and non-ionic degradation substances which can be deposited around the amine circuit leading to fouling of flow paths and heat exchanger surfaces, which results in reduced performance of the carbon capture plant. Ionic salts are removed by the ion exchange (IX) unit. The non-ionic substances are removed by the thermal recovery unit (TRU).

As described above, the amine treatment process is a batch operation on a sidestream from the main amine solvent circulation. Continuous treatment of a portion of the overall flow gradually reduces the concentration of insolubles and degradation



products in the flow. The side stream is envisaged as being able direct flow to the filtration, IX Unit, and TRU Package with a return from filtration is treatment is not required, and a bypass to the TRU if the IX Unit is regenerating or not required.

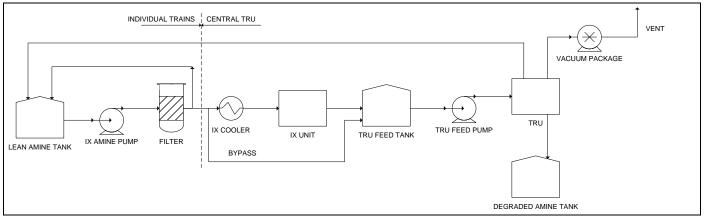


Figure 12 - Central TRU Process Scheme

#### **IX Unit**

The lon Exchange (IX) Unit removes heat stable salts from the amine circuit. The heat stable salts are formed by the reaction of the amine solvent with components of the flue gases (NOx, SOx). Heat stable salts must be removed otherwise they will precipitate on surfaces within the amine circuit clogging the system and fouling exchanger, in time preventing the efficient and reliable capture of  $CO_2$ .

IX is a batch process: the amine is directed through a pressure vessel containing the active resin. Once the resin is saturated the flow of amine is stopped and the resin bed is regenerated. The amount of heat stable salts formed will be a function of the contamination in the flue gas. The Generic Business Case plant is designed with Selective Catalytic Reduction (SCR) to limit NOx to low ppm level and the natural gas contains only low levels of sulphur; therefore it can be assumed that the formation of heat stable salts should be limited, such that the IX unit would not need to be batching continuously.

The IX units are compact and therefore could easily be located on each train: for this case the IX unit will be moved to the central amine treatment area. A slip stream for each train (in turn) will be sent to the central IX unit for treatment. The treated amine will be returned to the relevant train (via the TRU if required). The size of the IX unit has been increased to allow higher flow rates from each train in turn to be treated. Approximately two treatment and regeneration cycles per day would be processed from each train (9 to 10 batch operations per day). The actual amount of treatment will be proportionate with the amount of heat stable salts in the amine which would be regularly sampled and analysed to provide feedback to the operators.

Safety in Design: there are hazardous chemicals associated with the IX unit and therefore there would be a reduction in risk exposure if the IX unit operations were confined to one area of the plant as opposed to being located per CC unit.

There will be an increase in feed pump duty because the IX unit has been moved away from each CC train.

#### **Thermal Recovery Unit Package**

The Thermal Recovery Unit removes non-ionic degradation substances from the engineered amine solvent circuit using a 3 stage vacuum distillation process.

The Thermal Recovery Unit Package for Shell Peterhead CCS FEED was a licensed design. The basis of the work for this Technical Note is the KKD information available from the DECC / BEIS website. The design of the unit is a licensed design and the information is not available to further optimise.





The design margin on the Shell Peterhead CCS project of the Thermal Reclaimer Unit was 50% <sup>10</sup> on the processing rate. This was higher than the 10% used for the majority of the equipment on the plant. The design margin for this case has been reduced from 50% back down to 10%. The basis for the resizing is therefore:

$$5 \times \frac{110}{150} = 3.7$$

The risk associated with this decision is that the degradation rate is higher than that envisaged by the Licensor. However, the risk is minimised in that:

- The GBC is not a licensor design and therefore should not consider the specifics of individual formulations.
- The flue gas should be low NOx and low SOx because of the Natural Gas Composition and the Flue Gas Treatment.
- Formulations of Engineered Amine Solvent should have been improved since the 2014/2015 design of Shell Peterhead.

#### Vacuum Package

The Vacuum Package serves the 2<sup>nd</sup> and 3<sup>rd</sup> stage columns of the Thermal Recovery Unit.

Larger machines have been selected for the vacuum pumps as the machine sizes are too small for an alternative configuration (e.g. multiple 50% sized machines) to be economic.

## 9.3 Outcome of Design / Cost Estimating

### **Process Design**

The equipment for the Solvent Treatment Plant has been scaled up from that used for each train in the Generic Business Case using the resizing factor above.

### Layout

The amine treatment plant associated with each train would be deleted and replaced with a centrally positioned common unit as can be seen in the following figure.

181869-0001-T-EM-TNT-AAA-00-01008 A05 Design Optimisations.docx

<sup>&</sup>lt;sup>10</sup> Basis of Design for the CCS Chain, PCCS-00-PT-AA-7704-00001, revision K06, © Shell U.K. Limited 2015. Any recipient of this document is hereby licensed under Shell U.K. Limited's copyright to use, modify, reproduce, publish, adapt and enhance this document.



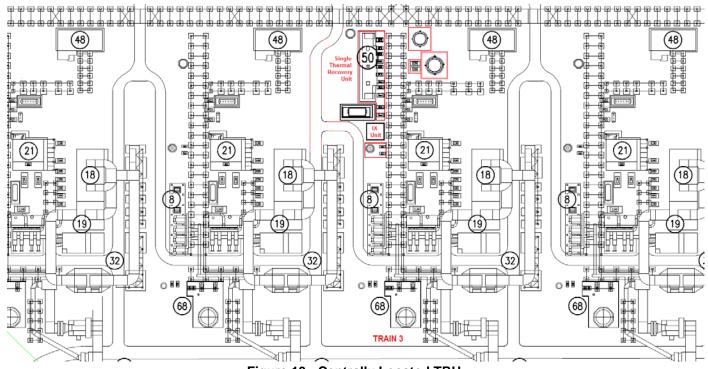


Figure 13 - Centrally Located TRU

The equipment in the centrally located single unit has been resized for the combined duty per the equipment list. The resized equipment has been used for the dimensional layout of a single TRU but the separation distances have been maintained.

The central location allows for the sidestream of amine solvent for treatment from each train to be routed along the train and common piperacks. The selected location is adjacent to the pipe rack for train 3 to allow pipe work connections within amine treatment to be carried along the rack.

The access road way between trains 2 and 3 has required modification to accommodate the single amine treatment unit. The new layout still allows maintenance access to the major pieces of equipment. The substation for train 3 has had to be moved towards train 4 on the plot to maintain a safety separation distance to the amine treatment equipment: this can be accommodated within the plot without further modification.

The Instrument Air Buffer Tank for Train 3 has had to be repositioned to make way for the amine treatment equipment.

#### **Electrical, Instrument, and Control**

There are fewer electrical connections to the carbon capture substation because the drives for each train's solvent recovery equipment have been deleted: with the exception if train 3 which retains the same number of drives but at larger sizes. There is not an overall power saving as it is assumed that the same amount of fluid power is required for the combined unit: there might be an increase in electrical power required as the pressure drops along pipe work will increase with the distance from the further trains to the single solvent recovery unit on the plant.

The control system costs for each train have been reduced slightly due to the removal of the control and instrumentation for the solvent recovery unit on each train. There will be a smaller additional cost for the control system I/O dedicated to the single solvent recovery unit for the plant.



#### **Piping**

The piping routing will be more extensive than for the Generic Business Case because the amine solvent sidestream needs to be sent around the plant from each train to the central solvent recovery unit, and returned.

#### **Cost Estimating**

The Single Solvent Recovery unit optimisation results in significant cost savings compared to the one unit per train option. In addition to a reduction in equipment and labour costs for the solvent recovery unit, associated tanks, pumps, vessels, and ICSS, it also decreases contractor and owner soft costs, as well as commissioning expenses.

The bulk materials and the associated installation subcontracts would also be affected by the change. The significant changes will be seen in the piping and equipment foundations. It is assumed that the Electrical and Instrumentation scopes are not significantly affected as there are a similar number of devices within the single Solvent Recovery unit compared to a Solvent Recovery unit within one train. Within the single Solvent Recovery unit, with a higher flow rate (please refer to section 9.2 above), the bulks and labour cost of the foundations and piping is expected to increase by 17%: this was calculated by a comparison of increasing pipe and foundation sizes within the subcontracts for the design of the ingle Solvent Recovery unit.

Bulk Material Subcontracts	Addition
Concrete	4,625,106
Steelwork	
Site transport & Rigging	
Piping	7,668,984
Supplementary Piping for TRU	
Electrical and Instrumentation, Telecoms	
Ducting	
Scaffolding	
Painting & Insulation	

Table 5 - Increase in Estimate within Single Solvent Recovery Unit

The cost impact of the additional piping required to run the solvent over longer distances to and from the single unit is estimated as approximately £3 million.

There is a saving on bulk materials and subcontracts for the removal of the Solvent Recovery Unit within each train. The savings apply to the pipe work, foundations, electrical devices and cable, and instrument devices and cable not required as a result of the Solvent Recovery Unit being combined for the whole plant. The saving is assumed to be proportional for the 17% equipment cost removed from each Carbon Capture Unit.



Bulk Material Subcontracts	Deduction 1 Train	Deduction 4 Trains
Concrete	- 4,625,106	- 18,500,422
Steelwork		
Site transport & Rigging		
Piping	- 7,668,984	- 30,675,937
Supplementary Piping for TRU		
Electrical and Instrumentation, Telecoms	- 6,104,888	- 24,419,551
Ducting		
Scaffolding		
Painting & Insulation		

Table 6 - Reduction in Estimate for Removal of Solvent Recovery Unit per Train

The overall savings for a 5 train plant could be £162 million, or 3.0% of total installed cost.

#### **OPEX Cost Estimation**

The design of the Single Solvent Recovery Unit case results in a reduced number of equipment items in the CCC unit.. Compared to five trains of individual Solvent Recovery within the GBC this results in:

- A reduction in the number of maintenance personnel as a benefit of a smaller number of equipment items, instrumentation, devices, valves, and pipe work. Control will remain the same as the batch treatment of amine per train will still be required, and therefore there will not be an impact on the number of operators.
- There will be a reduction in the spares because significant equipment items within the TRU unit have been reduced from 5 items on the plant to 1; however, this amounts to only £65k annually for 5 trains.
- The overall impact on average OPEX (annual over 25 years) is 0.05% or £640k annually.

### 9.4 Conclusion

A single solvent recovery unit is feasible, will fit within the existing plot space, and results in a significant cost saving in the capital cost estimate for 5 trains. There is not a perceived impact on the plant performance.

# 10 Combination of the 3 Scenarios

### 10.1 Conceptual Design

The combination case amalgamates the following sensitivity cases:

- Use of brochure efficiency for the carbon capture plant / reboiler.
- 150 barg compression.
- Combined solvent recovery unit.

The combined concept can be seen in Attachment 1.5 – Block Diagram.

### 10.2 Design Decisions

There were no design decisions required as there were not any interactions identified between the optimisations.

## 10.3 Outcome of Design / Cost Estimating

#### **Process**

The combined equipment list can be found in Attachment 2.5 and the combined heat and mass balance can be found in Attachment 3.5.

#### Layout

The combined layout can be seen in Attachment 4.5.

#### **Overall Performance**

The overall performance of the plant has been improved by combining the output of the Sensitivity Cases. The change in performance has been shown in the table used at the front of the main reports:

	Power Generation	
Item	Per Train	5 Train Plant
Gross	732 MW	3.66 GW
Efficiency @ Generator Terminals	62.0% (LHV)	
Net (Gross minus Parasitic Loads)	715 MW	3.58 GW
Efficiency Net	60.6% (LHV)	
Steam Abated (Gross Power with Abatement Steam Extracted)	694 MW	3.47 GW
CCGT Parasitic Electrical Load	17 MW	0.09 GW



CC Parasitic Electrical Load	51 MW	0.26 GW
Net Abated (Steam Abated minus CCGT & CC Parasitic Loads)	624 MW	3.12 GW
Efficiency Net (abated)	52.9% (LHV)	
Efficiency Loss for CC	-7.6 percentage points (LHV)	
	Carbon Capture & Compression	
ltem	Per Train	5 Train Plant
CO <sub>2</sub> Purity (Volume Basis)	98%	98%
(Volume Basis)	007	
<del>-</del>	98%  221 T/hr 1.93 MT/annum	98% 1103 T/hr 9.66 MT/annum
(Volume Basis)  CO <sub>2</sub> Mass Flow	221 T/hr	1103 T/hr

Table 7 - Performance Improvement from the Reduced Compressor Discharge Pressure

#### **Cost Estimating**

The impact on CAPEX for combining all 3 optimisations combines the savings gained from the revised reboiler efficiencies, the resized compressor unit and the single solvent recovery unit for 5 trains. The revised reboiler contributed £15 million savings, the compressor £5 million, and the solvent recovery the majority of the savings at £88 million,, for a total savings of £108 million for a 5 train plant.

The OPEX costs decrease as per Case 4 – Combined Solvent Recovery Unit, with an overall average annual reduction of approximately £640,000 made up primarily of maintenance staff costs. The cost per kW based on the decreased parasitic loads drops from £377 per kW to £372 per kW.

### 10.4 Conclusion

It is technically feasible to combine the three cases. There appears to be no interaction between the cases,

The plant performance is improved by the combination of the three optimisation cases. The efficiency loss from the carbon capture unit is reduced from 7.9% for the Generic Business Case to 7.6%, which increases the power generated by the plant and the potential to generate revenue.

The plant savings are £182 million for a 5 train plant.



# 11 Abbreviations

The following abbreviations have been used in this document:

Abbreviation	Description
3D	Three Dimensional
BEIS	Department for Business, Energy and Industrial Strategy
CAPEX	Capital Expenditure
СС	Carbon Capture
ССС	Carbon Capture and Compression
CCGT	Combined Cycle Gas Turbine
ccs	Carbon Capture and Storage
CfD	Contract for Difference
CFD	Computational Fluid Dynamics
CO <sub>2</sub>	Carbon Dioxide
DCC	Direct Contact Cooler
DECC	Department of Energy and Climate Change (now BEIS)
EPC	Engineering, Procurement, and Construction
ETI	Energy Technologies Institute
FEED	Front End Engineering Design
GBC	Generic Business Case
H&MB	Heat and Material Balance
HAZID	Hazard Identification Study
HAZOP	Hazard and Operability Study
HRSG	Heat Recovery Steam Generator
ICSS	Integrated Control and Safety System
1/0	Input / Output
IP	Intellectual Property
IX	Ion Exchange
KKD	Key Knowledge Documents



Abbreviation	Description
LHV	Lower Heating Value
LLP	Limited Liability Partnership
LP	Low Pressure
MEA	Monoethanolamine
MP	Medium Pressure
OPEX	Operating Expenditure
PFD	Process Flow Diagram
SCR	Selective Catalytic Reduction
Т-Т	Tan to Tan
TRU	Thermal Recovery Unit
ик	United Kingdom

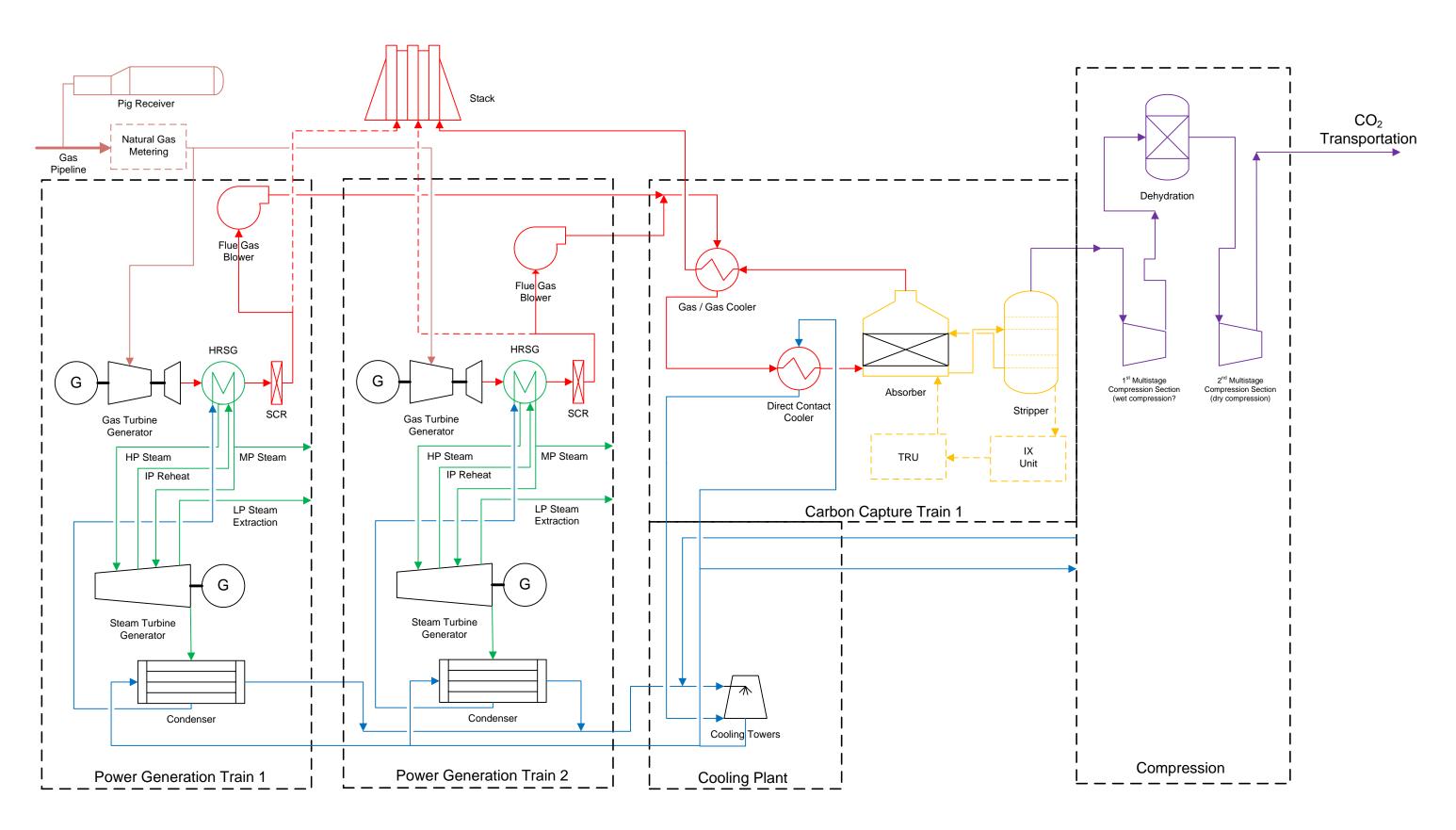
Table 8 - Abbreviations

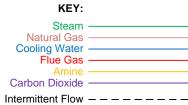
# 12 Attachments



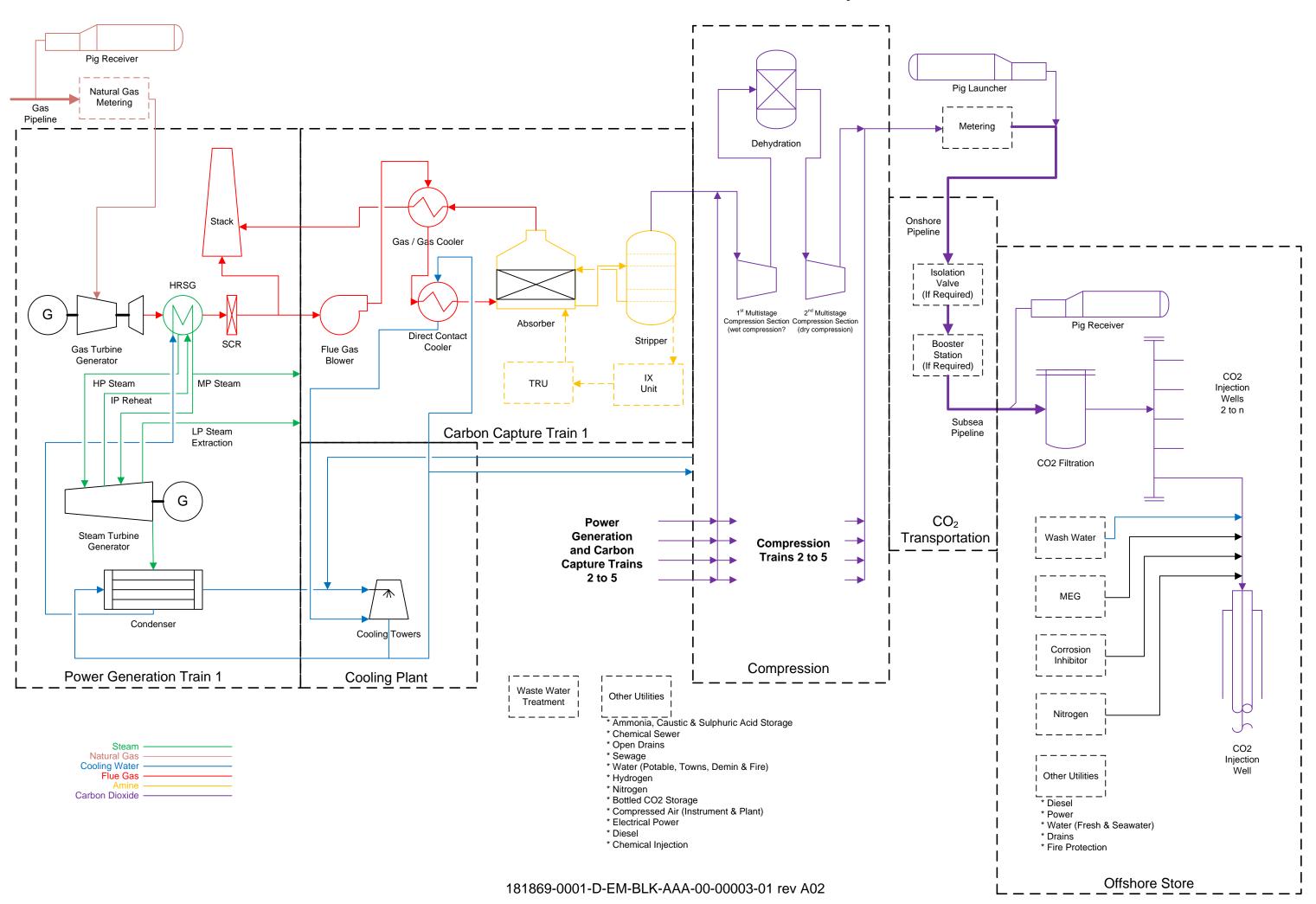
# **ATTACHMENT 1 - Block Diagrams**

# ATTACHMENT 1.1 - 2 CCGT into 1 CCC

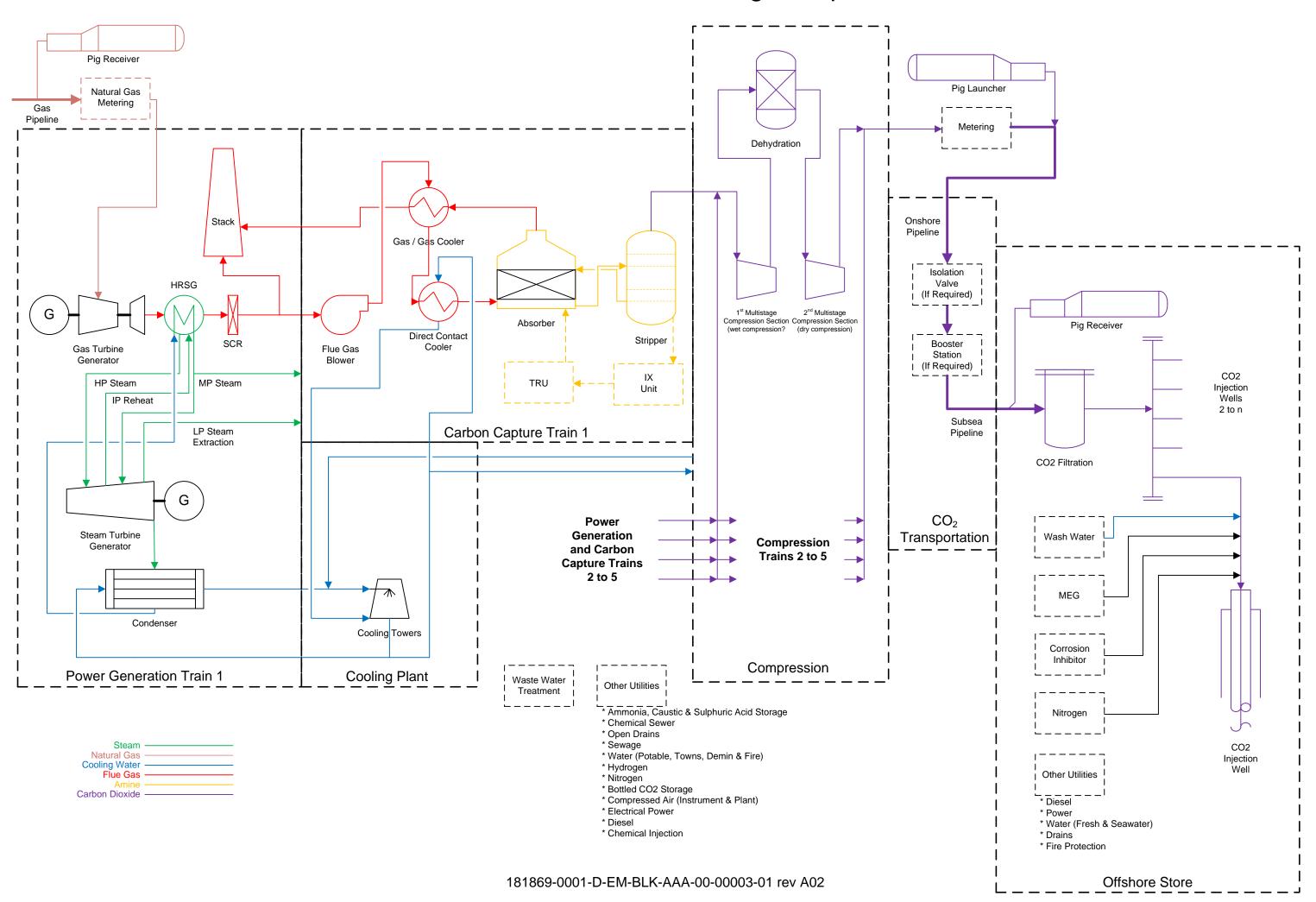




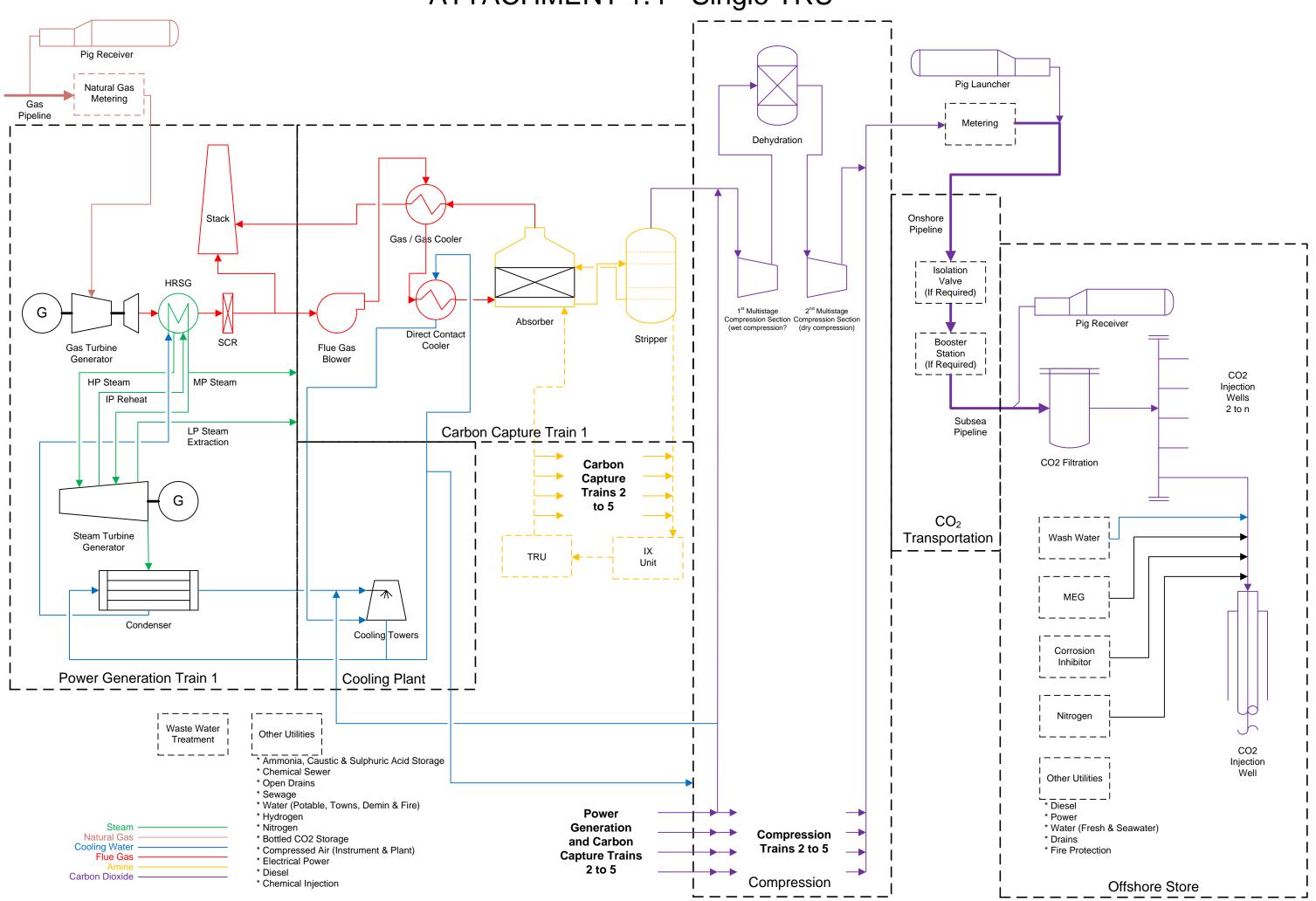
# ATTACHMENT 1.2 - Brochure Efficiency Reboiler



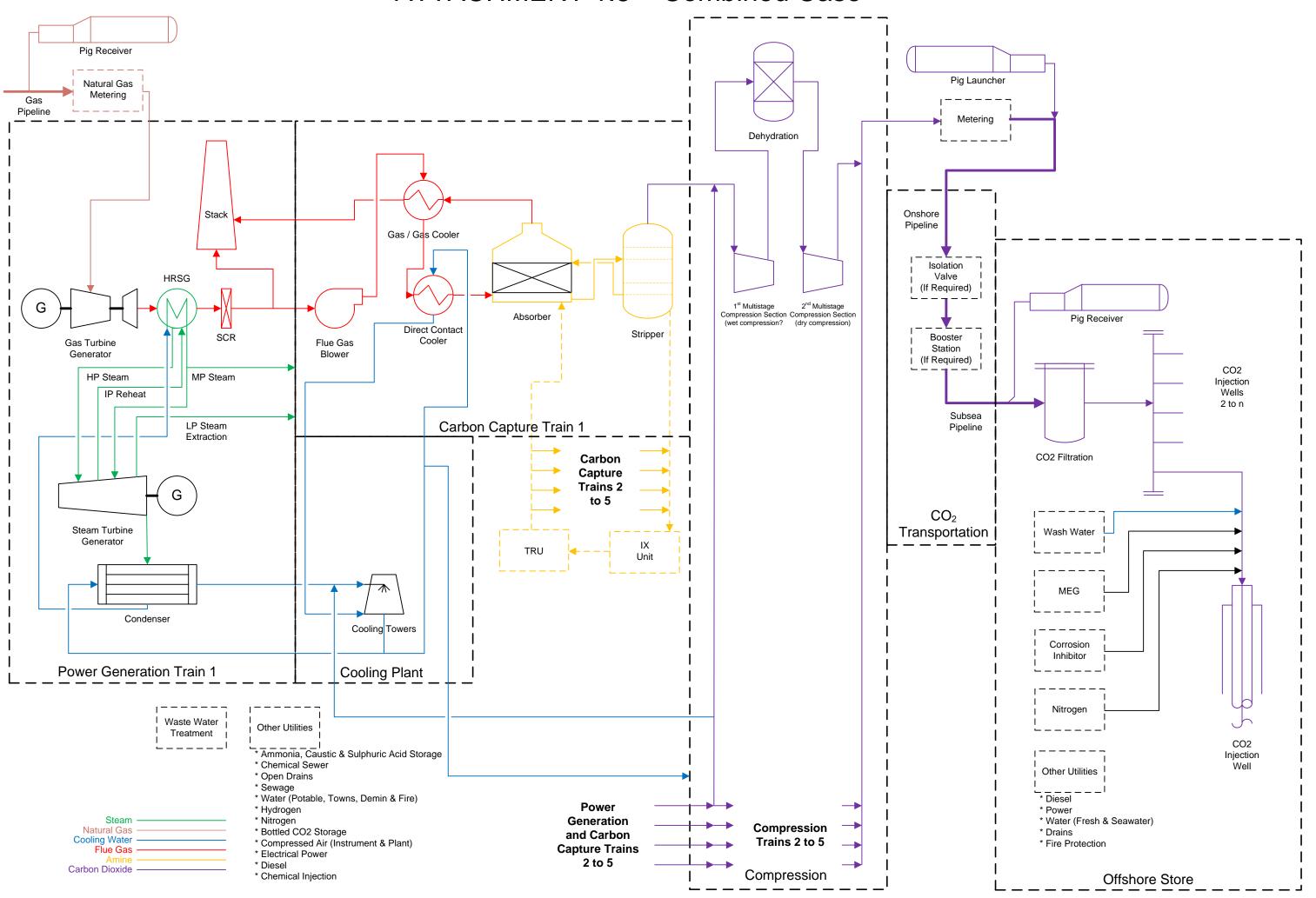
# ATTACHMENT 1.3 - 150 barg Compression



# ATTACHMENT 1.4 - Single TRU



# ATTACHMENT 1.5 – Combined Case





# **ATTACHMENT 2 - Equipment List (CCC only)**

# Attachment 2.1 - 2 CCGT into 1 CC Case



**EQUIPMENT LIST (MAJOR ITEMS)** ONSHORE PLANT - OPTIMISATION - 2 CCGT INTO 1 CC

PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00002

PLANT AREA			EQUIPI	MENT N	UMBER	R		ITEM DESCRIPTION	TYPE	PFD Number		ELI	CTRICAL	POWER			OPERATIN PRESSUR			PERATINI IPERATU		DESIGN PRESSURE	DESIO TEMPI ATUR	ER-	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	MENSIC	NS	WEIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	S S S S S S S S S S S S S S S S S S S	TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	TAGE (HV,	CCS STANDBY (kW)	INTERMITTENT (kW) DUTY - STANDBY	(KW) MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg) MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes) OPERATING (tonnes)	
Compressors						-								_		-					_												Part of Package U-101
Compression	NE		С	1-2	01	-		CO <sub>2</sub> Compressor	Centrifugal	03	48000	52800	MV	_	_	-	See	Pkg	Below		-	-							-				Motor sizing includes 10% API 617 Margin
Stack						+								-		+						-											
Power	NE		D	1&2	01			Gas Turbine Outlet Flues	Self Supporting	02	0	0	n/a				0.013			87.77			-5	750	3551	T/hr		CS - outer		25.0	90.0		Includes baseplate, anchor bolting, inner liner, outer shell, top cover, insulation, Flue Gas Inlet, Access/cleaning doors, condensation drain,
						-				02				_	_	_												316Ti - liner					ladders, platforms, AWLs, sample points, earth points, lifting lugs,
Carbon Capture Power	NE NE		D D	1-2	02	_		CO <sub>2</sub> Vent Stack  Carbon Capture Outlet Flue	Self Supporting	-	0	0	n/a n/a	-	-	+	0.72			-10 64.6		-	_	250 750	458612 7102	kg/hr T/hr		316L SS		42"	30.0	7.5	Sch 40S Flue included in combined stack with D101 and D201
						$^{\perp}$	士				Ė	_				1																	
Heat Exchangers  Carbon Capture	NE		E	1-2	01			Gas-Gas Heat Exchanger	Rotary	02	15	15	LV				1.093			98.4 / 70 32.7 / 64.8		0.125	-5	130	59400	kW	30650	Weathering Steel	22.0	22.0	5.5	550.0	Purge and Scavenge Fan shall be part of this package Proven technology. Howden has been providing since 1923. Howden's have references up to 1000 MW coal fired plants - similar thermal duty to gas turbines. Howden confirm that it is feasible to provide a Rotary Heat Exchanger against the required duty. Potential leakage with Purge + Scavenge system is 0.4%
Carbon Capture	NE		Е	1-2	09	A-	F	Lean / Rich Amine Exchanger	Welded Plate	02	0	0	n/a				5.1 / 5.9			122.3 / 111		18	-20	140	77734	kW	14457	316L SS	2.5	3.5	18.0	400.0 430.0	Compact design such as Packinox type or equal.  Limit on maximum size, therefore split into 6 units
Carbon Capture	NE		Е	1-2	10	A-	L	CO <sub>2</sub> Stripper Reboilers	Welded Plate	02	0	0	n/a				2.1			122.3		5	-5	150	36847	kW	1403	316L SS	2.8	1.8		10.6	Already at limit of exchanger size. Add additional units for duty.
Carbon Capture	NE		Е	1-2	11		-	Overhead Condenser	Welded Plate	02	0	0	n/a				2			26		12	-5	160	65037	kW	2244	316L SS	2.3	1.1	2.2	6.5 8.0	Sizing within range for welded plate exchangers.
Carbon Capture	NE		E	1-2	12 13	_	В	Wash Water Cooler	Welded Plate	02	0	0	n/a	_		-						10	-5	85	107835	kW kW	3111	316L SS	2.0		2.2	6.4 7.6	Sizing within range for welded plate exchangers.
Carbon Capture  Carbon Capture	NE NE		E	1-2	13	+	i/C	Lean Amine Cooler  DCC Cooler	Welded Plate Plate & Frame	02 02	0	0	n/a n/a	-		+						12 9	-5 -5	85 85	71479 84194	kW	1857 3854	316L SS 316L SS	2.3 6.1		3.6	6.5 8.0 14.7 21.8	Sizing within range for welded plate exchangers.  Duty was for 2 units - now split into 3 units
Carbon Capture	NE		E	1-2	15	_	-	CO <sub>2</sub> Vent Vapouriser	Inverted Kettle		0	0	n/a			1						FV 10/27	7 -79	270	7669	kW	222	CS / 316L SS	4.5		0.0	11.0	Say marks 2 and hor opin mic 5 and
Carbon Capture	NE		Е	1-2	16	A	В	CC Unit Condensate Cooler	Plate & Frame		0	0	n/a									8	-5	160	36254	kW	767	316L SS	2.7	1.3	4.6	7.3 10.4	Sizing well within range for plate & frame exchangers.
Carbon Capture	NE		E	1-2	18			Thermal Reclaimer Pre-Heater	Welded Plate		0	0	n/a	_	_	-						8	-5	160	1189	kW	123	316L SS	3.6	1.5	1.5		Sizing well within range for welded plate exchangers.
Carbon Capture  Carbon Capture	NE NE		E	1-2 1-2	19 20	_		IX Amine Cooler IX Demin Water Cooler	Welded Plate Plate & Frame		0	0	n/a n/a	_		+						12	-5 -5	85 160	691 5783	kW kW	120 19	316L SS 316L SS	3.6 1.4	1.0	2.8	12.0 12.7 0.7 0.8	Sizing well within range for welded plate exchangers.  Sizing well within range for welded plate exchangers.
Compression	NE		E	1-2	05	+-		6th Stage Cooler	Shell & Tube	03	0	0	n/a			1	68.2			97.5 /					12432	kW		cs					Part of Package U-101
Compression	NE		Е	1-2	06			8th Stage Cooler	Shell & Tube	03	0	0	n/a				182.9			119.8 / 36					26400	kW		cs					Part of Package U-101
Compression	NE		E	1-2	07			CO <sub>2</sub> Dehydration Electric Heater	Electric Heater	03	6975	7600	MV			1	37.4			22.9 / 290		47	-5	310	6975	kW		316L SS	5.6	2.3	3.1	8.0	Alternative DT= -79°C for Rapid Depressurisation
Compression	NE		Е	1-2	08	T		Dehydration Cooler	Shell & Tube	03	0	0	n/a			1	36.6			290		47	-5	310	6647	kW	332	316L SS					Alternative DT= -79°C for Rapid Depressurisation
Instrumentation and C		quipmer	JDF	0	02	+	+	CO <sub>2</sub> Metering	Coriolis	03			LV	_		+	182.9			26	$\perp$	200	-5	100	2280	T/hr		316L SS	25.0	0.0	7.0	122.7	Materiae sinchased as similar seems - to the sector
Compression	NE NE		JCP	0	02	_	+	CO <sub>2</sub> Metering CO <sub>2</sub> Metering Panel	Panel	03	1	1	LV	+	+	+	102.9			36	$\dashv$	200	-5	100	2200	1/11		3101.33	35.0 7.2	_		0.7	Metering - size based on similar scope pipeline meter Safe Area Panel
Compression	NE		JDC	0	02	_	1	CO <sub>2</sub> Metering Analyser House					LV			1													2.0			2.3	Analyser House and Speciality Bottle House
Utilities	NE		JDC	0	05			DCS (ICSS)	Panel		110	110	LV																36.8	0.8	2.1	31.5 31.5	ICSS for whole Power + CCS chain controlled from single control room. Price includes F&G and well as HIPPS
Fans						+	+			<del> </del>				-	+	+	+			$\vdash$	+	+	+	$\dashv$				-					<del>                                     </del>
Carbon Capture	NE		K	1 & 2	01	1	+	Booster Fan	Axial	02	13122	13900	MV	$\dashv$		$\top$	1.013 /			87.8	$\dashv$		+ +	$\dashv$	3551	T/hr	∆ 0.08bar	Steel Plate	9.9	9.3	8.1	111.4	Conceptual design for 1 fan per CCGT
Carbon Capture	NE		KF	1 & 2		A-	н	Booster Fan Motor Cooling Fans	Axial		24	60	LV	$\dashv$	+	+	1.093				$\dashv$	+	+ +	$\dashv$									Included in Booster Fans Supply
Carbon Capture	NE		KU	1 & 2	01			Booster Fan Lube Oil Skids			15	41	LV																				Included in Booster Fans Supply
Carbon Capture	NE		K	1-2	02	+	4	Damper Sealing Air Fan	Centrifugal		293	322	MV	_		$\perp$					$ \Box$		+					Weathering Steel	4.0			10.7	Included in package with Gas Gas Heat Exchanger
Carbon Capture	NE		K	1-2	03	$\perp$	$\perp$	Damper Purge & Scavenge Air Fans	Centrifugal		6	7.5	LV			$\bot$							$\perp$		1500	m³/hr	800 mmWG	Weathering Steel	1.0	1.0	2.5	0.3	Included in package with Gas Gas Heat Exchanger
Mechanical Handling	Egyinma	nt				+	+							-		+					+	-	+										
Compression	NE		L	1-2	04	+	+	CO <sub>2</sub> Compressor Overhead Crane	Single Girder		0	30	LV	$\dashv$		+					$\dashv$		-5	-+	50	Т		CS					
Mixer						1	_	Thermal Reclaimer No 1 Feed Tank						$\perp$		$\perp$	$\perp$				_		1						_				
Carbon Capture	NE		М	1-2	14	_	$\perp$	Mixer			9	15	LV			4	Atm			Amb		0.29		85				316L SS		0.7		0.4	
Carbon Capture	NE		М	1-2	08			Amine Degraded Tank Mixer	l		9	15	LV		ı	-	0.06			20	ı	1	-5	160				316L SS		0.7		0.7	1



EQUIPMENT LIST (MAJOR ITEMS)
ONSHORE PLANT - OPTIMISATION - 2 CCGT INTO 1 CC

PROJECT No.
PROJECT NAME
LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE 181869-0001-T-EM-MEL-AAA-00-00002

PLANT AREA		EQUIP	MENT N	UMBER		ITEM DESCRIPTION	ТҮРЕ	PFD Number		ELEC	TRICAL	. POWER			RATING ESSURE		OPERATII EMPERAT		DESI PRESS		DESIGN TEMPER- ATURE	DUTY (Per Unit	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	MENSIC	DNS	WE	EIGHT	REMARKS
	ASSET CODE AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY TRIM OR AUX ELEC FOLIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	LV)	CCS STANDBY (kW) DUTY - INTERMITTENT (kW)	DUTY - STANDBY (kW)	MIN (barg)	NORMAL (barg) MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C) MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Pumps											-					-		+			-	-	+			1					
Carbon Capture	NE	Р	1-2	04	A/B/C	Absorber Feed Pumps	Centrifugal	02	1258	2100	MV				3.4	+	53	+ +		10	-5	2829	m³/hr	@69.5m	316 SS	5.0	1.7	1.2	11.0		Change selection to 3 x 50% as is better economic sizing for a 2x sized CCS
Carbon Capture	NE	P	1-2	05	A/B/C	Lean Amine Pumps	Centrifugal	02	741		MV			$\vdash$	4.1	+	122.4	1 1		-	-5	3042	m³/hr	@39.3m	316 SS	5.0	1.9	1.4	9.1	+	unit. Change selection to 3 x 50% as is better economic sizing for a 2x sized CCS
Carbon Capture	NE NE	P	1-2	06	A/B/C	Rich Amine Pumps	Centrifugal	02	1422		MV				5.6	-	41	+			-5	2833	m³/hr	@129.4m	316 SS	4.8	2.5	1.4	17.9		unit. 3 x 50%. Already in 3 x 50% arrangement: therefore just double duty.
Carbon Capture	NE	Р	1-2	07	A/B	Stripper Reflux Pumps	Centrifugal	02	44		LV				1	1	26				-5	156	m³/hr	@61.1m	316 SS	2.1	1.2	2.6	1.6		1 Pump is a Spare for IX Transfer Pump
Carbon Capture	NE	Р	1-2	17	A/B	Waste Wash Water Pumps	Centrifugal		19	44	LV									10	-5	128	m³/hr	@22.8m	CS	1.8	1.1	1.0	1.2		
Carbon Capture	NE	Р	1-2	19		Chemical Sewer Tank Pump	Centrifugal		12		LV										-5 85	_	m³/hr	@19.5m	316 SS				<u> </u>		
Carbon Capture	NE	P	1-2	18	A/B	CC Unit Condensate Pumps	Centrifugal		150		LV			7.5	8.5		50	$\vdash$			-5	763	m³/hr	@44.6m	CS / SS Impeller	1.8	1.2	2.6	7.0		
Carbon Capture Carbon Capture	NE NE	P P	1-2	08	A-D A/B	Direct Contact Cooler Pumps  Acid Wash Pumps	Centrifugal Centrifugal	02 02	3780 235		MV LV				7.4		41 85	+			-5 -5	4240 2390	m <sup>3</sup> /hr	@ 61.4m @18.7m	CS 316 SS	6.0 5.4	2.3	3.3	21.4		Retain selection for 4 x 33%
Carbon Capture	NE	P	1-2	10	A/B/C	Water Wash Pumps	Centrifugal	02	1059		MV			-	0.7	+	46	+ +			-5	4205	m³/hr	@34.9m	316 SS	5.0	1.7		11.0	+	Change selection to 3 x 50% as is better economic sizing for a 2x sized CCS
Carbon Capture	NE	P	1-2	28	A/B/C	Fresh Amine Transfer Pumps	Centrifugal	02	8		LV			-	2.2		25	+			-5	56	m³/hr	@22.8m	316 SS	1.8	1.1	0.0	11.0		unit.
Carbon Capture	NE NE	P	1-2	29	AD.	Amine Container Pump	Centrifugal	1	1		LV			$\vdash$	1	+	25	+ +			-5	20	m³/hr	@11.3m	316 SS	1.5		0.7	0.4		No change to duty - this is transfer from containers.
Carbon Capture	NE	Р	1-2	25		IX Amine Pump	Centrifugal		43		LV				8.8		85				-5	236	m³/hr	@74.3m	316 SS	2.1		0.9	1.5	_	
Carbon Capture	NE	Р	1-2	26		Amine Drain Pump	Centrifugal		23	30	LV				4.4		160			10	-5	86	m <sup>3</sup> /hr	@49.7m	316 SS	1.8	0.9	0.8	1.1		
Carbon Capture	NE	Р	1-2	27		IX Transfer Pump	Centrifugal		51	55	LV				8.9		110			10	-5	179	m³/hr	@60.8m	316 SS	2.1	1.2	1.0	1.6		
Carbon Capture	NE	Р	1-2	21	A/B	Thermal Reclaimer NO. 1 MP Condensate Pumps	Centrifugal		4	11	LV				22		250		FV	27	-5 27	19	m <sup>3</sup> /hr	@21m	CS	1.8	0.9	0.8	0.5		
Carbon Capture	NE	Р	1-2	22	A/B	Thermal Reclaimer NO. 2 MP Condensate Pumps	Centrifugal		2	7.4	LV				22		250		FV	27	-5 27	2	m³/hr	@19.8m	cs	1.8	0.9	0.8	0.5		
Carbon Capture	NE	Р	1-2	23	A/B	Thermal Reclaimer NO. 3 MP Condensate Pumps	Centrifugal		2	7.4	LV				22		250		FV	27	-5 27	3	m³/hr	@19.7m	cs	1.8	0.9	0.8	0.5		
Compression	NE	Р	1-2	24	A/B	Process Condensate Return Pumps	Centrifugal	03	2	4.4	LV				1		20			35	-5	4.0	m³/hr	@32m	316 SS	1.8	0.9	0.7	0.7		
									$\vdash$	-	+					+	+	+			+	+	+						1	-	
Filters																						1									
Carbon Capture	NE	S	1-2	04	A/B	Amine Filter	Cartridge	02	0	0	n/a				7.1		40			12	-5 85	236	m3/hr		316L SS		0.2	2.3	0.3		99% removal > 10micron
Carbon Capture	NE	S	1-2	80		Amine Drain Filter	Cartridge		0	0	n/a				3.6		40			7	-5 16	66	m3/hr		316L SS		0.2	1.5	0.2		99% removal > 10micron
Compression	NE	S	1-2	02		CO <sub>2</sub> Dehydration Filter Coalescer	Disposable Catridge	03	0	0	n/a				37.9		36			47	-5 16	6372	m3/hr		316L SS		3.8	8.1	129.0	)	99.999% removal > 0.3micron Alternative DT= -79°C for Rapid Depressurisation
Compression	NE	S	1-2	05	A/B	CO <sub>2</sub> Dehydration Outlet Filter	Basket	03	0	0	n/a				36.6		36			47	-5 16	5768	m3/hr		316L SS		4.4	8.1	176.0	0	> 5micron Alternative DT= -79°C for Rapid Depressurisation
Compression	NE	S	1-2	09	A/B	CO <sub>2</sub> Dehydration Regeneration Gas Discharge Filters	Basket	03	0	0	n/a				36.6		36			47	-5 310	2325	m3/hr		316L SS		3.3	8.1	94.5		> 5micron Alternative DT= -79°C for Rapid Depressurisation
						,																									
Tanks																															
Carbon Capture	NE	Т	1-2	01		Lean Amine Tank	Vertical - API 650	02	0	0	n/a				Atm	$\perp$	Amb			0.15	-5 85	6374	m <sup>3</sup>		316L SS		20.0	22.0	)		Pressure at top is 0.04 barg (vent connected to absorber) Double walled tank Lined carbon steel could be considered as a lower cost alternative Pressure at top is 0.04 barg (vent connected to absorber)
Carbon Capture	NE	Т	0	03		Fresh Amine Tank	Vertical - API 620		0	0	n/a									0.2	-5 85	6516	m <sup>3</sup>		316L SS		20.0	22.0	)		* Sized for 5 trains
Carbon Capture	NE	T	1-2	07		Amine Drain Tank	Horizontal		0	0	n/a									1	-5 16	211	m <sup>3</sup>		316L SS	9.0	5.5		23.1		Underground Horizontal Tank
Carbon Capture	NE	Т	1-2	80		Degraded Amine Drain Tank	Horizontal		0	0	n/a			$\sqcup$	0.06		20	$\sqcup$	-0.5	1	-5 16	54	m <sup>3</sup>		316L SS	5.8	3.5		6.2		Underground Horizontal Tank. Includes a mixer.
Carbon Capture	NE	Т	0	09		Waste Wash Water Tank	Vertical		0	0	n/a				Atm		Amb			ATM	-5 85	13512	m <sup>3</sup>		CS + 3mm CA		26.7	24.1			Sized for 5 trains
Carbon Capture	NE	Т	0	15		Amine Maintenance Tank	Vertical		0	0	n/a				Atm		Amb			ATM	-5 85	12800	m3		316L SS		26.0	24.4	266		Sized to hold inventory of 1 train during maintenance
Carbon Capture	NE	Т	1-2	10	$\Box$	Chemical Sewer Tank	Horizontal		0		n/a	$\Box$		-	Atm		Amb	$\sqcup$	_		-5 10	_	m <sup>3</sup>		CS Lined	9.0	5.5		27.7		Underground Horizontal Tank
Carbon Capture	NE	Т	1-2	14	$\vdash$	Thermal Reclaimer No 1 Feed Tank	Vertical		0	0	n/a			$\vdash$	Atm	-	Amb	$\vdash$		0.29	-5 85	206	m <sup>3</sup>		316L SS		5.0	11.0	20.0	1	Pressure at top = 0.04 barg (Vent connected to Absorber)
Packages		-	-					-	$\vdash$		-			$\vdash$	_	-	-	$\vdash$		-	+	+	+		<del>                                     </del>	-		-	+	+	
Packages  Carbon Capture	NE	U	1-2	03	<del>                                     </del>	Thermal Reclaimer Unit		02	22	31	LV			$\vdash$	_	+		+	FV	3.5	-5 33	187	m³/hr		316L SS	77.3	38.7	25.0	1		
Carbon Capture  Carbon Capture	NE NE	U	1-2	15	A/B	Thermal Reclaimer Vacuum Packages		02	9	-	LV			$\vdash \vdash$	-0.1	+	35		FV		-5 33 -5 85/1	+	m³/hr		316L SS 316L SS	11.3	30.7	∠5.0	6.0		
Carbon Capture	NE	U	1-2	04		Ion Exchange Package		02	15	17	LV			$\vdash$	-	+	+	+ +		+	+	6	m³/hr		316L SS	8.2	8.2	7.1	+	+	
Compression	NE NE	U	1-2			CO <sub>2</sub> Compression Package	Integral Geared	03			LV	_			2/183	-	123	$\vdash$		200	-5 15		m³/nr T/hr		316L SS 316L SS	27.0			748.8	3	
Compression	NE	U	1-2	02		CO <sub>2</sub> Dehydration Package	Mole Sieve	03	0		n/a			<del>                                     </del>	37.9	+	123	<del>   </del>			-5 15		T/hr		316L SS	N/A	N/A	_	_		Equipment elsewhere - line item for price for design and mole sieve
Compression	NE NE	U	0	10	<del>                                     </del>	Tracer Dosing Package	API 675 Pumps	- 55	0		LV	-		$\vdash$	01.0	+	-	+ +			-5 85		ppbv		316L SS 316L SS	2.2		-	0.9	+	Redesign to a 3 column system.  Addition to give CO <sub>2</sub> smell to allow leakage detection
Compression	1	ı	ı	ı '°	1 1		7.1.0.01 dilipo	ı	ı'l	٠ I	I	1 1	I	1 1	I	I	I	ı I	I		1 30	1 100	I PPOV	I	1 3.52.55	I	I '	I 2.0	1 0.3	I	



**EQUIPMENT LIST (MAJOR ITEMS)** ONSHORE PLANT - OPTIMISATION - 2 CCGT INTO 1 CC

PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00002

PLANT AREA			EQUIP	MENT N	UMBER		ITEM DESCRIPTION	TYPE	PFD Number		ELEC	TRICAL	POWER			OPERATI PRESSU			PERATIN MPERAT		DESIGN PRESSURE	. TE	ESIGN EMPER- TURE	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	IMENSIO	ONS	WEIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (kW)	INTERMITTENT (KW) DUTY - STANDBY	(kW) MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg) MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes) OPERATING (tonnes)	
Drums and Vessels												-	+	_	+	+					_	+	+	-					-			
Carbon Capture	NE		V	1-2	06		Direct Contact Cooler	Rectangular Tower	02	0	0	n/a				0.063	3		70		0.08	35 -5	85	507	T/hr (CO <sub>2</sub> )		Lined Concrete 304SS Internals	25.5	24.0	28.2		Column lining design temperature 120°C which could be subject to 110°C flue gas during start-up Scale up using flue gas flow rate: refer to 181869-0001-T-EM-CAL-AAA-00-00004 rev A02
Carbon Capture	NE		>	1-2	07		CO <sub>2</sub> Absorber	Rectangular Tower	02	0	0	n/a				0.026	6		30		0.08	5 -5	85	507	T/hr (CO <sub>2</sub> )		Lined Concrete 304/316SS Internals	48.0	24.0	64.3		* High efficiency mist eliminator at the top of the water wash  *Knit mesh mist eliminator at the top of acid wash section  *High quality gravity distributor  *Leak & splash proof chimney tray  *Structured packing  *Shoepentouter inlet devices (two off)
Carbon Capture	NE		٧	1-2	08		Amine Stripper	Vertical	02	0	0	n/a				1			122.3		3.5	; -5	160	456	T/hr (CO <sub>2</sub> )		CS with 316L Cladding		13.6	34.6	520.0	* Top =dia 8m, Middle = dia 14m, Top = dia 11m.  * Upper rectification: predistributor, distributor (with chimney tray), splash plate, demister mat  * Stripping: predistributor, distributor (with chimney tray), demisters  * Structured packing
Carbon Capture	NE		V	1-2	09		Amine Reflux Drum	Vertical	02	0	0	n/a				1			26.3		3.5	-5	105	456	T/hr (CO <sub>2</sub> )		316L SS		6.4	12.8	49.5	* Half open pipe inlet device * Mesh * Mist Eliminator
Carbon Capture	NE		V	1-2	21		Vent KO Drum	Horizontal	<u> </u>	0		n/a									FV 10			31	m <sup>3</sup>		316L SS		2.7	4.5		Kept pressurised with Instrument Air
Carbon Capture  Carbon Capture	NE NE		V	1-2	28		CC Unit Condensate Drum  Thermal Reclaimer Column No 1	Vertical Vertical		0		n/a n/a									FV 5.5				m <sup>3</sup>		CS + 3mm CA 316L SS		1.3	5.0 8.9		Includes inlet hood and wear plate  * Packed section  * Predistribution, distributor (with chimney tray)  * Vane collector  * Structured packing
Carbon Capture	NE		V	1-2	29		Thermal Reclaimer Column No 2	Vertical		0	0	n/a									FV 3.5	-5	215	16	m <sup>3</sup>		316L SS		1.4	9.4	5.2	Packed section Predistribution, distributor (with chimney tray) Vane collector Structured packing
Carbon Capture	NE		V	1-2	30		Thermal Reclaimer Column No 3	Vertical		0	0	n/a									FV 3.5	i -5	335	22	m <sup>3</sup>		316L SS		1.7	9.1	5.8	* Packed section * Predistribution, distributor (with chimney tray) * Vane collector * Structured packing
Carbon Capture	NE		V	0	33		Instrument Air Buffer Vessel	Vertical		0	0	n/a				8.5			25		10	-5	85				316L SS		3.4	10.1	23.8	
Compression	NE		V	1 & 2	11		1st Stage CO <sub>2</sub> Compressor KO Drum	Vertical	03	0	0	n/a				0.15			25		3.5	-7	105	456	T/hr (CO <sub>2</sub> )		316L SS		4.8	11.0	24.5	Includes * Intlet hood and mist eliminator
Compression	NE		V	1 & 2	12		2nd Stage Integrated KO Drum	Vertical	03	0	0	n/a				1.95			122/36					456	T/hr (CO <sub>2</sub> )		316L SS					Part of Package U-101 Includes integral water cooled tube bundle
Compression	NE		V	1 & 2	13		3rd Stage Integrated KO Drum	Vertical	03	0	0	n/a			+	5.925	5		123/36					456	T/hr (CO <sub>2</sub> )		316L SS					Part of Package U-101
Compression	NE		V	1 & 2	14		4th Stage Integrated KO Drum	Vertical	03	0	0	n/a			+	15.52	,		121.8/		_			537	T/hr		316L SS					Includes integral water cooled tube bundle Part of Package U-101
			V										+		+		-		36 116.7/		-	-	+	-	(CO <sub>2</sub> ) T/hr							Includes integral water cooled tube bundle Part of Package U-101
Compression	NE		-	1 & 2	15		5th Stage Integrated KO Drum	Vertical	03	0		n/a	_	_	-	38	1		36			-	-	537	(CO <sub>2</sub> ) T/hr		316L SS		-	-		Includes integral water cooled tube bundle
Compression	NE		V	0	17		CO <sub>2</sub> Pipeline Pig Launcher	Horizontal	03	0	0	n/a				181.7	<u>'</u>		36		200	-46	85	1140	(CO <sub>2</sub> )		LTCS	11.4	1.1	1.3	15.6 19.0	Internals and spinits of spinits and spinits are spini
Compression	NE		V	1-2		3/C	CO <sub>2</sub> Dehydration Absorber	Vertical	03	0	_	n/a				37.7	-				47	-5	150	537	T/hr (CO <sub>2</sub> )		316L SS		3.3		102.6	Internals = molecular sieves, cermaic balls, supports, grid support Material: CS clad with SS also acceptable.  Weight excludes internals Includes Inlet Hood and Mist Eliminator
Compression	NE		V	1-2	19		Dehydration KO Drum	Vertical	03	0	0	n/a	_		$\perp$	35.4			36		47	-5	300	456	T/hr (CO <sub>2</sub> )		316L SS		1.3	3.0	6.9	Depressurisation = -79°C at 0 barg
Electrical Equipment						+			<b> </b>	$\vdash$	-+	+	+	+	+	+				$\vdash$	-+	+	+					$\vdash$			<del>                                     </del>	
							Low Voltage Equipment																									
Carbon Capture	NE		ESG	1-2	01		LV Switchboard			684	894	LV																				Doubling GBC = 144 loads LV switchgear. Combination of CC units reduced number to 116 loads
Carbon Capture	NE		ESG	1-2	02		LV Emergency Switchboard			294		LV											T			-						No change as number of loads is not reduced
Compression	NE		ESG	1-2	03		LV Switchboard			1114		LV			$\perp$																	Non-Process Equipment Loads No reduction to non-process loads in Compression Area
Compression	NE		ESG	1-2	04	+	LV Emergency Switchboard		-	290	520	LV	+	_	+	-				$\vdash$		-		+								No change as number of loads is not reduced
						1	Medium Voltage Equipment				-+	$\dashv$	$\top$	_	$\top$	1																
Carbon Capture	NE		ESG	1-2	13		MV Switchboard					MV																				No change as number of loads is not reduced
Carbon Capture	NE			1-2			Booster Fan VFD					MV			$\perp$																	Part of K-101 Supply No change as number of loads is not reduced
Compression	NE		ESG	1-2	14		MV Switchboard					MV																				Doubling GBC = 50 loads MV switchgear. Combination of CC units reduces number to 40.
Compression	NE		ESG	1-2	15		Switchgear					MV																2.3	0.7	1.7	1.3	Part of Package U-101 No change as load is not reduced
Compression	NE		ETR	1-2	16		Transformer					MV																				Part of Package U-101 No change as load is not reduced
Compression	NE			1-2			CO <sub>2</sub> Compressor VFD					MV			1													4.4	9.4	1.0	10.0	Part of Package U-101
Buildings	-					+		<b> </b>		$\vdash$	-+	+	+	+	+	+	-			$\vdash$	-+	+	+						-	-	+	
]	I	ı l			ı I	1	1	ı	ı	1 1	I	ı	1	I	1	ı	I	1 1	ı	ı I	1	I	ı	ı	I	I	ı	I	I	I	1 1	1

### ATTACHMENT 2.1



**EQUIPMENT LIST (MAJOR ITEMS)** ONSHORE PLANT - OPTIMISATION - 2 CCGT INTO 1 CC

PROJECT No. 181869

PROJECT NAME Thermal Power with CCS: Generic Business Case LOCATION

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00002

	PLANT AREA			EQ	UIPME	NT NU	JMBER	R			ITEM DESCRIPTION	TYPE	PFD Number			ELEC1	TRICAL	POWE	R			PERATIN			PERATIN IPERATI		DES PRES	SIGN	DES TEMI ATU	PER-	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or $\Delta P$ (Per Unit)	P 5	I	DIMENS	SIONS	,	WEIGHT	IT REMARKS
		ASSET CODE	AREA / UNIT CODE	Chidoo Tidawaiii oa		TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC	EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	2007	հ I <del>í</del>	LV)	CCS STANDBY (kW)	DUTY - INTERMITTENT (KW)	DUTY - STANDBY (kW)	MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)		tonnes	OPERATING (tonnes)
	Facilities	NE		ВІ	_D	1-2	08			С	Carbon Capture Electrical Substation			8		3 1	LV					+ve		10		40	N/A	N/A	N/A	N/A	3038	m <sup>3</sup>			37.5	5 18.	0 4	1.5		Height to Eaves Only need 1 building instead of 2. Majority of drives are just larger power (not more multiple units). Consider 2 x HVAC for twice heat disapation.
Ŀ																																								



# Attachment 2.2.1 – Brochure Efficiency Reboiler Case 2.7 GJ/tonne CO<sub>2</sub> case

EQUIPMENT LIST (MAJOR ITEMS)

ONSHORE PLANT - OPTIMISATION - BROCHURE EFFICIENCY REBOILER

**SNC·LAVALIN** 

PROJECT No.
PROJECT NAME
LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

 DOCUMENT No.
 181869-0001-T-EM-MEL-AAA-00-00003

 REVISION
 A01

 DATE
 OCTOBER 2017

Part	PLANT AREA		EQUI	PMENT I	NUMBE	ER		ITEM DESCRIPTION	ТҮРЕ			ELE	CTRICAL	. POWE	R								TEMPER-		STINU	TRANSFER AREA or ΔP	MATERIAL OF CONSTRUCTION	DII	MENSIO	NS	WEIGH	IT REMARKS
Content		ASSET CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (kW)	DUTY - INTERMITTENT (KW) DUTY - STANDBY	(KW) MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C) NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C) MAX (°C)			m²		Length-OVL/TT (m)	Or DIA	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)
Content											1					1						1		1								
Controlled   Control   C	Stack																															
Controllary   1	Carbon Capture	NE	D	1	02			CO <sub>2</sub> Vent Stack	Self Supporting		0	0	n/a	n/a	_	+	0.72		-10	_		<del>     </del>	-79 250	229306	kg/hr		316L SS		30"	30.0	4.5	Sch 10S
Controllary   1	Heat Exchangers																															
Controllary		NE	Е	1	01			Gas-Gas Heat Exchanger	Rotary	02	15	15	LV	0								0.125	-5 130	30269	kW	13521	Weathering Steel	15.6	15.6	4.5	340.2	Purge and Scavenge Fan shall be part of this package
Controllary   1	Carbon Captura	NE	_	1	00	A/P/C			Wolded Blots	02			n/o	n/o			5.1 /		122.3	3/		40	20 140	77724	F/V/	14457	2461 00	2.5	2.5	40.0	400.0 4	a a Deckiney time or equal Duty was for 2 units about collitints 2 units
Mathematical Part					_						Ů						_			_					KVV		3102.33			16.0		Assume no change - would be minor difference but not affecting unit pricing
Controllage   A			_		_	_					_	_	_	_																	_	
Controllation   March   Marc													_	_		-	2		26				_	_								
Control pages   March   Marc			_	_	_	_					_		_	_																		
Control Cont		NE	Е	1	14	A/B/C					0	0											-5 85	42097	kW	1927		6.1			13.0	Duty was for 2 units - now split into 3 units
Controllation   Controllatio	Carbon Capture	NE	Е	1	15			CO <sub>2</sub> Vent Vapouriser	Inverted Kettle		0		n/a	n/a							FV	10 / 27	-79 270	3835	kW	111	CS / 316L SS	3.7	1.5		5.5	
Control Cont	Carbon Capture		_					CC Unit Condensate Cooler			0	_										8					316L SS	4.3	1.3	2.3		
Controllaries   M					_	-		<u> </u>			_	+ +			_	+	-			-	-											
From			_		4					-	+	-			_	+				-	-									13		
Control Course   No.	Carbon Capture	145	+-	+ '	20		1	IX Deffill Water Cooler	riate a rianie		<del>ا</del> ٽ	+ + +	II/a	ıγα		+	+			+	1	1 9	-5 100	2092	KVV	3	3102.33	0.7	0.5	1.3	0.0	
Properties   Pro											1													1				Н				
Control Courts   No.   N	Fans																															
Control Cont	Carbon Capture	NE	К	1	01			Booster Fan	Axial	02	13122	13900	MV	0					87.8	3	1			3551	T/hr	Δ 0.08bar	Steel Plate	9.9	9.3	8.1	111.4	
Conforciagnee   Martin   Mar	Carbon Capture	NE	KF	1	01	A-H		Booster Fan Motor Cooling Fans	Axial		24	60	LV	0																		Included in Booster Fans Supply
Carbon Cigative   Me   March   Carbon Cigative   Me   March	· · · · · · · · · · · · · · · · · · ·		_	-	+																	$\perp$										
Marcon   M		<del>                                     </del>	_	+	+-	-					1	+			_	+	-			_	_	+ +		+	-							
Cation Cigative   No.	Carbon Capture	NE	K	1	03		-	Damper Purge & Scavenge Air Fans	Centrifugal		6	7.5	LV	6		+	-				<u> </u>			1500	m³/hr	800 mmWG	Weathering Steel	1.0	1.0	2.5	0.3	Included in package with Gas Gas Heat Exchanger
Carbon Capture   NE   M   1   16   M   1   16   M   Internal Recisioner No.   Front Tends   Many   S   5   5   LV   5   M   M   M   M   M   M   M   M   M	Miyer													-	_	_																
Carbon Capture   NE   NE   NE   NE   NE   NE   NE   N		NF	М	1	14			Thermal Reclaimer No 1 Feed Tank			5	5	IV	5			Atm		Ami	,		0.29	-5 85				3161 SS		0.5		0.4	
Pumps							-	Mixer Amine Degraded Tank Mixer			<u> </u>	+ - +	_			+	_				<del>                                     </del>											
Carbon Cinglature   NE   P   1   04   A8   Absorber Fees Purings   Coemfringial   02   829   1400   MV   377     1   1   1   1   1   1   1   1   1	Carbon Captaro		-	† ·	1 00			7 annie Bogradoù Faint mixor			Ť	+ +	-	+		1	0.00		1 20			+ +	- 100	1			0.02.00		0.0		0.1	
Carbon Capture NE P 1 0 6 AB Lean Amine Pumps Centrifugal 02 371 860 MV 222 N 1 4.1 N 12.2 N 1 10 5.5 N 3042 m³h; 6383m 316.55 5.0 1.9 1.4 9.1 N 3.50% N 1.5	Pumps																															
Carbon Capture   NE   P   1   06   ABC   Rich Amine Pumps   Centifugal   02   711   1170   MV   427     5.6   41     13.8   5   1417   m²/hz   0129.4m   31655   3.5   1.8   1.0   13.0   3.x50%	Carbon Capture	NE		1	_			Absorber Feed Pumps	Centrifugal	-		-					+						-5	+		<del> </del>	316 SS	-	1.7	1.2		
Carbon Capture   NE   P   1   07   AB   Stripper Reflux Pumps   Centrifugal   02   21   60   LV   12   V   1   V   2   V   6   V   12   V   6   V   12   V   6   V   12   V   6   V   V   V   V   V   V   V   V	-			_	_	-	1	-			+	-		-	$\perp$		_	_			_			+		<del> </del>				1.4		
Carbon Capture NE P 0 17 AB Waste Wast Waste Pumps Centrifugal 10 22 LV 6 1 10 5 6 64 m/hr @22 Bm CS 1.8 1.1 1.0 1.0 1.0 Carbon Capture NE P 1 19 Chemical Sewer Tank Pump Centrifugal 8 11 LV 5 5 5 6.5 0 10 5 5 85 46 m/hr @15 m/h	-		_		_	-	1	· ·	-			+ +			-	+	+		-							<del> </del>		-				
Carbon Capture   NE   P   1   19   Chemical Sever Tank Pump   Centrifugal   8   11   LV   5   N   N   N   N   N   N   N   N   N	· · · · · · · · · · · · · · · · · · ·				_		1			02		-			$\overline{}$	+	+ '		26	+	$\vdash$			_				-				1 1 unity is a Spare for in Transfer Purity
Carbon Capture NE P 1 1 68 A8 CC Unit Condensate Pumps Centrifugal 02 501 575 MV 301 5.5 41 10 5.5 2120 m³hr @44.6m CS / SS impeter 2.4 1.1 1.0 2.0 Carbon Capture NE P 1 08 A-D Direct Contact Cooler Pumps Centrifugal 02 501 575 MV 301 5.5 41 10 5.5 2120 m³hr @61.4m CS 4.0 12 1.5 5.5 Carbon Capture NE P 1 1 09 A/B Acid Wash Pumps Centrifugal 02 50 1200 MV 318 0.7 4 6 10 5.5 420 m³hr @61.4m CS 4.0 12 1.5 5.5 Carbon Capture NE P 1 1 10 A/B Water Wash Pumps Centrifugal 02 50 1200 MV 318 0.7 4 6 10 5.5 4205 m³hr @34.9m 316.SS 5.0 1.7 1.2 11.0 Carbon Capture NE P 0 28 A/B Fresh Amine Transfer Pumps Centrifugal 3 5.5 LV 0 1 1 2.2 LV 0 1 1 2.5 LV 0 1 1 1 1 1 2.5 LV 0 1 1 1 1 1 2.5 LV 0 1 1 1 1 2.5 LV 0 1 1 1 1 1 2.5 LV 0 1 1 1 1 1 2.5 LV 0 1 1 1 1 2.5 LV 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-		_		+		1	· · · · · · · · · · · · · · · · · · ·			_	-	_		$\dashv$	1	1									<b>!</b>						
Carbon Capture NE P 1 09 A/B Acid Wash Pumps Centrifugal 02 81 180 LV 49 7.4 85 10 -5 1195 m²/hr @18.7m 316.SS 3.5 1.0 1.0 6.0 Carbon Capture NE P 1 10 A/B Water Wash Pumps Centrifugal 02 530 1200 MV 318 0.7 46 10 -5 4205 m²/hr @34.9m 316.SS 5.0 1.7 1.2 11.0 Carbon Capture NE P 0 28 A/B Fresh Amine Transfer Pumps Centrifugal 3 5.5 LV 0 1 2.2 LV 0 1 1 2.5 3 5 -5 28 m²/hr @22.8m 316.SS 1.8 0.8 0.7 0.6 Carbon Capture NE P 1 25 IX Amine Drain Pump Centrifugal 3 6 45 LV 0 1 8.8 8 85 10 -5 118 m²/hr @44.3m 316.SS 2.1 0.8 0.8 0.6 Carbon Capture NE P 1 26 Amine Drain Pump Centrifugal 10 15 LV 0 1 4.4 110 10 -5 118 m²/hr @44.7m 316.SS 2.1 0.8 0.8 0.5 Carbon Capture NE P 1 27 IX Transfer Pump Centrifugal 2 27 37 LV 16 8.9 110 -5 120 m²/hr @60.8m 316.SS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 27 IX Transfer Pump Centrifugal 2 27 37 LV 16 8.9 110 -5 120 m²/hr @60.8m 316.SS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 21 A/B Thermal Recisimer NO. 1 M/P Condensate Pumps Centrifugal 2 2 7.4 LV 1 22 22 25 25 FV 27 -5 270 1 m²/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 22 A/B M/P Condensate Pumps Centrifugal 2 7.4 LV 1 22 22 25 D. FV 27 -5 270 1 m²/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 22 A/B M/P Condensate Pumps Centrifugal 2 7.4 LV 1 22 22 25 D. FV 27 -5 270 1 m²/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 22 A/B M/P Condensate Pumps Centrifugal 2 7.4 LV 1 22 25 25 FV 27 -5 270 1 m²/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 22 A/B M/P Condensate Pumps Centrifugal 2 7.4 LV 1 2 22 25 25 FV 27 -5 270 1 m²/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 22 A/B M/P Condensate Pumps Centrifugal 2 7.4 LV 1 1 22 25 25 D. FV 27 -5 270 1 m²/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 22 A/B M/P Condensate Pumps Centrifugal 2 7.4 LV 1 1 22 2 25 D. FV 27 -5 270 1 m²/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 1 22 A/B M/P Condensate Pumps Centrifugal 2 7.4 LV 1 1 22 2 25 D. FV 27 -5 270 1 m²/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 1 22 A/B M/P Condensate Pumps Centrifugal 2 7.4 LV 1	Carbon Capture	NE	Р	1	18	A/B		CC Unit Condensate Pumps	Centrifugal		75	150	LV	75		7.5		8.5	50			10	-5 160	355	_		CS / SS Impeller	2.4	1.1	1.0	2.0	
Carbon Capture NE P 1 10 AB Water Wash Pumps Centrifugal 02 530 1200 MV 318 0.7 46 10 -5 4205 m³/hr @34.9m 316.SS 5.0 1.7 1.2 11.0 Carbon Capture NE P 0 28 A/B Fresh Amine Transfer Pumps Centrifugal 3 5.5 LV 0 22 25 25 35 -5 28 m³/hr @22.8m 316.SS 1.8 0.8 0.7 0.6 Carbon Capture NE P 1 25 IX Amine Pump Centrifugal 1 22 LV 0 1 1 25 IX Amine Pump Centrifugal 3 6 45 LV 0 8.8 BS 10 -5 118 m²/hr @74.3m 316.SS 2.1 0.8 0.8 0.6 Carbon Capture NE P 1 26 Amine Drain Pump Centrifugal 1 10 15 LV 0 1 4.4 160 10 -5 43 m³/hr @44.7m 316.SS 2.1 0.8 0.8 0.6 Carbon Capture NE P 1 27 Carbon Capture NE P 1 27 Carbon Capture NE P 1 27 AB Thermal Reclaimer NO.1 MP Condensate Pumps Centrifugal 4 11 LV 2 2 22 25 Express FV 27 -5 270 10 m³/hr @41.7m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 22 A/B Thermal Reclaimer NO.2 MP Condensate Pumps Centrifugal 2 7.4 LV 1 22 25 25 FV 27 -5 270 1 m³/hr @41.7m CS 1.8 0.9 0.8 0.5 MP Condensate Pumps Centrifugal 2 7.4 LV 1 2 2 2 2 2 2 50 FV 27 -5 270 1 m³/hr @41.7m CS 1.8 0.9 0.8 0.5 MP Condensate Pumps Centrifugal 2 7.4 LV 1 1 22 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2				_	_	-		ļ			_	+ +	_						-							<b>!</b>		-				
Carbon Capture NE P 0 28 A/B Fresh Amine Transfer Pumps Centrifugal 3 5.5 LV 0 1 2.2 LV 0 1 1 25 LV 0 1 2 LV 0 1 1 25 LV 0 1 2 LV 0 1 LV 0 LV 0	-	<del>                                     </del>		1	+		1	· ·	-		_	+ +				+	+			_	_			+	_							
Carbon Capture NE P 0 29	· · · · · · · · · · · · · · · · · · ·		_		_		1	<u> </u>		02	+	-			_	+	_				$\vdash$					<del> </del>		-				+
Carbon Capture NE P 1 25    IX Amine Pump				+	_	-	+		-		1	-	_		+	+	+					+						-				
Carbon Capture NE P 1 27	· · · · · · · · · · · · · · · · · · ·		_		+			· · · · · · · · · · · · · · · · · · ·			36				_	1	_							_	_	1		-				
Carbon Capture NE P 1 21 A/B Thermal Reclaimer NO.1 MP Condensate Pumps Centrifugal 4 11 LV 2 22 250 FV 27 -5 270 10 m³/hr @21m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 22 A/B Thermal Reclaimer NO.2 Centrifugal 2 7.4 LV 1 22 250 FV 27 -5 270 1 m³/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 23 A/B Thermal Reclaimer NO.3 Centrifugal 2 7.4 LV 1 22 250 FV 27 -5 270 1 m³/hr @19.8m CS 1.8 0.9 0.8 0.5 Carbon Capture NE P 1 23 A/B Thermal Reclaimer NO.3 Centrifugal 2 7.4 LV 1 22 250 FV 27 -5 270 2 m³/hr @19.7m CS 1.8 0.9 0.8 0.5	Carbon Capture	NE	Р	1	26			Amine Drain Pump	Centrifugal		10	15	LV	0			4.4		160	)		10	-5	43	m³/hr	@49.7m	316 SS	1.8	0.9	0.8	0.5	
Carbon Capture NE P 1 21 A/B MP Condensate Pumps Certiflugal 4 11 LV 2 2 250 FV 27 -5 270 10 m²/nr @21ml CS 1.6 0.9 0.8 0.5  Carbon Capture NE P 1 22 A/B Thermal Reclaimer NO. 2 Centrifugal 2 7.4 LV 1 22 250 FV 27 -5 270 1 m³/nr @19.8m CS 1.8 0.9 0.8 0.5  Carbon Capture NE P 1 23 A/B Thermal Reclaimer NO. 3 Centrifugal 2 7.4 LV 1 22 250 FV 27 -5 270 2 m³/br @19.7m CS 1.8 0.9 0.8 0.5	Carbon Capture	NE	-	+	27			-	Centrifugal		27	37	LV	16			+		110	)		10	-5	90	m³/hr	@60.8m	316 SS	1.8	1.1	1.0	1.1	
Carbon Capture NF P 1 22 A/B MP Condensate Pumps Certificial 2 7.4 LV 1 22 250 FV 27 -5 270 1 m/nr @19.011 CS 1.0 0.9 0.0 0.5  Carbon Capture NF P 1 23 A/B Thermal Reclaimer NO.3 Centrifugal 2 7.4 LV 1 22 250 FV 27 -5 270 2 m <sup>3</sup> / <sub>12</sub> @19.7m CS 1.8 0.9 0.8 0.5	Carbon Capture	NE	Р	1	21	A/B		MP Condensate Pumps	Centrifugal		4	11	LV	2			22		250	)	FV	27	-5 270	10	m³/hr	@21m	cs	1.8	0.9	0.8	0.5	
Carbon Cantura NF P 1 23 A/B Thermal Reclaimer NO.3 Centrifugal 2 7.4 LV 1 22 250 EV 27 .5 270 2 m <sup>3</sup> br @19.7m CS 1.8 0.9 0.8 0.5	Carbon Capture	NE	Р	1	22	A/B			Centrifugal		2	7.4	LV	1			22		250	)	FV	27	-5 270	1	m³/hr	@19.8m	CS	1.8	0.9	0.8	0.5	
	Carbon Capture	NE	Р	1	23	A/B		Thermal Reclaimer NO. 3	Centrifugal		2	7.4	LV	1			22		250	)	FV	27	-5 270	2	m³/hr	@19.7m	CS	1.8	0.9	0.8	0.5	
Filters Filters	Filters																															





PROJECT No.
PROJECT NAME
LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE 181869-0001-T-EM-MEL-AAA-00-00003

ONSHORE PLANT - OPTIMISATION - BROCHURE EFFICIENCY REBOILER

A01

OCTOBER 2017

PLANT AREA		l	EQUIPM	MENT NU	IMBER			ITEM DESCRIPTION	TYPE	PFD Number		ELI	ECTRICA	L POWE	ER			RATING SSURE		OPERAT			SIGN SSURE	TEM	SIGN IPER- URE	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DII	MENSIC	ONS	WEIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (kW)	DUTY - INTERMITTENT (KW)	DUTY - STANDBY (KW)	ĝ.	NORMAL (barg)	MAX (barg)		. 1 6	MIN (barg)	MAX (barg)	(°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	
Carbon Capture	NE		S	1	04	A/B		Amine Filter	Cartridge	02	0	0	n/a	n/a				7.1		40	_		12	-5	85	118	m3/hr		316L SS		0.5	<del>                                     </del>	3	99% removal > 10micron
Carbon Capture	NE		S	1	08			Amine Drain Filter	Cartridge		0	0	n/a	n/a				3.6		40	_		7	-5	160	33	m3/hr		316L SS		0.3	1	3	99% removal > 10micron 99.999% removal > 0.3micron
Compression	NE		S	1	02			CO <sub>2</sub> Dehydration Filter Coalescer	Disposable Catridge	03	0	0	n/a	n/a			3	37.9		36	5		47	-5	160	3186	m3/hr		316L SS		2.7	8.1	70.4	Alternative DT= -79°C for Rapid Depressurisation
Tanks																																		
Carbon Capture	NE		Т	1	01			Lean Amine Tank	Vertical - API 650	02	0	0	n/a	n/a			A	Atm		Amt	b		0.15	-5	85	3187	m <sup>3</sup>		316L SS		14.2	22.0		* Pressure at top is 0.04 barg (vent connected to absorber)  * Double walled tank  * Lined carbon steel could be considered as a lower cost alternative
Carbon Capture	NE		Т	0	03			Fresh Amine Tank	Vertical - API 620		0	0	n/a	n/a									0.2	-5	85	6516	m <sup>3</sup>		316L SS		20.0			* Pressure at top is 0.04 barg (vent connected to absorber) * Dip Tubes * Sized for 5 trains
Carbon Capture	NE		T	1	07		<u> </u>	Amine Drain Tank	Horizontal		0		_	n/a					+				1	-5	160	106	m <sup>3</sup>		316L SS	9.0			++	Underground Horizontal Tank
Carbon Capture	NE		T	1	80		-	Degraded Amine Drain Tank	Horizontal		0	0	n/a	n/a	+	-+	0	0.06	+	20	'	-0.5	1	-5	160	25	m <sup>3</sup>		316L SS	5.8	2.4	<del>                                     </del>	+	Underground Horizontal Tank. Includes a mixer.
Carbon Capture	NE		Т	0	09			Waste Wash Water Tank	Vertical		0	0	n/a	n/a			A	Atm		Amt	b		ATM	-5	85	13512	m <sup>3</sup>		CS + 3mm CA		26.7	24.1		Sized for 5 trains
Carbon Capture	NE		T	0	15			Amine Maintenance Tank	Vertical		0	0	n/a	n/a				Atm		Amt			ATM	-5	85	6400	m3		316L SS		26.0	-		2.0 Sized to hold inventory of 1 train during maintenance
Carbon Capture	NE NE		T T	1	10 14			Chemical Sewer Tank	Horizontal		0	0	n/a	n/a	-	-		Atm Atm	+	Amb	_	-	ATM	-5	100	106	m <sup>3</sup>		CS Lined	9.0	3.9 4.4	_	105.6	Underground Horizontal Tank
Carbon Capture	INE		'	1	14			Thermal Reclaimer No 1 Feed Tank	Vertical		0	J J	n/a	n/a	-+	$\dashv$	-   -	AUII	+	Aint		$\vdash$	0.29	-5	85	103	m <sup>3</sup>		316L SS		4.4	6.8	<u> </u>	Pressure at top = 0.04 barg (Vent connected to Absorber)
Packages																																		
Carbon Capture	NE		U	1	03			Thermal Reclaimer Unit		02	11	15	LV	7								FV	3.5	-5	335	93	m³/hr		316L SS	38.7	19.3	25.0		
Carbon Capture	NE		U	1	15	A/B		Thermal Reclaimer Vacuum Packages			5	11	LV	3			-	0.1		35	5	FV	3.5	-5	85 / 170	93	m³/hr		316L SS				3.0	
Carbon Capture	NE		U	1	04			Ion Exchange Package		02	7	8	LV	4				_		+						6	m <sup>3</sup> /hr		-	5.8	5.8	5.0	)	
Drums and Vessels																																		
Carbon Capture	NE		٧	1	06			Direct Contact Cooler	Rectangular Tower	02	0	0	n/a	n/a			0.	.063		70	)		0.085	-5	85	254	T/hr (CO <sub>2</sub> )		Lined Concrete 304SS Internals	18.1	17.0	28.2	2	Column lining design temperature 120°C which could be subject to 110°C flue gas during start-up Scale up using flue gas flow rate: refer to 181869-0001-T-EM-CAL-AAA-00-00004 rev A02
Carbon Capture	NE		٧	1	07			CO <sub>2</sub> Absorber	Rectangular Tower	02	0	0	n/a	n/a			0.	.026		30	)		0.085	-5	85	254	T/hr (CO <sub>2</sub> )		Lined Concrete 304/316SS Internals	34.0	17.0	64.3	3	High efficiency mist eliminator at the top of the water wash Knit mesh mist eliminator at the top of acid wash section High quality gravity distributor Leak & splash proof chimney tray Structured packing Shoepentouter inlet devices (two off)
Carbon Capture	NE		٧	1	08			Amine Stripper	Vertical	02	0	0	n/a	n/a				1		122.	.3		3.5	-5	160	228	T/hr (CO <sub>2</sub> )		CS with 316L Cladding		9.6	34.6	261.0	* Top =dia 5.9m, Middle = dia 10m, Top = dia 8m.  * Upper rectification: predistributor, distributor (with chimney tray), splash plate, demister mat  * Stripping: predistributor, distributor (with chimney tray), demisters  * Structured packing
Carbon Capture	NE		٧	1	09			Amine Reflux Drum	Vertical	02	0	0	n/a	n/a				1		26.3	3		3.5	-5	105	228	T/hr (CO <sub>2</sub> )		316L SS		4.5	8.0	31.0	* Half open pipe inlet device * Mesh * Mist Eliminator
Carbon Capture	NE		٧	1	21			Vent KO Drum	Horizontal		0	0	n/a	n/a	$\dashv$	_		$\perp$	$\perp$	+		FV	-	-79	160	15	m <sup>3</sup>		316L SS		1.9	_	2.8	Kept pressurised with Instrument Air
Carbon Capture  Carbon Capture	NE NE		V	1	28			CC Unit Condensate Drum  Thermal Reclaimer Column No 1	Vertical Vertical		0	0	n/a n/a	n/a n/a								FV		-5 -5	160	6	m <sup>3</sup>		CS + 3mm CA 316L SS		0.9			Includes inlet hood and wear plate  * Packed section  * Predistribution, distributor (with chimney tray)  * Vane collector  * Structured packing
Carbon Capture	NE		V	1	29			Thermal Reclaimer Column No 2	Vertical		0	0	n/a	n/a								FV	3.5	-5	215	8	m <sup>3</sup>		316L SS		1.0	9.4	1 2.2	Structured packing Packed section Predistribution, distributor (with chimney tray) Vane collector Structured packing
Carbon Capture	NE		٧	1	30			Thermal Reclaimer Column No 3	Vertical		0	0	n/a	n/a								FV	3.5	-5	335	11	m³		316L SS		1.2	9.1	2.7	Packed section Predistribution, distributor (with chimney tray) Vane collector Structured packing
Carbon Capture	NE		V	0	33			Instrument Air Buffer Vessel	Vertical		0	0	n/a	n/a			8	8.5		25	i		10	-5	85				316L SS		3.4	10.1	23.8	
																_		$\perp$		_														
Electrical Equipment								Low Voltago Equipment																										
Carbon Capture	NE	-	ESG	1	01			Low Voltage Equipment  LV Switchboard			342	446.9	LV	205	$\dashv$	$\dashv$	-+	+	+	+		$\vdash$	+			<del>                                     </del>			<del>                                     </del>	-	-	<del>                                     </del>	++-	
Carbon Capture	NE		ESG	1	02			LV Emergency Switchboard			147	-	LV	88				$\vdash$								1							1	
								Medium Voltage Equipment							[	[																	$\bot$	
Carbon Capture	NE		ESG	1	13			MV Switchboard				l l	MV	n/a	I	I		1	I			I				l	1		]	l	l	l	1	I





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PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00003

PLANT AF	REA			EQUIF	MENT	NUMBE	:R		ITEM DESCRIPTION	TYPE	PFD Number		ELI	ECTRICA	AL POW	ER		PERAT PRESSU			ERATIN PERATU		DES PRESS		DESIG TEMPE ATUR	R-	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or $\Delta P$ (Per Unit)	MATERIAL OF CONSTRUCTION	D	IMENS	IONS	,	WEIGH	нт	REMARKS
		ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (KW)	DUTY - INTERMITTENT (kW) DUTY - STANDBY	MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)		MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)		DAT (tollies)	OPERATING (tonnes)	
Carbon Ca	pture	NE			1				Booster Fan VFD			1		MV	n/a																						Part of K-101 Supply
Buildings																																					
Facilitie	s	NE		BLD	1	08			Carbon Capture Electrical Substation			4	4	LV	n/a			+ve		10		40	N/A	N/A	N/A	N/A	1350	m <sup>3</sup>			25.0	12.0	) 4	4.5			Height to Eaves
																														·							



# Attachment 2.2.2 – Brochure Efficiency Reboiler Case 2.4 GJ/tonne CO<sub>2</sub> case



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A01

OCTOBER 2017

																										BARE HEAT	OF NOI					
PLANT AREA		EQ	UIPMEN	T NUMB	ER		ITEM DESCRIPTION	TYPE	PFD Number		ELI	ECTRICAL	POWER			PERATING RESSURE		PERATIN		DESIG PRESS		TEMPI ATUR	ER-	DUTY (Per Unit)	UNITS	TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DIMEN	NSIONS		WEIGHT	REMARKS
	ASSET CODE	AKEA/UNII CODE		NIANI PONDILICAN	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	REDUNDANCY TRIM OR AUX ELEC FOLIDMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)		CCS STANDBY (kW)  DUTY -	DUTY - STANDBY (kW)	MIN (barg)	NORMAL (barg) MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-Over (m)	Width Of DIA (m)	Height-OVL / TT (m)	DRY (tonnes) OPERATING (tonnes)	
Steam Generation Equ	ipment																															
Power	NE		3	1 0	1		Heat Recovery Steam Generator	Horizontal Drum	01	0	0	n/a	n/a			173.3		647.6			190	-5	600	600718	kW		CS (TP409 / T91 / T22 on high temp side)	0.0 2	5.0 3	31.0		Includes SCR catalyst, CO calayst, and Ammonia System
Power	NE		3	1 0	2		Auxiliary Boiler	Package		112	167	LV	n/a			7		220			10	-5	250	23	T/hr		CS (SA 192 Tubes)	8.3	4.3	4.7 1	103 151.0	Assume 1 Auxiliary Boiler per Train
-													_																			
Compression  Compression	NE	-	5	1 0	1		CO <sub>2</sub> Compressor	Centrifugal	03	24297	27000	MV	0			See Pkg	Below															Part of Package U-101 Motor sizing includes 10% API 617 Margin
Stack																																
Power	NE	_   -	)	1 0	1		Stack	Self Supporting	02	0	0	n/a	n/a			0.013		87.77				-5	750	3551	T/hr		CS - outer 316Ti - liner	1	0.0	90.0		Includes baseplate, anchor bolting, inner liner, outer shell, top cover, insulation, Flue Gas Inlet, Access/cleaning doors, condensation drain, ladders, platforms, AWLs, sample points, earth points, lifting lugs.
Power	NE		)	1 0			Auxiliary Boiler Stack	Self Supporting		0			n/a			0.02		184					750				CS		_	30.0		
Carbon Capture	NE	-	)	1 0	2		CO <sub>2</sub> Vent Stack	Self Supporting		0	0	n/a	n/a		-	0.72	$\vdash$	-10		_		-79	250	229306	kg/hr		316L SS	3	0" ;	30.0 4	4.5	Sch 10S
Heat Exchangers																																
Power	NE			1 0	2		Condenser (Water Cooled)	2 pass	01	0	0	n/a	n/a			-0.93		39.16		FV	1	-5	110	355487	kW	12055	304 SS Tubes 2	0.7	6.1	51	10.0	Including steam ejectors for vaccuum
Power	NE		<b>=</b>	1 0	3		Fuel Gas Heater	Shell & Tube	01	0	0	n/a	n/a			49.1 / 36.6		204.4 / 242.9		5	55 / 41	-5	310	10674	kW	500	CS / 316L SS Tube 1	2.4	0.9	2	23.9	Feedwater - Tubeside, Fuel Gas - Shellside
Power	NE			1 0	4		Gland Steam Condenser	Shell & Tube	01	0	0	n/a	n/a							FV/0 .	.45/34	-5	270 / 100	378	kW	14	SS Tubes	4.5	1.7	3.1 3	3.5	Part of Steam Turbine Supply
Power	NE		<b>=</b>	1 2	2		Electric Superheater	Electric Heater		0	4415	MV	n/a			49.1		70			55		310	2677	kW		316L SS / Alloy 800 pockets	5.5	1.3			Start Up Heater (sized to provide superheat only), includes pressure vessel, thyristor control panel (safe area)
Power	NE		=	1 2	3 /	A-E	GT + Generator Lube Oil Cooler	Plate & Frame		0	0	n/a	n/a			3		37.5			6	-5	50	1417	kW							Part of RS-101
Power	NE		<u> </u>	1 2	-+	A-F	GT Generator Cooler	Plate & Frame		0	0		n/a	1		3		37.5				-	50		kW				_			Part of R-101
Power	NE NE	_		1 2	_	A/B A/B	ST + Generator Lube Oil Cooler	Plate & Frame Plate & Frame		0	0	_	n/a n/a	+	1	3		37.5 37.5	-	-		_	50 50		kW kW			-	-	_		Part of RS-102 Part of R-102
Carbon Capture	NE	_		1 0	_	N/B	ST Generator Cooler Gas-Gas Heat Exchanger	Rotary	02	15	15		0	1	+	3		37.3				-	130		kW	13521	Weathering Steel 1	5.6 1	5.6	4.5 34	40.2	Purge and Scavenge Fan shall be part of this package
Carbon Capture	NE		<b>=</b>	1 0	9 A	/B/C	Lean / Rich Amine Exchanger	Welded Plate	02	0	0	n/a	n/a			5.1 / 5.9		122.3 / 111			18	-20	140	77734	kW	14457			3.5	18.0 40	00.0 430.0	e.g. Packinox type or equal. Duty was for 2 units - now split into 3 units Assume no change - would be minor difference but not affecting unit pricing
Carbon Capture	NE		≣	1 1	0 /	A-F	CO <sub>2</sub> Stripper Reboilers	Welded Plate	02	0	0	n/a	n/a			2.1		122.3			5	-5	150	30436	kW	1159	316L SS	2.8	1.8	10	0.6	
Carbon Capture	NE	_		1 1		A/B	Overhead Condenser	Welded Plate	02	0			n/a			2		26				_	160		kW	694		_	1.7		7.5	
Carbon Capture  Carbon Capture	NE NE			1 1	_	A/B	Wash Water Cooler  Lean Amine Cooler	Welded Plate Welded Plate	02 02	0	0	n/a n/a	n/a								10 12	_	85 85		kW kW	1555 574			_	3.8 13 2.0 29	3.7	
Carbon Capture	NE	_	_	1 1	_	/B/C	DCC Cooler	Plate & Frame	02		0	_	n/a									_	85		kW	1927		_		_		Duty was for 2 units - now split into 3 units
Carbon Capture	NE	_	_	1 1	_		CO <sub>2</sub> Vent Vapouriser	Inverted Kettle			0		n/a								10 / 27		_		kW	111		3.7	_	_	5.5	
Carbon Capture	NE		_	1 1	_	A/B	CC Unit Condensate Cooler  Thermal Registers Pro Heater	Plate & Frame			0	_	n/a										160		kW	315		4.3	1.3	_	6.1	
Carbon Capture  Carbon Capture	NE NE	_	-	1 1	_		Thermal Reclaimer Pre-Heater  IX Amine Cooler	Welded Plate Welded Plate		0	0	n/a n/a	n/a n/a	+	+					+		-	160 85	-	kW kW	60	316L SS 316L SS	1.0	1.0	_	4.6 0.6	
Carbon Capture	NE		_	1 2	_		IX Demin Water Cooler	Plate & Frame		0	_		n/a		t								160		kW	9			_		0.5	
Compression	NE			1 0	5		6th Stage Cooler	Shell & Tube	03	0	0	n/a	n/a			68.2		97.5 / 36						6216	kW		CS					Part of Package U-101
Compression	NE		≣	1 0	6		8th Stage Cooler	Shell & Tube	03	0	0	n/a	n/a			182.9		119.8 / 36						13200	kW		cs					Part of Package U-101
Compression	NE		≣	1 0	7		CO <sub>2</sub> Dehydration Electric Heater	Electric Heater	03	3488	3800	MV	0			37.4		22.9 / 290			47	-5	310	3488	kW		316L SS	5.6	1.6	2.4 4	4.0	Alternative DT= -79°C for Rapid Depressurisation
Compression	NE			1 0			Dehydration Cooler	Shell & Tube	03	0	0		n/a			36.6						_	310	-	kW	166	316L SS					Alternative DT= -79°C for Rapid Depressurisation
Cooling Plant Utilities	NE NE	_	=	1 2 0 1		A-T	Cooling Towers  47WT% Caustic Storage Tank Electric Heater	Wet Electric Heater		3	0 5		n/a n/a			3 15		13 / 23 ATM			6 ATM	-	50 85		kW	856 kg/s		-	0.2	25.0	0.0	Dimensions each cell
Instrumental'	ontrol Com																															
Instrumentation and C	NE NE		DC	1 0	6	A-H	Sampling	Analyser		8	8	LV	n/a														304 SS	2.0	2.0	3.0 2	2.3	Feedwater and Steam Sampling
Power	NE		С	1 0			Continuous Emissions Monitoring System (CEMS)	Analyser					n/a		1							$\dashv$	$\dashv$	+	$\dashv$			$\dashv$	$\dashv$		_	Measurements NOx, SO <sub>2</sub> , CO <sub>2</sub> , O <sub>2</sub> , H <sub>2</sub> O, °C, and flow
Natural Gas	NE	JI	)F	0 0	1		Natural Gas Metering	Orifice	01	0		LV	n/a		L	65-85	1		38		85	-5	85	158 I	lm³/s		Carbon Steel 3	35.0	6.0	6.9 12	22.7	Metering - size based on similar scope pipeline meter
Natural Gas	NE			0 0			Natural Gas Panel	Panel		1	1		n/a															_	_	_		Safe Area Panel
Natural Gas	NE	JI	С	0 0	1		Natural Gas Analyser House	l				LV	n/a		l				l l					1			l l	2.0	2.0	2.7 2	2.3	Analyser House and Speciality Bottle House





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181869

Thermal Power with CCS: Generic Business Case UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00003

PLANT AREA     PLANT AREA   P	7.2 0.8	(iii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiii) (iiiii) (iiii)	WEIGHT  (ounes)  122.7  0.7  2.3  31.5  31.5	Metering - size based on similar scope pipeline meter  Safe Area Panel  Analyser House and Speciality Bottle House  [CSS for whole Power + CCS chain controlled from single control room.]
Section Capture   NE   NE   NE   NE   NE   NE   NE   N	35.0 6.0 7.2 0.3 2.0 2.0 36.8 0.8	6.0 7.0 0.8 2.1 2.0 2.7 0.8 2.1	122.7 0.7 2.3	Metering - size based on similar scope pipeline meter  Safe Area Panel  Analyser House and Speciality Bottle House  [CSS for whole Power + CCS chain controlled from single control room.]
Compression   NE   JDF   0   02   CO2   Metering   Coriolis   03   0   LV   0   182.9   36   200   -5   100   1140   T/hr   315L.SS	7.2 0.4 2.0 2.0 36.8 0.8	0.8 2.1 2.0 2.7 0.8 2.1	0.7 2.3	Safe Area Panel Analyser House and Speciality Bottle House  [SS for whole Power + CCS chain controlled from single control room.]
Compression         NE         JDC         0         02         CC <sub>2</sub> Metering Analyser House         LV         LV         Image: Compression of the compression of	2.0 2.0 36.8 0.8	2.0 2.7 0.8 2.1	2.3	Analyser House and Speciality Bottle House  [5] ICSS for whole Power + CCS chain controlled from single control room.
Utilities   NE	36.8 0.8	0.8 2.1	<del>                                     </del>	5 ICSS for whole Power + CCS chain controlled from single control room.
Fans         V <td></td> <td></td> <td>31.5 31.5</td> <td></td>			31.5 31.5	
Carbon Capture         NE         K         1         01         Booster Fan         Axial         02         13122         13900         MV         0         1.013 / 1.093         87.8         87.8         3551         T/hr         Δ 0.08bar         Steel Plate           Carbon Capture         NE         KF         1         01         A-H         Booster Fan Motor Cooling Fans         Axial         24         60         LV         0         9	9.9 9.3	0.3 8.1		Price includes F&G and well as HIPPS
Carbon Capture         NE         K         1         01         Booster Fan         Axial         02         13122         13900         MV         0         1.0137         1.093         87.8         3551         T/hr         Δ 0.08bar         Steel Plate           Carbon Capture         NE         KF         1         01         A-H         Booster Fan Motor Cooling Fans         Axial         24         60         LV         0	9.9 9.3	0.3 8.1		
Carbon Capture         NE         KF         1         01         A-H         Booster Fan Motor Cooling Fans         Axial         24         60         LV         0           Carbon Capture         NE         KU         1         01         A/B         Booster Fan Lube Oil Skids         15         41         LV         15           Carbon Capture         NE         K         1         02         Damper Sealing Air Fan         Centrifugal         293         322         MV         0         150         m³/hr         800 mmWG         Weathering Stee           Carbon Capture         NE         K         1         03         Damper Purge & Scavenge Air Fans         Centrifugal         6         7.5         LV         6         1500         m³/hr         800 mmWG         Weathering Stee	5.5		111.4	
Carbon Capture         NE         KU         1         01         A/B         Booster Fan Lube Oil Skids         15         41         LV         15           Carbon Capture         NE         K         1         02         Damper Sealing Air Fan         Centrifugal         293         322         MV         0         0         MV         0         0         Weathering Stee           Carbon Capture         NE         K         1         03         Damper Purge & Scavenge Air Fans         Centrifugal         6         7.5         LV         6         1500         m³/hr         800 mmWG         Weathering Stee		0.0		Included in Booster Fans Supply
Carbon Capture         NE         K         1         02         Damper Sealing Air Fan         Centrifugal         293         322         MV         0         MI         MV         MV<		+		Included in Booster Fans Supply  Included in Booster Fans Supply
Carbon Capture NE K 1 03 Damper Purge & Scavenge Air Fans Centrifugal 6 7.5 LV 6 1500 m³/hr 800 mmWG Weathering Stee	el 4.0 2.2	2.2 3.2	10.7	Included in package with Gas Gas Heat Exchanger
		1.0 2.5	0.3	Included in package with Gas Gas Heat Exchanger
Cooling Plant NE EF 1 01 A-T Cooling Tower Fans Axial 2107 2600 MV 632 ATM 10 10 1-5 1578 T/hr				Total duty for CCGT + CCC
Mechanical Handling Equipment				
Power         NE         L         1         01         Gas Turbine Overhead Crane         Double Girder Gantry         0         164         LV         n/a         164				
Power         NE         L         1         02         Steam Turbine Overhead Crane         Double Girder Gantry         0         115         LV         n/a         115         -5         70         T         40m Span         CS				
Power NE L 1 03 Steam Turbine Auxiliary Crane Double Girder Gantry 0 30 LV n/a 20 5-5 16 T 10m Span CS				
Compression         NE         L         1         04         CO2 Compressor Overhead Crane         Single Girder         0         30         LV         n/a         20         -5         35         T         CS           Water Treatment         NE         L         0         0.5         Demin Plant Hoist         Single Girder         0         12         LV         n/a         10         -5         8         T         CS		+		
Water Treatment         NE         L         0         05         Demin Plant Hoist         Single Girder         0         12         LV         n/a         10         -5         8         T         CS           Water Treatment         NE         L         0         06         Waste Water Treatment Plant Hoist         Single Girder         0         12         LV         n/a         10         -5         8         T         CS	+ + -	+++	<del>                                     </del>	
Water frequirent         NE         L         0         07         Fire Fighting Pump Station Hoist         Single Girder         0         6         LV         n/a         6         -5         4         T         CS	++-	+		
Facilities         NE         L         0         08         Workshop building Crane         Single Girder         0         22         LV         n/a         21         -5         10         T         30m Span         CS				
Facilities         NE         L         0         09         A/B         Weighbridge         0         1         LV         n/a         1         -5         60         T         CS	20.0 3.0	3.0	12.5	
Mixer Thomas Deplainer Not Food Trail				
Carbon Capture         NE         M         1         14         Thermal Reclaimer No 1 Feed Tank Mixer         5         5         LV         5         Atm         Amb         0.29         -5         85         316L SS		0.5	0.4	
Carbon Capture         NE         M         1         08         Amine Degraded Tank Mixer         5         5         LV         5         0.06         20         1         -5         160         316L SS	0.5	0.5	0.4	
Pumps         NE         P         1         01         A/B         Condensate Pump         Centrifugal         01         426         950         MV         n/a         4         39.7         19         -5         90         574         T/hr         @36.92m         Chrome Steel	4.0 1.8	1.8 1.8	10.0	Provides pressure for LP Stage - i.e. Operates as LP Feedwater Pump
Power NE P 1 02 A/B HP Feedwater Pump Ring Section 01 5143 11400 MV n/a 250.5 147 400 -5 250 589 m³/hr @2438.4m Chrome Steel	$\rightarrow$		21.4	1 Totales pressure for Li Glage - i.e. Operates as LF Feedward Pump
Power         NE         P         1         03         A/B/C         IP Feedwater Pump         Ring Section         01         281         504         MV         n/a         58.5         143         -5         71         m³/hr         @548.6m         Chrome Steel				
Power         NE         P         1         11         A/B         LTE Recirculation Pump         Centrifugal         1         1.5         LV         n/a         4.023         104.4         -5         32         m³/hr         @1.2m         Chrome Steel		-	0.7	
Power         NE         P         1         12         A/B         Auxiliary Boiler Feedwater Pumps         Centrifugal         0         37         LV         n/a         14         7         105         10         -5         150         25         m³/hr         @75m         Chrome Steel			<del> </del>	
Power         NE         P         1         13         A/B         GT + Generator Lube Oil Pump         Centrifugal         LV         n/a				
Power         NE         P         1         14         A/B         GT Generator Control Oil Pump         Centrifugal         LV         n/a				
Power         NE         P         1         15         A/B         ST + Generator Lube Oil Pump         Centrifugal         0         0         n/a         6.5         40         248         m³/hr	$\perp$	$\perp$		Shaft Driven
Power         NE         P         1         17         A/B         ST Generator Control Oil Pump         Centrifugal         30         39         LV         n/a           Power         NE         P         1         17         A/B         ST Generator Control Oil Pump         Centrifugal         30         39         LV         n/a         10 <td>0.4</td> <td>44 :-</td> <td>1.0</td> <td>_</td>	0.4	44 :-	1.0	_
Power         NE         P         1         20         A/B         Clean Drains Return Pump         Centrifugal         26         60         LV         n/a         2.7         20         3.5         -5         85         316         m³/hr         @15.2m         CS           Cooling Plant         NE         P         1         16         A-F         Cooling Water Pump         Centrifugal         4984         6267         MV         1495         3         17.5         6         -5         85         12321         T/hr         @23.7m         CS	7.2 1.9	-		5 pumps operating, 1 spare
Cooling Plant NE P 1 10 A-F Cooling Water Pump Centinugal 494 6207 MV 1495 3 17.5 6 -5 65 12521 17/11 625.7111 CS  Carbon Capture NE P 1 04 A/B Absorber Feed Pumps Centrifugal 02 629 1400 MV 377 3.4 53 10 -5 2829 m <sup>3</sup> /hr @69.5m 316 SS			11.0	o pampo operating, i opere
Carbon Capture NE P 1 05 A/B Lean Amine Pumps Centrifugal 02 371 840 MV 222 4.1 122.4 10 -5 3042 m³/hr @39.3m 316 SS			9.1	
Carbon Capture NE P 1 06 A/B/C Rich Amine Pumps Centrifugal 02 711 1170 MV 427 5.6 41 13.8 -5 1417 m³/hr @129.4m 316 SS			13.0	3 x 50%
Carbon Capture NE P 1 07 A/B Stripper Reflux Pumps Centrifugal 02 21 60 LV 12 1 26 10 -5 78 m³/hr @61.1m 316 SS	1.8 1.1	1.1 1.0	1.1	1 Pump is a Spare for IX Transfer Pump
Carbon Capture         NE         P         0         17         A/B         Waste Wash Water Pumps         Centrifugal         10         22         LV         6         10         -5         64         m³/hr         @22.8m         CS	1.8 1.1	1.1 1.0	1.0	
Carbon Capture         NE         P         1         19         Chemical Sewer Tank Pump         Centrifugal         8         11         LV         5         10         -5         85         46         m³hr         @19.5m         316 SS				
Carbon Capture         NE         P         1         18         A/B         CC Unit Condensate Pumps         Centrifugal         68         150         LV         68         7.5         8.5         50         10         -5         160         320         m³/hr         @44.6m         CS/SS Impelle           Carbon Capture         NE         P         1         08         A-D         Direct Contact Cooler Pumps         Centrifugal         02         501         575         MV         301         5.5         41         10         -5         2120         m³/hr         @61.4m         CS			2.0	
Carbon Capture         NE         P         1         08         A-D         Direct Contact Cooler Pumps         Centrifugal         02         501         575         MV         301         5.5         41         10         -5         2120         m³/hr         @ 61.4m         CS           Carbon Capture         NE         P         1         09         A/B         Acid Wash Pumps         Centrifugal         02         81         180         LV         49         7.4         85         10         -5         1195         m³/hr         @ 18.7m         316 SS	4.0 1.2 3.5 1.0		5.5 6.0	
Carbon Capture NE P 1 09 A/B Mater Wash Pumps Centrifugal 02 530 1200 MV 318 0.7 46 10 -5 4205 m <sup>3</sup> /hr @34.9m 316 SS			11.0	
Carbon Capture         NE         P         0         28         A/B         Fresh Amine Transfer Pumps         Centrifugal         3         5.5         LV         0         2.2         25         35         -5         28         m³/hr         @22.8m         316 SS	1.8 0.8	-	0.6	
Carbon Capture         NE         P         0         29         Amine Container Pump         Centrifugal         1         2.2         LV         0         1         25         35         -5         20         m³/hr         @11.3m         316 SS	1.5 0.8		<del> </del>	
Carbon Capture NE P 1 25   IX Amine Pump   Centrifugal   36 45 LV 0   8.8   85   10 -5   118 m³/hr @74.3m   316 SS	2.1 0.8	0.8	0.6	



**EQUIPMENT LIST (MAJOR ITEMS)** 

ONSHORE PLANT - OPTIMISATION - BROCHURE EFFICIENCY REBOILER

**\*))** SNC·LAVALIN

PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00003

Power   NE	REMARKS
Controllage   1	
Secondary   Seco	
Control   Cont	
Control   Cont	
Control   Cont	
Mathematical Part	
Marker   M	
Section   Part	umps in operation at start-up
State   March   Marc	
Section   Sect	surised
Second Continue	
Part	
Profest   No.   1.   1.   1.   1.   1.   1.   1.	
Profest   No.   1.   1.   1.   1.   1.   1.   1.	
New   No.   No.	
Private   March   Ma	
Figure   No.   N	
Pase   No.   No.   Pase   No.	nent such as Lube Oil Consoles (Dims turbine only)
Part	t would be multi casing or multi shaft machine for s auxiliary equipment such as Lube Oil Consoles
New Note   Not	
New Note   Not	
Pewer   NE	
Carbon Capture NE S 1 1 04 AB Amine Filter Connidge 02 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
Centron Capture   NE   S   1   0.6   NE   S   NE   NE	s 100% > 3 micron and entrained liquids
Compression   NE   S   1   102   C.Q. Dehydration Filter Coatescer   Disposable Catridge   03   0   0   n/a   n/a   37.9   36   4.7   5   160   3186   mahr   3186. SS   2.2   8.1   70.4   40   9999/K removal > 0.3 micro   Alternative Dr 1990 Congression   NE   S   1   05   AB   C.Q. Dehydration Outlet Filter   Basket   03   0   0   n/a   n/a   36.6   36   4.7   5   100   2884   m3hr   316. SS   1.3   1.2   46.4   Alternative Dr 1990 Congression   NE   S   1   0   AB   C.Q. Dehydration Regineration Giss   Basket   0.3   0   0   n/a   n/a   36.6   36   4.7   5   310   1162   m3hr   316. SS   2.3   2.6   21.3   Alternative Dr 1990 Congression   NE   S   1   0   AD   Cooling Water Filters   Basket   0.3   0   0   n/a   n/a   36.6   36   4.7   5   55   20534   7/hr   C.S.   4.0   7.0   3.5   11.0   AD   Cooling Water Filters   Basket   0.3   0   n/a   n/a   1.0   1.75   1.	
Compression   NE   S   1   02   No. Dehydration from Categories   Use production   Ne   S   1   05   AB   CO.Dehydration Collect Filter   Basket   03   0   0   na   na   na   36.6   36   47   -5   100   2884   m3hr   316.8   2.3   2.6   40.4   Abernative Dir -97°C for Rapid Degree   Compression   NE   S   1   09   AB   CO.Dehydration Regeneration Gas   Basket   03   0   0   na   na   na   36.6   36   47   -5   310   1102   m3hr   316.8   2.3   2.6   21.3   Abernative Dir -97°C for Rapid Degree   Compression   NE   S   1   09   AB   Co.Dehydration Regeneration Gas   Basket   03   0   0   na   na   na   10   17.5   12   -5   85   20534   Thr   CS   4.0   7.0   3.5   11.0   Abortation End   Three Press   Abernative Dir -97°C for Rapid Degree   Co.Dehydration Regeneration Gas   Basket   0   0   na   na   na   10   17.5   12   -5   85   20534   Thr   CS   4.0   7.0   3.5   11.0   Abortation Degree   Co.Dehydration Regeneration Gas   Abernative Dir -97°C for Rapid Degree   Co.Dehydration Regeneration Gas   Co.Dehyd	
Compression   NE   S   1   00   AB   College   Colleg	
Configuration   Ne	r Rapid Depressurisation
Tanks         Image: Composition Capture of Carbon Capture of Carbon Capture of NE or T of 1 of Carbon Capture of NE or T of 1 of Carbon Capture of NE or T of 1 of Carbon Capture of NE or T of 1 of Carbon Capture of NE or T of 1 of Carbon Capture of NE or T of 1 of Carbon Capture of NE or T of 1 of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of 1 of S of Carbon Capture of NE or T of S of Carbon Capture of NE or T of S of Carbon Capture of NE or T of S of Carbon Capture of NE or T of S of Carbon Capture of NE or T of S of Carbon Capture of NE or T of S of Carbon Capture of NE or T of S of Carb	r Rapid Depressurisation
Carbon Capture NE T 1 01 NE Lean Amine Tank Vertical - API 650 02 0 0 n/a n/a Am Amb 0 0.15 -5 85 3187 m³ 316LSS 14.2 22.0 **Pressure at top is 0.04 barg (vent Double walled be considered and No. 1 1 0.05 0.05 85 3187 m³ 316LSS 14.2 22.0 **Pressure at top is 0.04 barg (vent Double walled be considered and No. 1 1 0.05 0.05 85 0.05 0.05 0.05 0.05 0.05 0	s)
Carbon Capture NE T 1 01 NE Lean Amine Tank Vertical - API 650 02 0 0 n/a n/a NA	
Carbon Capture NE T 0 03 Fresh Amine Tank Vertical - API 620 0 0 0 n/a n/a	barg (vent connected to absorber)
Carbon Capture NE T 1 07 Amine Drain Tank Horizontal 0 0 0 n/a n/a 0 0 0 0 0 n/a n/a 0 0 0 0 0 n/a n/a 0 0 0 0 0 0 n/a n/a 0 0 0 0 0 n/a n/a 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
Carbon Capture NE T 0 09 Waste Wash Water Tank Vertical 0 0 n/a n/a Atm Amb Amb ATM -5 85 13512 m³ CS + 3mm CA 26.7 24.1 Sized for 5 trains  Carbon Capture NE T 0 15 Amine Maintenance Tank Vertical 0 0 n/a n/a Atm Amb ATM -5 85 6400 m³ 316LSS 26.0 12.2 133 6,562.0 Sized to hold inventory of 1 train du Carbon Capture NE T 1 1 10 Chemical Sewer Tank Horizontal 0 0 n/a n/a Atm Amb Amb ATM -5 100 106 m³ CS Lined 9.0 3.9 105.6 Underground Horizontal Tank Carbon Capture NE T 1 1 14 Thermal Reclaimer No 1 Feed Tank Vertical 0 0 n/a n/a Atm Amb 0 0.29 -5 85 103 m³ 316LSS 4.4 6.8 Pressure at top = 0.04 barg (Vent of	iank
Carbon Capture         NE         T         0         15         Amine Maintenance Tank         Vertical         0         0         n/a         n/a         Atm         Amb         ATM         -5         85         6400         m3         316LSS         26.0         12.2         133         6,562.0         Sized to hold inventory of 1 train due           Carbon Capture         NE         T         1         10         Chemical Sewer Tank         Horizontal         0         0         n/a         Atm         Amb         ATM         -5         100         106         m³         CS Lined         9.0         3.9         105.6         Underground Horizontal Tank           Carbon Capture         NE         T         1         14         Thermal Reclaimer No 1 Feed Tank         Vertical         0         0         n/a         Atm         Amb         0.29         -5         85         103         m³         316LSS         4.4         6.8         Pressure at top = 0.04 barg (Vent of the Companies)	ank. Includes a mixer.
Carbon Capture         NE         T         1         10         Chemical Sewer Tank         Horizontal         0         0         n/a         n/a         Atm         Amb         ATM         -5         100         106         m³         CS Lined         9.0         3.9         105.6         Underground Horizontal Tank           Carbon Capture         NE         T         1         14         Thermal Reclaimer No 1 Feed Tank         Vertical         0         0         n/a         n/a         Atm         Amb         0.29         -5         85         103         m³         316LSS         4.4         6.8         Pressure at top = 0.04 barg (Vent or controlled)	
Carbon Capture NE T 1 14 Thermal Reclaimer No 1 Feed Tank Vertical 0 0 n/a n/a Atm Amb 0.29 -5 85 103 m³ 316L SS 4.4 6.8 Pressure at top = 0.04 barg (Vent or	1 train during maintenance
Ominies INC I U U ATID ATID ATID ATID ATID ATID ATID ATID	
Utilities         NE         T         0         0.4         Demineralised Water Tank         Vertical - API 650         0         0         n/a         Atm         Amb         Am         -5         85         7000         m³         CS Lined         22.5         20.0         Sized for 5 trains	is - resized for 5



**\*))** SNC · LAVALIN

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DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00003

A01

OCTOBER 2017

PLANT AREA		E	QUIPM	ENT NU	MBER		ITEM DESCRIPTION	ТҮРЕ	PFD Number		ELE	CTRICAL P	OWER			ERATING ESSURE		OPERA TEMPER			SIGN	DESI TEMF ATU	PER-	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	MENSIO	NS	W	EIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV) CCS STANDBY (KW)	1.5	DUTY - STANDBY (KW)	MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C) NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Utilities	NE		T	0	06		Raw / Fire Water Tank	Vertical - API 650		0	0	n/a n/a				Atm		Am	_		Atm	-5	85	75500	m <sup>3</sup>		CS Lined		70.0	20.0	)		Sized for 5 trains
Utilities Utilities	NE NE		T T	0	11 12		47WT% Caustic Storage Tank	Vertical - API 650		0	0	n/a n/a				Atm Atm		Am Am		-	ATM ATM	-5 -5	85 85	1500 100	m <sup>3</sup>		CS Lined CS + 6mm CA		12.0 4.0	14.0 8.0	_	-	Sized for 7 days storage
Utilities	NE NE		T	0	02		Concentrated Sulphuric Acid Tank  Towns Water Break Tank	Vertical - API 650 Vertical - API 650		0	0	n/a n/a				Atm		Am		1	ATM	-5 -5	85	208	m <sup>3</sup>		CS + 6mm CA  CS Lined		6.0		_	+	MOC: In accordance with NACE SP0294. Sized for 7 days storage
Packages																																	
Power	NE		U	1	13		Anti Icing Skid					LV n/s				_		_	_	+		$\vdash$									<del> </del>	+	
Power	NE NE		U	1	14 07		CO <sub>2</sub> / N <sub>2</sub> Storage Skid  Condensate Polishing Plant		01	0	0	n/a n/a LV n/a			$\vdash$	10		30	,	+	19	90		311	T/hr		316L SS				-	-	Fire Fighting for Gas Turbines  Polishing of Condensate Return from Carbon Capture Unit
Power	NE		U	1	09		HRSG Chemical Feed Skid	API 675 Pumps	01	2	5	LV n/s	_			10		20	_	1	12	-5	85	311	1/111		316L SS	8.0	3.0	2.7	7 7.0	1	Boiler Feedwater Dosing Chemicals - O2 Scavenger, Alkaline, Corrosion
Carbon Capture	NE		U	1	03		Thermal Reclaimer Unit	74 1 0.0 1 dilipo	02	11	15	LV 7			$\vdash$	-+	_	+	+	FV	3.5	-	335	93	m³/hr		316L SS	38.7	_		_	+	Inhibitor
Carbon Capture	NE		U	1	15	A/B	Thermal Reclaimer Vacuum			5	11	LV 3	+			-0.1	$\dashv$	35	,	FV	3.5		85 / 170	93	m³/hr		316L SS	50.1		20.0	3.0	+	†
						,,,,	Packages								$\vdash \vdash$	0.1		35		· ·	3.3	~	JU / 1/U				3101.33	<i>-</i> -				1	+
Carbon Capture  Compression	NE NE		U	1	04 01		Ion Exchange Package CO <sub>2</sub> Compression Package	Integral Geared	02 03	7 176	8 313.74	LV 4	_			0.2/183		12	3	+	200	-5	150	6 230	m <sup>3</sup> /hr T/hr		316L SS	5.8 25.0	5.8 18.0		360.0	-	+
Compression	NE		U	1	02		CO <sub>2</sub> Dehydration Package	Mole Sieve	03	0	0	n/a 0	_			37.9		12		+	47	-5	150	269	T/hr		316L SS	N/A	N/A	N/A	N/A	_	Equipment elsewhere - line item for price for design and mole sieve
Compression	NE		U	1	10		Tracer Dosing Package	API 675 Pumps		0	0.1	LV 0									200	-5	85	100	ppbv		316L SS	2.2	1.2		_	_	Addition to give CO <sub>2</sub> smell to allow leakage detection
Cooling Water	NE		U	0	11		Chemical Dosing Package	API 675 Pumps		33	37	LV n/a	а								12	-5	85					11.0	3.5	4.0	30.0		Cooling Water Dosing Chemicals
Water Treatment	NE		U	0	05		Water Treatment Plant			6267	8671.8	MV 376	60					20				-5	85	13844	m³/hr		Various	644.2	128.8				Includes CCGT + Ion Exchange + Waste Wash Water + Acid Wash Effluent Treatment
Utilities	NE		U	0	06	A/B/C	Instrument Air Compression Package	Centrifugal		1690	2700	MV n/a	a				8.5	20	)		10	-5	85	145	m³/min	FAD		8.1	2.4		22.7		3 x 50% machines Sized for Carbon Capture and CCGT (Refer to Utilities Schedule)
Utilities	NE		U	0	12		Demineralisation Package	RO + Ion Exchange		60	360	LV n/a	a											448	m³/hr			40.6	12.7				Sized for 5 trains
Utilities	NE		U	0	80		Ammonia Tanker Unloading			0	0	LV n/s	a							FV	9	-5	85				CS				0.8		
D d Wd.			_													_		_													-	-	
Drums and Vessels Power	NE		V	1	01		HP Steam Drum	Horizontal	01	0	0	n/a n/a	a			173.3		353	.9		206	-5	420				15NiCuMoNb5-6-4	17.0	1.9		130		Part of HRSG
Power	NE		V	1	02		IP Steam Drum	Horizontal	01	0	0	n/a n/a	_			36.6		245	_	1							cs				+	+	Part of HRSG
Power	NE		V	1	03		LP Steam Drum	Horizontal	01	0	0	n/a n/a	a			3.792		141	.7								cs						Part of HRSG
Power	NE		V	1	31		Oil / Water Separator	Horizontal		0	55	LV n/s	a	45										136	m³/hr		CS	2.0	2.0	2.0	2.2	_	
Power	NE		V	1	23		Blowdown Vessel / Tank	Vertical		0	0	n/a n/a				ATM		10		FV	3.5	-5	180	5	m <sup>3</sup>		CS		1.3		_	_	
Power	NE NE		V	1	27 05		Fuel Gas Scrubber Feedwater Tank	Vertical Horiz / Vertical	01	0	0	n/a n/a				48 3	65	1 25	_	+	85 8	-29 -5	55 200	2 659	m <sup>3</sup> T/hr		CS Alloy Steel	20.5	1.0 4.3		_	+	Including Deaerator
Power	NE		V	1	25	A/B	Flash Tanks (Start-Up & Shut Down)	Vertical	01	0	0	n/a n/a	_			1.3	_	57	_	+	7	-5	600	16	m <sup>3</sup>		Alloy Steel	20.5	2.0		3 18.5	+	Including Deaerator
Power	NE		V	1	26	A/B	Drain Vessel	Vertical		0	0	n/a n/a	_			1.3		57	_	+	7	-5	600	16	m m³		Alloy Steel		2.0		3 18.5	+	+
Power	NE		v	1	22		Instrument Air Buffer Vessel - CCGT	Vertical		0	0	n/a n/a	_			8.5	_	25		+	10	-5	85	90	m <sup>3</sup>		316L SS		3.2		+-	+	
Power	NE		v	1	24		Area Flash Drum	Vertical		0	0	n/a n/a	_			17		20	_	FV	19	-	_	6	m <sup>3</sup>		CS		1.4		3.4	_	+
Natural Gas	NE		V	0	04		Natural Gas Pig Receiver	Horizontal	01	0	0	n/a n/a			45		65	1	38	_	85	-29	55	158	Nm³/hr		cs	5.1	1.3		_		
Natural Gas	NE		V	0	32		Natural Gas Pig Launcher	Horizontal		0	0	n/a n/a	a		45		65	1	38		85	-29	55	158	Nm³/hr		cs	5.1	1.3	1.3	3 13.9		Located at NTS connection
Carbon Capture	NE		V	1	06		Direct Contact Cooler	Rectangular Tower	02	0	0	n/a n/a	a			0.063		70	)		0.085	-5	85	254	T/hr (CO <sub>2</sub> )		Lined Concrete 304SS Internals	18.1	17.0	28.2	2		Column lining design temperature 120°C which could be subject to 110°C flue gas during start-up Scale up using flue gas flow rate: refer to 181869-0001-T-EM-CAL-AAA-00-00004 rev A02
Carbon Capture	NE		V	1	07		CO <sub>2</sub> Absorber	Rectangular Tower	02	0	0	n/a n/a	a			0.026		30	)		0.085	-5	85	254	T/hr (CO <sub>2</sub> )		Lined Concrete 304/316SS Internals	34.0	17.0	64.3	3		* High efficiency mist eliminator at the top of the water wash  * Knit mesh mist eliminator at the top of acid wash section  * High quality gravity distributor  * Leak & splash proof chimney tray  * Structured packing  * Shoepentouter inlet devices (two off)  * Top office Op. Middle offs don Top office Re
Carbon Capture	NE		V	1	08		Amine Stripper	Vertical	02	0	0	n/a n/a	a			1		122	1.3		3.5	-5	160	228	T/hr (CO <sub>2</sub> )		CS with 316L Cladding		9.6	34.6	261.0	)	* Top =dia 5.9m, Middle = dia 10m, Top = dia 8m.  * Upper rectification: predistributor, distributor (with chimney tray), splash plate, demister mat  * Stripping: predistributor, distributor (with chimney tray), demisters  * Structured packing
Carbon Capture	NE		٧	1	09		Amine Reflux Drum	Vertical	02	0	0	n/a n/a	a			1		26.	3		3.5	-5	105	228	T/hr (CO <sub>2</sub> )		316L SS		4.5	8.0	31.0		* Half open pipe inlet device * Mesh * Mist Eliminator
Carbon Capture	NE		٧	1	21		Vent KO Drum	Horizontal		0	0	n/a n/a	a					+	+	FV	10	-79	160	15	m <sup>3</sup>		316L SS		1.9	4.5	5 2.8	+	* Mist Eliminator  Kept pressurised with Instrument Air
Carbon Capture	NE		٧	1	38		CC Unit Condensate Drum	Vertical		0	0	n/a n/a	_							FV	5	-5	160				CS + 3mm CA		2.6		_	+	Includes inlet hood and wear plate
Carbon Capture	NE		V	1	28		Thermal Reclaimer Column No 1	Vertical		0	0	n/a n/a	a							FV	3.5	-5	160	6	m <sup>3</sup>		316L SS		0.9	8.9	1.9		* Packed section * Predistribution, distributor (with chimney tray) * Vane collector * Structured packing



**\*))** SNC · LAVALIN

PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00003

PLANT AREA		E	QUIPME	NT NUM	IBER		ITEM DESCRIPTION	TYPE	PFD Number		ELECTR	ICAL PO	)WER		OPERAT PRESSU			PERATING IPERATU		DESIGN PRESSUI	N_   T	DESIGN EMPER- ATURE	-	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	MENSION	IS	WEIG	ЭНТ	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW) VOLTAGE (HV, MV,	CCS STANDBY (KW)	DUTY - INTERMITTENT (KW) DUTY - STANDBY	(kW) MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MAX (°C)	(a) North		m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Carbon Capture	NE		v	1	29		Thermal Reclaimer Column No 2	Vertical		0	0 n/a									FV 3	3.5 -	5 21	15 8	m³		316L SS		1.0	9.4	2.2		Predistribution, distributor (with chimney tray) Vane collector Structured packing
Carbon Capture	NE		٧	1	30		Thermal Reclaimer Column No 3	Vertical		0	0 n/a	a n/a								FV 3	3.5 -	5 33	35 11	m <sup>3</sup>		316L SS		1.2	9.1	2.7		Predistribution, distributor (with chimney tray) Vane collector Structured packing
Carbon Capture	NE		٧	0	33		Instrument Air Buffer Vessel	Vertical		0	0 n/a	a n/a			8.5			25		1	10 -	5 8	5			316L SS		3.4	10.1	23.8		Citable of Patricia
Compression	NE		V	1	11		1st Stage CO <sub>2</sub> Compressor KO Drum	Vertical	03	0	0 n/a	n/a			0.15			25		3	3.5	7 10	05 228	T/hr (CO <sub>2</sub> )		316L SS		3.4	5.5	11.5		Includes * Intlet hood and mist eliminator
Compression	NE		٧	1	12		2nd Stage Integrated KO Drum	Vertical	03	0	0 n/a	n/a			1.95			122/36					228	T/hr (CO <sub>2</sub> )		316L SS						Part of Package U-101 Includes integral water cooled tube bundle
Compression	NE		V	1	13		3rd Stage Integrated KO Drum	Vertical	03	0	0 n/a	a n/a		$\top$	5.925	5		123/36		$\top$			228	T/hr (CO <sub>2</sub> )		316L SS				$\neg$		Part of Package U-101 Includes integral water cooled tube bundle
Compression	NE		V	1	14		4th Stage Integrated KO Drum	Vertical	03	0	0 n/a	a n/a		+	15.52	2		121.8/	$\dashv$	$\dashv$	$\dashv$	+	269	T/hr		316L SS			$\dashv$			Part of Package U-101
	NE		v		15			Vertical	03		0 n/a	-	+	-	38	-		36 116.7/				+	269	(CO <sub>2</sub> ) T/hr		316L SS			-			Includes integral water cooled tube bundle Part of Package U-101
Compression							5th Stage Integrated KO Drum			0		_	+-+	-	_		$\vdash$	36						(CO <sub>2</sub> )			,			45.5	46 -	Includes integral water cooled tube bundle
Compression	NE				17		CO <sub>2</sub> Pipeline Pig Launcher	Horizontal	03	0	0 n/a	-	+	+	181.7	+	$\vdash \vdash$	36			200 -4		_	(CO <sub>2</sub> )		LTCS	11.4	1.1		15.6	19.0	
Compression	NE		V	0	34		CO <sub>2</sub> Pipeline Pig Receiver	Horizontal		0	0 n/a	n/a		$\bot$	181.7	7		36		2	200 -4	16 8	5 228	T/hr (CO <sub>2</sub> )		LTCS	11.4	1.1	1.3	15.6	19.0	Located at Shore Crossing (except Teesside)
Compression	NE		V	0	35		CO <sub>2</sub> Pipeline Pig Launcher	Horizontal		0	0 n/a	a n/a			181.7	7		36		2	200 -4	16 8	5 228	T/hr (CO <sub>2</sub> )		LTCS	11.4	1.1	1.3	15.6	19.0	Located at Shore Crossing (except Teesside)
Compression	NE		٧	1	18	A/B	CO <sub>2</sub> Dehydration Absorber	Vertical	03	0	0 n/a	n/a			37.7					4	47 -	5 15	50 269	T/hr (CO <sub>2</sub> )		316L SS		3.3	9.0			Internals = molecular sieves, cermaic balls, supports, grid support Material: CS clad with SS also acceptable
Compression	NE		V	1	19		Dehydration KO Drum	Vertical	03	0	0 n/a	n/a		$\top$	35.4			36		4	47 -	5 30	00 228	T/hr (CO <sub>2</sub> )		316L SS		0.9	3.0			Includes Inlet Hood and Mist Eliminator Depressurisation = -79°C at 0 barg
Utilities	NE		V	0	36		Demin Water Expansion Vessel	Vertical		0	0 n/a	a n/a				t					5 -	5 8	5	(332)		CS + 3mm CA		1.9	4.0	3.9		
Utilities	NE		V	0	37		Instrument Air Dry Air Receiver	Vertical		0	0 n/a	n/a			8.5			25			10 -	5 8	5 764	m <sup>3</sup>		316L SS						
Miscellaneous														$\perp$																		
Power	NE		XJ	1	01		Steam Jet Air Ejector			0	0 n/a	a n/a																				Part of Water Cooled Condenser
							·																									
Electrical Equipment																																
			+	_	_		Low Voltage Equipment		-			+	+	+		+	$\vdash$			_	_	+		+-					_			
Power	NE		+	1	$\dashv$		Low Voltage Equipment			366	LV	′ n/a	+ +	1		+	<del>   </del>				$\dashv$	+	+	+					-+	$\dashv$		Transformers, Circuit Breakers, Switchgear, MCCs, etc
Carbon Capture	NE		SG		01		LV Switchboard			342	446.9 LV																					
Carbon Capture	NE		SG		02		LV Emergency Switchboard			147	290 LV			_		_							$\perp$	1					_	[		
Compression  Compression	NE NE				03 04		LV Switchboard  LV Emergency Switchboard		-	557 145	681.9 LV 260 LV			+		-	$\vdash$			_	_	+	+	-				$\vdash$	_	_		Non-Process Equipment Loads
Utilities	NE			_	05		LV Switchboard				681.9 LV			+	+	+	$\vdash$		$\dashv$	_	$\dashv$	+	+	+				$\vdash$	$\dashv$			
Utilities	NE				06		LV Emergency Switchboard			145	260 LV	/ n/a																				
Facilities	NE		SG	0	07		LV Switchboard			145	260 LV	n/a		$\perp$		1	$\prod$				$\perp$	$\perp$		1					_			
			+	+	_	+	Transmission Values Feetings					+	+	+	+	+	$\vdash$		$\dashv$	+	+	+	+	+				$\vdash$	+	_		
Power	NE		ETR	1	08		Transmission Voltage Equipment  Export Transformer		-	3660	H\	/ n/a	+	+		-	$\vdash$			_	_	+	+	-				$\vdash$	_	_		
Power	NE		TR		09	+	Unit Transformer			5500	H\			+	+	+			$\dashv$	-+	$\dashv$	+	+	+					$\dashv$	$\dashv$		
Power	NE			_	10		Circuit Breakers				HV																					
Power	NE			1			Miscellaneous PEACE Electrical Equipment				HV	/ n/a																				Cost Bookmark
					[								$\perp$	_		_							$\perp$	1					_	[		
			_	_			Generating Voltage Equipment						$\perp$			_							$\bot$	1								
Power	NE NE		СВ	1	11	_	Generator Buswork  Circuit Breakers		-		M\	_		+	+	+-	$\vdash$		-+	_	_	+	-	+					+	-		
Power	NE			1			Miscellaneous PEACE Electrical				M\			1		+	<del>   </del>				$\dashv$	+	+	+				$\vdash$	-+	_		Cost Bookmark
	<u> </u>		-		$\dashv$		Equipment					+	+ +	+	+	+	$\vdash$		$\dashv$	_	$\dashv$	+	+	+				$\vdash$	$\dashv$			
							Medium Voltage Equipment																									
Power	NE		<del></del>	1	$\Box$		Miscellaneous PEACE Auxiliaries			2902	M\			$\bot$			Щ		二					1				$\Box$	$\Box$	$\Box$		
Power	NE		_	1	_		Medium Voltage Equipment				M\	_		+	$\perp$	+	$\vdash \vdash$		$\dashv$			$\perp$		$\perp$			$\vdash$	$\vdash \vdash$	$\dashv$	_		Transformers, Circuit Breakers, Switchgear, MCCs, etc
Power	NE		l	1	1		HP Feedwater Pumps VFD		I	l	M\	/ n/a	1 1	ı	I		I	I	I		I	I	I	1			I	I	I	l		I



**\*))** SNC·LAVALIN

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Thermal Power with CCS: Generic Business Case

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DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00003

PLANT AREA		EQU	JIPMENT	NUMBE	ER		ITEM DESCRIPTION	TYPE	PFD Number		ELEC	TRICA	L POWEF	₹			RATING SSURE		OPERATI MPERAT		DES PRESS		DESIG TEMPE ATUR	R-	DUTY Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	С	DIMENSI	ONS	WE	IGHT	REMARKS
	ASSET CODE	AKEA/UNIT CODE	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (KW)	INTERMITTENT (KW)	(kW)	g [	NORMAL (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Entire Plant	NE	ES	_	12			MV Main Switchboard				-	_	n/a																					
Carbon Capture	NE	ES	iG 1	13	3		MV Switchboard						n/a																		ļ			
Carbon Capture	NE		1				Booster Fan VFD				-	_	n/a								$\sqcup$											_		Part of K-101 Supply
Compression	NE	ES	_	14			MV Switchboard				-	MV	n/a																		ļ			
Compression	NE	ES		15			Switchgear				-	_	n/a								$\sqcup$								2.3	0.7	1.7	1.3		2 off - inlet and outlet. Part of Package U-101
Compression	NE	ET	R 1	16	3		Transformer				-	MV	n/a																		ļ			Part of Package U-101
Compression	NE		1				CO <sub>2</sub> Com pressor VFD					MV	n/a																2.2	9.4	1.0	5.0		Part of Package U-101
										_	$\sqcup$	$\perp$		$\perp$	_				_				_											
Buildings																																		
Facilities	NE	BL	_	01	I		Warehouse			3	3	LV	n/a				+ve	5		35	-	N/A	N/A	N/A	8550	m <sup>3</sup>			_	30.0	_	)		Height to Eaves
Facilities	NE	BL	_	02			Workshop			5	-	_	n/a				+ve	5		35	N/A		N/A	_	14250	m <sup>3</sup>			_	30.0	_	)		Height to Eaves
Facilities	NE		.D 0				Admin & Control Building			22	_	_	n/a				+ve	20		25	-		N/A	_	2160	m <sup>3</sup>			40.0	_	_	_		Height to Eaves
Facilities	NE	BL		04	_		Office Block			164	164	LV	n/a				+ve	20		25					16500	m <sup>3</sup>			33.0					Height to Top of Roof
Facilities	NE	BL	_	05			Lockers, Welfare, & Training			49	49	LV	n/a				+ve	20		25	-	N/A	N/A		4950	m <sup>3</sup>			_	25.0	6.0	)		Height to Eaves
Facilities	NE	BL		06	_		Guardhouse			1	1	LV	n/a				+ve	20		25				N/A	135	m <sup>3</sup>			10.0	3.0	4.5			Height to Eaves
Facilities	NE	BL	.D 0	07	7		Compression Electrical Substation			34	34	LV	n/a				+ve	10		40	N/A	N/A	N/A	N/A	11813	m <sup>3</sup>			75.0	35.0	4.5			Height to Eaves
Facilities	NE	BL	.D 1	08	3		Carbon Capture Electrical Substation			4	4	LV	n/a				+ve	10		40	N/A	N/A	N/A	N/A	1350	m <sup>3</sup>			25.0	12.0	4.5	-		Height to Eaves
Facilities	NE	BL	.D 1	09	9		Steam Turbine Building			34	34	LV	n/a			T .	+ve	5		35	N/A	N/A	N/A	N/A	115200	m <sup>3</sup>			72.0	40.0	40.0			Height to Top of Roof
Facilities	NE	BL	D 1	10	)		Cooling Water Power Distribution Centre			2	2	LV	n/a				+ve	10		40	N/A	N/A	N/A	N/A	720	m <sup>3</sup>			16.0	10.0	4.5			Height to Eaves
Facilities	NE	BL	.D 1	11	ı		HRSG Power Distribution Centre			1	1	LV	n/a				+ve	10		40	N/A	N/A	N/A	N/A	225	m <sup>3</sup>			10.0	5.0	4.5			Height to Eaves
Facilities	NE	BL	.D 1	12	2		Power Generation Power Distribution Centre			2	2	LV	n/a			Π.	+ve	10		40	N/A	N/A	N/A	N/A	720	m <sup>3</sup>		·	20.0	8.0	4.5			Height to Eaves
Facilities	NE	BL	D 1	13	3		HV / LV Power Distribution Centre			2	2	LV	n/a		_	1	+ve	10		40	N/A	N/A	N/A	N/A	720	m <sup>3</sup>			20.0	8.0	4.5			Height to Eaves
						+			1	-	$\vdash$		_	-	+	-	_	_	+	$\vdash$	$\vdash$			+					₩	+	-	₩	-	<del> </del>



# <u>Attachment 2.3 – 150 barg Compressor Case</u>





PROJECT No. PROJECT NAME LOCATION

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Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00004

A01 NOVEMBER 2017

Compressors Compression NE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	INCE	ر ادر ا ادر			Number			ICAL PO	WER		PERATING RESSURE		PERATINO IPERATU		DESIGN RESSURE	DES TEMI ATU	PER-	DUTY (Per Unit)	UNITS	TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DIN	MENSIONS	3	WEIGH	T REMARKS
				SEQUENCE	REDUNDANCY TRIM OR AUX EL EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (kW)	INSTALLED (KW) VOLTAGE (HV, MV,	CCS STANDBY (kW)	DUTY - INTERMITTENT (kW) DUTY - STANDBY (kW)	MIN (barg)	NORMAL (barg) MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MAX (barg)	MIN (°C)	MAX (°C)			m²	Ū	Length-OVL/TT (m)	Width Or DIA (m)	5	DRY (tonnes)	OPERA IING (comes)
									+ +	+		++	+ +				-	+											
Compression NE																													
		С	1	01		CO <sub>2</sub> Compressor	Centrifugal	03	23423	25800 MV	0			See Pkg	Below														Part of Package U-101 Motor sizing includes 10% API 617 Margin
Heat Exchangers																													
Compression NE		Е	1	05		6th Stage Cooler	Shell & Tube	03	0	0 n/a	n/a			74.4		106.3 / 36					7889	kW		CS					Part of Package U-101
Compression NE		Е	1	06		7th Stage Cooler	Shell & Tube	03	0	0 n/a	n/a			150.7		89.1 / 36					10060	kW		CS					Part of Package U-101
Compression NE		Е		07		CO <sub>2</sub> Dehydration Electric Heater	Electric Heater	03	3488	3800 MV				37.4		22.9 / 290		47		310		kW		316L SS	5.6	1.6	2.4	4.0	Alternative DT= -79°C for Rapid Depressurisation
Compression NE		E	1	80		Dehydration Cooler	Shell & Tube	03	0	0 n/a	n/a	<del>                                     </del>	+	36.6	+		_	47	-5	310	3323	kW	166	316L SS	igsqcut		_		Alternative DT= -79°C for Rapid Depressurisation
Instrumentation and Control Equi	quipme	it																											
Compression NE		JDF	0	02		CO <sub>2</sub> Metering	Coriolis	03	0	LV	0			150.5		36		165	-5	100	1140	T/hr		316L SS	35.0	6.0	7.0 1:	22.7	Metering - size based on similar scope pipeline meter No change - same Piping Material Class and Pipe Wall Schedule.
Compression NE		JCP		02		CO <sub>2</sub> Metering Panel	Panel		1	1 LV	_														7.2	0.8		0.7	Safe Area Panel
Compression NE		JDC	0	02	-	CO <sub>2</sub> Metering Analyser House			+	LV		+ + -	+			$\vdash$		+	+						2.0	2.0	2.7	2.3	Analyser House and Speciality Bottle House
Mechanical Handling Equipment	nt																												
Compression NE			1	04		CO <sub>2</sub> Compressor Overhead Crane	Single Girder		0	30 LV	n/a	20	+					+	-5		35	T		CS			+		
Pumps																													
Compression NE		Р	1	24	A/B	Process Condensate Return Pumps	Centrifugal	03	1	1.5 LV	0			1		20	4	35	-5		2.0	m³/hr	@32m	316 SS	1.0	0.5	0.5	0.2	
Filters																													
Compression NE		S	1	02		CO <sub>2</sub> Dehydration Filter Coalescer	Disposable Catridge	03	0	0 n/a	n/a			37.9		36		47	-5	160	3186 r	m3/hr		316L SS		2.7	8.1 7	0.4	99.999% removal > 0.3micron Alternative DT= -79°C for Rapid Depressurisation
Compression NE		S	1	05	A/B	CO <sub>2</sub> Dehydration Outlet Filter	Basket	03	0	0 n/a	n/a			36.6		36		47	-5	160	2884 r	m3/hr		316L SS		3.1	2.6 4	6.4	> 5micron Alternative DT= -79°C for Rapid Depressurisation
Compression NE		s	1	09	A/B	CO <sub>2</sub> Dehydration Regeneration Gas Discharge Filters	Basket	03	0	0 n/a	n/a			36.6		36		47	-5	310	1162 r	m3/hr		316L SS		2.3	2.6 2	1.3	> 5micron Alternative DT= -79°C for Rapid Depressurisation
Packages  Compression NE		U	1	01		CO <sub>2</sub> Compression Package	Integral Geared	03	176	313.74 LV	106			0.2 /		123		165	-5	150	230	T/hr		316L SS	25.0	18.0	9.0 3	56.0	No change to package / utilities as is same frame size compressor - just one
Compression NE		U		02		CO <sub>2</sub> Compression Fackage CO <sub>2</sub> Dehydration Package	Mole Sieve	03	0	0 n/a	_			37.9		123		47	-5	150	_	T/hr		316L SS		N/A		N/A	less stage  Equipment elsewhere - line item for price for design and mole sieve
Compression NE		U		10		Tracer Dosing Package	API 675 Pumps		0	0.1 LV	0			150.5		36		165	-5	85	100	ppbv		316L SS	2.2	1.2		0.9	Addition to give CO <sub>2</sub> smell to allow leakage detection
Drums and Vessels																													
Compression NE		v	1	11		1st Stage CO <sub>2</sub> Compressor KO Drum	Vertical	03	0	0 n/a	n/a			0.15		25		3.5	-7	105	228	T/hr (CO <sub>2</sub> )		316L SS		3.4	5.5 1	1.5	Includes
Compression NE		V		12		2nd Stage Integrated KO Drum	Vertical	03	0	0 n/a	+		+	1.95	+	122/36	$\dashv$	+	+			T/hr (CO <sub>2</sub> )		316L SS	$\vdash$	-	+		* Intlet hood and mist eliminator Part of Package U-101
Compression NE		V		13		3rd Stage Integrated KO Drum	Vertical	03	0	0 n/a	+	<del>                                     </del>	+	5.925	+	123/36	$\dashv$	+	+		220	T/hr		316L SS	$\vdash$	-+	+		Includes integral water cooled tube bundle Part of Package U-101
Compression NE		V		14		4th Stage Integrated KO Drum	Vertical	03	0	0 n/a	+		+	15.52	$\perp$	121.8/	+	+	+	-+	(	(CO <sub>2</sub> ) T/hr (CO <sub>2</sub> )		316L SS	$\vdash$	_	+	+	Includes integral water cooled tube bundle Part of Package U-101
Compression NE		V		15		5th Stage Integrated KO Drum	Vertical	03	0	0 n/a	-		+	38	+	36 116.7/	-	+	+			T/hr		316L SS	$\vdash \vdash$	+	-	1.1	Includes integral water cooled tube bundle Part of Package U-101
		V		17		CO <sub>2</sub> Pipeline Pig Launcher	Horizontal	03	0	0 n/a	_			150		36 36		165	-46	85	220	(CO <sub>2</sub> )		LTCS	11.4	1.1		_	Includes integral water cooled tube bundle
		V		34		CO <sub>2</sub> Pipeline Pig Launcher  CO <sub>2</sub> Pipeline Pig Receiver		- 03	0	0 n/a	_			150		36	-	165	_	85	220 (	(CO <sub>2</sub> ) T/hr			11.4	_	_	_	
		V	_	_			Horizontal				_			150		36	_		+	_	220 (	(CO <sub>2</sub> ) T/hr		LTCS	$\vdash$	_	-	_	8.1 Located at Shore Crossing (except Teesside)
Compression NE				35	1.5	CO <sub>2</sub> Pipeline Pig Launcher	Horizontal		0	0 n/a						36	-	165		85	220 (	(CO <sub>2</sub> )		LTCS	11.4			4.7	8.1 Located at Shore Crossing (except Teesside)  Internals = molecular sieves, cermaic balls, supports, grid support
Compression NE		V			A/B	CO <sub>2</sub> Dehydration Absorber	Vertical	03	0	0 n/a	+		+	37.7	+		_	47	+	150		T/hr (CO <sub>2</sub> )		316L SS	$\vdash \vdash$		9.0		Material: CS clad with SS also acceptable  Includes Inlet Hood and Mist Eliminator
Compression NE		V	1	19		Dehydration KO Drum	Vertical	03	0	0 n/a	n/a	+	+	35.4	+	36	$\perp$	47	-5	300	228 (	T/hr (CO <sub>2</sub> )		316L SS		0.9	3.0	_	Depressurisation = -79°C at 0 barg





**EQUIPMENT LIST (MAJOR ITEMS)** 

ONSHORE PLANT - OPTIMISATION - 150barg COMPRESSION

PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00004

A01 NOVEMBER 2017

PLANT AREA			EQUIPM	ENT NU	MBER			ITEM DESCRIPTION	ТҮРЕ	PFD Number		EL	ECTRIC	AL POW	ER		PERAT			ERATING PERATUI		DESIG PRESSI	JN .	DESIGN TEMPER- ATURE	DUTY (Per Uni	STINU	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	D	IMENSI	ONS	WE	EIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (kW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (KW)	DUTY - INTERMITTENT (KW) DUTY - STANDBY (KW)	MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	ING (to	
lectrical Equipment															_																		Ť	
								Low Voltage Equipment																										
Compression	NE		ESG	1	03			LV Switchboard			557	681.9	LV	334																				Non-Process Equipment Loads
Compression	NE		ESG	1	04			LV Emergency Switchboard			145	260	LV	87																				
								Medium Voltage Equipment																										
Compression	NE		ESG	1	14			MV Switchboard					MV	n/a																				
Compression	NE		ESG	1	15			Switchgear					MV	n/a															2.3	0.7	1.7	1.3		2 off - inlet and outlet. Part of Package U-101
Compression	NE		ETR	1	16			Transformer					MV	n/a																				Part of Package U-101
Compression	NE			1				CO <sub>2</sub> Com pressor VFD					MV	n/a															2.2	9.4	1.0	5.0		Part of Package U-101
uildings								_	_																									
Facilities	NE		BLD	0	07			Compression Electrical Substation			34	34	LV	n/a			+ve		10		40	N/A	N/A N	I/A N/	11813	m <sup>3</sup>			75.0	35.0	4.5			Height to Eaves
•									•																									



# <u>Attachment 2.4 – Single TRU Case</u>



**EQUIPMENT LIST (MAJOR ITEMS) ONSHORE PLANT - OPTIMISATION - SINGLE TRU** 

PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00005

A01 NOVEMBER 2017

PLANT AREA			EQUIPM	IENT NU	JMBER	ł		ITEM DESCRIPTION	ТҮРЕ	PFD Number		ELECTR	ICAL PO	OWER			ERATING ESSURE		PERATIN MPERAT		DESIG PRESSU	IDE TE	ESIGN EMPER- TURE	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DII	MENSION	s	WEIG	ЭНТ	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (kW) VOLTAGE (HV, MV,	CCS STANDBY (kW)	DUTY - INTERMITTENT (KW)	DUTY - STANDBY (kW)	MIN (barg)	NORMAL (barg) MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg) MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Steam Generation Equ	uipment																																
Power	NE		В	1	01			Heat Recovery Steam Generator	Horizontal Drum	01	0	0 n/a	n/a	1			173.3		647.6			190 -5	600	600718	kW		CS (TP409 / T91 / T22 on high temp side)	40.0	25.0	31.0			Includes SCR catalyst, CO calayst, and Ammonia System
Power	NE		В	1	02			Auxiliary Boiler	Package		112	167 LV	n/a	1			7		220			10 -5	250	23	T/hr		CS (SA 192 Tubes)	8.3	4.3	4.7	103	151.0	Assume 1 Auxiliary Boiler per Train
																					$\Box$												
Compressors																																	Part of Package U-101
Compression	NE		С	1	01			CO <sub>2</sub> Compressor	Centrifugal	03	24297 2	27000 M\	0	_			See Pkg	Below		$\vdash$	_		-										Motor sizing includes 10% API 617 Margin
Stack																																	
Power	NE		D	1	01			Stack	Self Supporting	02	0	0 n/a	n/a	1			0.013		87.77			-5	750	3551	T/hr		CS - outer 316Ti - liner		10.0	90.0			Includes baseplate, anchor bolting, inner liner, outer shell, top cover, insulation, Flue Gas Inlet, Access/cleaning doors, condensation drain, ladders, platforms, AWLs, sample points, earth points, lifting lugs,
Power	NE		D	1	03			Auxiliary Boiler Stack	Self Supporting		0	0 n/a	n/a	1			0.02		184			-5	750				CS		1.0	30.0			readors, pietorins, Avves, sample points, Editi points, ilitiliq itqs,
Carbon Capture	NE		D	1	02			CO <sub>2</sub> Vent Stack	Self Supporting		0	0 n/a	n/a	1			0.72		-10			-79	250	229306	kg/hr		316L SS		30"	30.0	4.5		Sch 10S
Heat Exchangers																																	
Power	NE		E	1	02			Condenser (Water Cooled)	2 pass	01	0	0 n/a	n/a				-0.93		39.16		FV	1 -5	110	355487	kW	12055	304 SS Tubes	20.7	6.1		510.0		Including steam ejectors for vaccuum
Power	NE		Е	1	03			Fuel Gas Heater	Shell & Tube	01	0	0 n/a	n/a	1			49.1 / 36.6		204.4 / 242.9		5	5 / 41 -5	310	10674	kW	500	CS / 316L SS Tube	12.4	0.9		23.9		Feedwater - Tubeside, Fuel Gas - Shellside
Power	NE		Е	1	04			Gland Steam Condenser	Shell & Tube	01	0	0 n/a	n/a								FV/0 .4	45/34 -5	270	378	kW	14	SS Tubes	4.5	1.7	3.1	3.5		Part of Steam Turbine Supply
Power	NE		E	1	22			Electric Superheater	Electric Heater		0	4415 M\	/ n/a	1			49.1		70			55 -5	310	2677	kW		316L SS / Alloy 800 pockets	5.5	1.3				Start Up Heater (sized to provide superheat only), includes pressure vessel, thyristor control panel (safe area)
Power	NE		Е	1	23	A-E		GT + Generator Lube Oil Cooler	Plate & Frame		0	0 n/a	n/a	1			3		37.5			6 -5	50		kW								Part of RS-101
Power	NE		E	1	24	A-F	_	GT Generator Cooler	Plate & Frame		0	0 n/a	+				3		37.5	$\vdash$		6 -5			kW								Part of R-101
Power	NE NE		E	1	25 26	A/B A/B	-	ST + Generator Lube Oil Cooler ST Generator Cooler	Plate & Frame Plate & Frame		0	0 n/a				$\vdash$	3	+	37.5 37.5	$\vdash$		6 -5 6 -5	50 50	850 4000	kW					$\dashv$			Part of RS-102 Part of R-102
Carbon Capture	NE		E	1	01	700	-	Gas-Gas Heat Exchanger	Rotary	02	15	15 LV							07.0		0	0.125 -5	130		kW	13521	Weathering Steel	15.6	15.6	4.5	340.2		Purge and Scavenge Fan shall be part of this package
Carbon Capture	NE		Е	1	09	A/B/C		Lean / Rich Amine Exchanger	Welded Plate	02	0	0 n/a	n/a	1			5.1 /		122.3 /			18 -20	140	77734	kW	14457	316L SS	2.5	3.5	18.0	400.0	430.0	e.g. Packinox type or equal. Duty was for 2 units - now split into 3 units
Carbon Capture	NE		Е	1	10	A-F		CO <sub>2</sub> Stripper Reboilers	Welded Plate	02	0	0 n/a	n/a	1			2.1		122.3			5 -5	150	36847	kW	1403	316L SS	2.8	1.8		10.6		
Carbon Capture	NE		Е	1	11	A/B		Overhead Condenser	Welded Plate	02	0	0 n/a		-			2		26			12 -5	160		kW	1122	316L SS	3.1	1.7	_	7.5		
Carbon Capture	NE		E	1	12	A/B	_	Wash Water Cooler	Welded Plate	02	0	0 n/a	+				_			$\vdash$		10 -5			kW	1555	316L SS	5.8	1.6		13.7		
Carbon Capture  Carbon Capture	NE NE		E	1	13	A/B/C		Lean Amine Cooler DCC Cooler	Welded Plate Plate & Frame	02 02	0	0 n/a	_	_						$\vdash$		12 -5 9 -5	85 85	35740 42097	kW	928 1927	316L SS 316L SS	5.0 6.1	1.5	2.0 3.6	29.0		Duty was for 2 units - now split into 3 units
Carbon Capture	NE		E	1	15	7,45,0	_	CO <sub>2</sub> Vent Vapouriser	Inverted Kettle	- 02	0	0 n/a						+				0 / 27 -79			kW	111	CS / 316L SS	3.7	1.5		5.5		Edg Was to 2 and Tow spir into 5 and
Carbon Capture	NE		Е	1	16	A/B		CC Unit Condensate Cooler	Plate & Frame		0	0 n/a	n/a	ı								8 -5	160	18127	kW	383	316L SS	4.3	1.3	2.3	6.1		
Carbon Capture	NE		E	_	18		-	Thermal Reclaimer Pre-Heater	Welded Plate		-	0 n/a	_	_							_	8 -5	_	_	kW	225	316L SS	4.1	1.0	-	4.6	6.0	
Carbon Capture  Carbon Capture	NE NE		E E		19 20		-	IX Amine Cooler IX Demin Water Cooler	Welded Plate Plate & Frame		-	0 n/a	n/a n/a	_							_	12 -5 9 -5	_		kW	219 35	316L SS 316L SS	4.1 2.6	1.0 0.5	_	5.0	6.5	
Compression	NE		E	1	05		_	6th Stage Cooler	Shell & Tube	03	0	0 n/a		_			68.2		97.5 /			-	100	6216	kW		CS CS	2.0	0.0	1.3			Part of Package U-101
Compression	NE		E	1	06			8th Stage Cooler	Shell & Tube	03	0	0 n/a		_			182.9	+	36 119.8 /				+	13200	kW		CS			$\dashv$			Part of Package U-101
Compression	NE	<del>   </del>	E	1	07	+	-+	CO <sub>2</sub> Dehydration Electric Heater	Electric Heater	03	-	3800 M\	-	+		$\vdash$	37.4	+	36 22.9 /			47 -5	310	+	kW		316L SS	5.6	1.6	2.4	4.0		Alternative DT= -79°C for Rapid Depressurisation
Compression	NE		E	1	08	++		Dehydration Cooler	Shell & Tube	03	0	0 n/a	-	1		$\vdash$	36.6	+	290			47 -5	_		kW	166	316L SS	5.0	"				Alternative DT= -79°C for Rapid Depressurisation
Cooling Plant	NE		E	1	21	A-T		Cooling Towers	Wet		0	0 n/a					3		13 / 23			6 -5	_		kW	856 kg/s		15.0	15.0	25.0			Dimensions each cell
Utilities	NE		Е	0	17			47WT% Caustic Storage Tank Electric Heater	Electric Heater		3	5 LV	n/a	1			15		ATM		1	ATM -5	85	3	kW		316L SS	0.6	0.2		0.0		
Instrumentation and C	1	quipmen		1	00	A		Complian	Anglicas			0 11	-1-														204.00	0.0	0.0	2.0	2.2		Faced union and Steam Complian
Power	NE NE		JDC	1	06	A-H		Sampling Continuous Emissions Monitoring	Analyser Analyser		8	8 LV	_	_		$\vdash$	+	+	<del>                                     </del>	$\vdash$	+		+	+	$\vdash$		304 SS	2.0	2.0	3.0	2.3		Feedwater and Steam Sampling  Measurements NOx, SO₂, CO₂, O₂, H₂O, °C, and flow
Natural Gas	NE		JDF	0	03	+	-	System (CEMS) Natural Gas Metering	Orifice	01	0	LV				$\vdash$	65-85	1	-	38	+	85 -5	85	158	Nm <sup>3</sup> /s		Carbon Steel	35.0	6.0	6.9	122 7		Metering - size based on similar scope pipeline meter
Natural Gas	NE		JCP	0	01	+	_	Natural Gas Panel	Panel	, , , , , , , , , , , , , , , , , , ,	1	1 LV						+ -		"		3   3	1 55	100	INITI /S		0.00.101001	7.2	-	2.1			Safe Area Panel
Natural Gas	NE		JDC	0	01		_	Natural Gas Analyser House				LV								╚			1	上				2.0	2.0				Analyser House and Speciality Bottle House
Compression	NE		JDF	0	02		_	CO <sub>2</sub> Metering	Coriolis	03	0	LV					182.9		36			200 -5	100	1140	T/hr		316L SS	35.0	6.0	7.0			Metering - size based on similar scope pipeline meter
Compression	NE		JCP	0	02		(	CO <sub>2</sub> Metering Panel	Panel		1	1 LV	1		1													7.2	0.8	2.1	0.7		Safe Area Panel



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UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00005

																						DESIGN	I DUTY	, "	BARE HEAT TRANSFER	CTION						
PLANT AREA		EQUIP	MENT N	UMBEF	₹		ITEM DESCRIPTION	TYPE	PFD Number		ELE	CTRICA	L POWER	t		OPERA' PRESS			PERATING		DESIGN PRESSURE	TEMPER	t-	=	AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	MENSION	IS	WEIGH	IT	REMARKS
	ASSET CODE AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (KW)	INTERMITTENT (kW) DUTY - STANDBY	(KW) MIN (barg)	NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	ν̈	MiN (barg) MAX (barg)	MIN (°C)	MAX ( C)		m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Compression	NE	JDC	0	02			CO <sub>2</sub> Metering Analyser House					LV															2.0	2.0	2.7	2.3	An	nalyser House and Speciality Bottle House
Utilities	NE	JDC	0	05			DCS (ICSS)	Panel		110	110	LV															36.8	0.8	2.1	31.5 3		SS for whole Power + CCS chain controlled from single control room. ice includes F&G and well as HIPPS
Fans																																
Carbon Capture	NE	К	1	01			Booster Fan	Axial	02	13122	13900	MV	0		1	1.013	3 /		87.8				3551	T/hr	Δ 0.08bar	Steel Plate	9.9	9.3	8.1	111.4		
Carbon Capture	NE	KF	1	01	A-H		Booster Fan Motor Cooling Fans	Axial		24	60	LV	0			1.09	13						1								Inc	cluded in Booster Fans Supply
Carbon Capture	NE	KU	1	01	A/B		Booster Fan Lube Oil Skids			15	41	LV	15																		Inc	cluded in Booster Fans Supply
Carbon Capture	NE	K	1	02			Damper Sealing Air Fan	Centrifugal		293	322	MV	0		_											Weathering Steel	4.0	2.2	3.2	10.7	Inc	cluded in package with Gas Gas Heat Exchanger
Carbon Capture	NE	К	1	03			Damper Purge & Scavenge Air Fans	Centrifugal		6	7.5	LV	6								$\perp$		1500			Weathering Steel	1.0	1.0	2.5	0.3		cluded in package with Gas Gas Heat Exchanger
Cooling Plant	NE	EF	1	01	A-T	-	Cooling Tower Fans	Axial		2107	2600	MV	632	_	+	ATN	М	$\vdash$	10	$-\!\!\!\!+$	+	-5	1578	T/hr	•		$\vdash \vdash$		_		Tot	tal duty for CCGT + CCC
Mechanical Handling	Equipment																															
Power	NE	L	1	01			Gas Turbine Overhead Crane	Double Girder Gantry		0	164	LV	n/a	16	4							-5	100	Т		CS						
Power	NE	L	1	02			Steam Turbine Overhead Crane	Double Girder Gantry		0	115	LV	n/a	115	5							-5	70	Т	40m Span	CS						
Power	NE	L	1	03			Steam Turbine Auxiliary Crane	Double Girder Gantry		0	30	LV	n/a	20	_							-5	16	Т	10m Span	CS						
Compression	NE	L	1	04	-		CO <sub>2</sub> Compressor Overhead Crane	Single Girder		0	30	LV	n/a	20	_	_	-			_		-5	35	T		CS					_	
Water Treatment Water Treatment	NE NE	L	0	05 06	-		Demin Plant Hoist  Waste Water Treatment Plant Hoist	Single Girder Single Girder		0	12 12	LV LV	n/a n/a	10		+	+			-		-5 -5	8	+ +	+	cs cs		-	-+		+	
Utilities	NE	L	0	07			Fire Fighting Pump Station Hoist	Single Girder		0	6	LV	n/a	6	+-							-5	4	Т.		cs			-		+	
Facilities	NE	L	0	08			Workshop building Crane	Single Girder		0	22	LV	n/a	21								-5	10	Т	30m Span	CS						
Facilities	NE	L	0	09	A/B		Weighbridge			0	1	LV	n/a	1								-5	60	Т		CS	20.0	3.0		12.5		
Mixer															+	+			-					-					-	-	-	
Carbon Capture	NE	М	0	14			Thermal Reclaimer No 1 Feed Tank			17	22	LV	22			Atm	1		Amb		0.29	-5 8	35			316L SS		1.0		0.8		
Carbon Capture	NE	M	1	_			Mixer Amine Degraded Tank Mixer			17	22	LV	22		+	0.06	6	-	20	+	_	-5 1	_	+		316L SS		1.0	$\dashv$	0.8	+	
Pumps																																
Power	NE	Р	1	01			Condensate Pump	Centrifugal	01		950	MV	n/a		$\perp$	4			39.7	_			90 574	_	+	Chrome Steel	4.0	_		10.0	Pro	ovides pressure for LP Stage - i.e. Operates as LP Feedwater Pump
Power	NE	Р	1	02	+		HP Feedwater Pump	Ring Section	01	_	11400	MV	n/a		_	250.			147	_	400		50 589	m³/h		Chrome Steel	6.4	2.3	_	21.4	_	
Power	NE	Р	1	03			IP Feedwater Pump	Ring Section	01	281	504	MV	n/a		$\perp$	58.5			143	_		-5	71	m³/h	-	Chrome Steel	6.0	2.2		7.0	_	
Power	NE NE	P P	1	11 12			LTE Recirculation Pump	Centrifugal		0	1.5 37	LV	n/a	44	-	4.02	_		104.4	_		-5	32			Chrome Steel	1.8	_	0.7	0.7	_	
Power	NE NE	P	1	13	_		Auxiliary Boiler Feedwater Pumps  GT + Generator Lube Oil Pump	Centrifugal Centrifugal		U	31	LV LV	n/a n/a	14	-	- '	+		105		10	-5 1	50 25	m³/h	er @75m	Chrome Steel	1.8	1.1	0.6	1.1		
Power	NE	P	1	14			GT Generator Control Oil Pump	Centrifugal			1 1	LV	n/a				+														+	
Power	NE	Р	1	15	A/B		ST + Generator Lube Oil Pump	Centrifugal		0	0	n/a	n/a			6.5	5		40				248	m³/h	г						Sh	naft Driven
Power	NE	Р	1	17			ST Generator Control Oil Pump	Centrifugal		30	-	LV	n/a		$\bot$				$\Box$		$\bot$								工		$\perp \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \! \!$	
Power	NE	P	1	20		1	Clean Drains Return Pump	Centrifugal		26	-	LV	n/a	_	+	2.7			20		_		316	_	-	CS	2.1		1.0			
Cooling Plant Carbon Capture	NE NE	P P	1	16 04		-	Cooling Water Pump  Absorber Feed Pumps	Centrifugal Centrifugal	02	_	6267 1400	MV	1495 377	_	+	3.4			17.5 53	_		-5 8 -5	35 1232 2829		+	CS 316 SS	7.2 5.0		2.4 1.2	18.0	5 p	pumps operating, 1 spare
Carbon Capture	NE NE	P	1	05		+	Lean Amine Pumps	Centrifugal	02	_	840		222	+	+	4.1		$\vdash$	122.4	-+		-5 -5	3042	_		316 SS 316 SS	5.0		1.4		$\dashv$	
Carbon Capture	NE	P	1	06	_		Rich Amine Pumps	Centrifugal	02	_	1170	MV	427	$\top$	$\top$	5.6		_	41	-		-5	1417		+	316 SS	3.5		1.0		3 x	x 50%
Carbon Capture	NE	Р	1	07	A/B		Stripper Reflux Pumps	Centrifugal	02	21	60	LV	12			1			26		10	-5	78	_	1	316 SS	1.8	1.1	1.0	1.1	1 F	Pump is a Spare for IX Transfer Pump
Carbon Capture	NE	Р	0	17	-		Waste Wash Water Pumps	Centrifugal		10	22	LV	6		$\perp$	1			$\Box$			-5	64			CS	1.8	1.1	1.0	1.0		
Carbon Capture	NE	P P	1	19		-	Chemical Sewer Tank Pump	Centrifugal		8	11	LV	5	_	+	-	0.5		50				35 46		-	316 SS	10	0.5	0.7	0.7	_	
Carbon Capture  Carbon Capture	NE NE	P	1	18 08		+	CC Unit Condensate Pumps  Direct Contact Cooler Pumps	Centrifugal Centrifugal	02	25 501	30 575	LV MV	15 301	+	7.5	5.5	8.5	$\vdash$	50 41	+	10	-5 -5	382 2120	_		CS / SS Impeller CS	1.6 4.0	_	_	0.7 5.5	+	
Carbon Capture	NE	P	1	09		1	Acid Wash Pumps	Centrifugal	02	81	180	LV	49	_	+	7.4			85		_	-5	1195	_	+	316 SS	3.5		_	6.0	$\dashv$	
Carbon Capture	NE	Р	1	10	+	L	Water Wash Pumps	Centrifugal	02	530	_	MV	318	_	╧	0.7	_		46			-5	4205	_	1	316 SS	5.0		1.2			
Carbon Capture	NE	Р	0	28	A/B		Fresh Amine Transfer Pumps	Centrifugal		3	5.5	LV	0			2.2	2		25		35	-5	28	m³/h	@22.8m	316 SS	1.8		_	0.6		
Carbon Capture	NE	Р	0	29			Amine Container Pump	Centrifugal		1	2.2	LV	0		_	1	_	_	25			-5	20	_		316 SS	1.5		_	0.4	<u> </u>	
Carbon Capture	NE NE	P P	0				IX Amine Pump	Centrifugal		130		LV	0			8.8			85			-5	433			316 SS	2.4	1.1	110	3.1	_	
Carbon Capture  Carbon Capture	NE NE	P	0	26 27	_		Amine Drain Pump  IX Transfer Pump	Centrifugal  Centrifugal		10 82	15 90	LV LV	90		+	4.4 8.9	_		160 110		10	-5 -5	43 329	_		316 SS 316 SS	1.8 2.5	0.9		0.5		
Carbon Capture	142		U	21	AID		or manifer i unip	Genunugai		02	30	LV	55			0.9			110		10	Ü	329	in /h	@ 00.0III	310 33	2.0	1.1	1.0	2.2		



PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00005

PLANT AREA		EG	UIPME	NT NUN	MBER		ITEM DESCRIPTION	TYPE	PFD Number		ELECTF	RICAL P	OWER			PERATING RESSURE		PERATII		DESIG PRESSU	IDE T	DESIGN EMPER-	DUTY	NITS	BARE HEAT TRANSFER AREA or AP	MATERIAL OF CONSTRUCTION	Di	IMENSION	ıs	WEIG	ЭНТ	REMARKS
									Number						"			=		2000		ATURE	(Per Unit)	) >	(Per Unit)	MATE						
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (kW)	INSTALLED (KW) VOLTAGE (HV, MV,	CCS STANDBY (kw)	PUTY -	INTERMITTENT (KW)  DUTY - STANDBY  (KW)	MIN (barg)	NORMAL (barg) MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MAX (°C)			m²	3	Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Carbon Capture	NE		Р	0	21	A/B	Thermal Reclaimer NO. 1 MP Condensate Pumps	Centrifugal		6	15 L\	/ 6	5			22		250		FV	27 -5	5 270	35	m³/hr	@21m	CS	1.8	1.0	0.9	1.1		
Carbon Capture	NE		Р	0	22	A/B	Thermal Reclaimer NO. 2 MP Condensate Pumps	Centrifugal		1	3 L\	/ 1	1			22		250		FV	27 -5	5 270	3	m³/hr	@19.8m	CS	1.8	0.9	0.7	0.7		
Carbon Capture	NE		Р	0	23	A/B	Thermal Reclaimer NO. 3 MP Condensate Pumps	Centrifugal		2	3 L\	/ 2	2			22		250		FV	27 -5	5 270	6	m³/hr	@19.7m	CS	1.8	0.9	0.7	0.7		
Compression	NE		Р	1	24	A/B	Process Condensate Return Pumps	Centrifugal	03	1	1.5 L\	/   0				1		20			35 -5	5	2.0	m³/hr	@32m	316 SS	1.0	0.5	0.5	0.2		
Utilities	NE		Р	0	13	A/B/C	Demineralised Water Pumps	Centrifugal		30	135 L\	/ n/	/a	90		5	5	8	20		10 -5	5 85	150	m³/hr	@50m	316 SS	2.1	1.2	1.0	1.3		1 Normal Operation - 3 pumps in operation at start-up
Utilities	NE			-	14	A-D	Fire Water Pumps	NFPA 20		0	L\	_	_			11	5	8	20		15 -5	_	1000	m³/hr	1	CS / SS Impeller	6.6	1.5		8.7		Diesel Engine Driven
Utilities Utilities	NE NE		-		15 30	A/B A/B	Fire Water Jockey Pumps 47WT% Caustic Transfer Pump	Centrifugal Centrifugal		38 7	45 L\	_				7 5.5	5	8 15	20		15 -5 10 -5	_	132 14	m³/hr	@73m @36.2m	CS / SS Impeller CS	1.8	_	_	0.3		Keep fire water main pressurised
Utilities	NE	-	-		31	A/B	Concentrated Sulphuric Acid Transfer	Positive Displacement	<del>                                     </del>	0.02	0.75 L\	_				5.5	+	13	+			05	0.2	m <sup>3</sup> /hr	@34.4m	316 SS	1.3	0.0	0.0	0.0		
Utilities	NE				19	A/B	Pump Service (Raw) Water Pumps	Centrifugal		9.20	11 L\	_	_			5	5	8	20		10 -5	5 85	_	m³/hr	@31m	CS / SS Impeller	1.8	1.1	1.1	1.3		
Utilities	NE		Р		32	A/B	Towns Water Pump	Centrifugal		40	110 L\	_				5.4	5	8	20	_	10 -5	_		m³/hr	<u> </u>	316 SS	1.3	<del>                                     </del>	_	0.3		
Power Generation	NE		R	1	04						0		<b>/-</b>										500	100/-								
Power	NE NE		R	-	01 02		Generator Generator		01 01	0	0 n/a	_	-				+		$\vdash$			-	232	MWe						369.0		Unabated Performance
Utilities	NE	-			03		Standby Emergency Power			0	0 n/a	_											2680	kVA			Incl	Incl	Incl	Incl		
Power	NE		RG	1	01		Generator Gas Turbine	Class H/J	01	1001	L\	/ n/	/a				+						500	MW			33.0	6.0		1,050		Includes auxiliary equipment such as Lube Oil Consoles (Dims turbine only)
Power	NE		RS	1	02		Steam Turbine	Multi-Casing with Steam Extraction	01	123	L\	/ n/	/a										232	MW			40.0	15.0	23.0	752		Advice from Vendors that would be multi casing or multi shaft machine for steam extraction. Includes auxiliary equipment such as Lube Oil Consoles
Utilities	NE		RE	1	03		Standby Emergency Power	Diesel Engine		3	13.2 L\	/ n/	/a										1				12.0	3.0	3.4	43.0		(Dims turbine only)
							Generation Engine	<u> </u>				+	+				+					-		1							-	
Filters																																
Power	NE		S	-	01		Inlet Air Filter		01	0	0 n/a	_				ATM .	-	ATM			ATM -1			T/hr		CS / PTFE	20.0	-	15.0			
Power	NE				07	A/B	Condensate Filter	Basket	01	0	0 n/a	_	_			4	-	40			30 -5			T/hr		CS	0.9					
Power	NE		S		06	4/0	Fuel Gas Coalescing Filter	Coalescing Elements		0	0 n/a	_				40		25	$\vdash$		85 -5			T/hr	0.87 m <sup>3</sup>	CS / 316L Internals		0.8	3.7	4.0		Removal of solid particles 100% > 3 micron and entrained liquids
Carbon Capture  Carbon Capture	NE NE		s s		04 08	A/B	Amine Filter  Amine Drain Filter	Cartridge Cartridge	02	0	0 n/a		_			7.1 3.6		40	$\vdash$		12 -5 7 -5	-	_	m3/hr m3/hr	1	316L SS 316L SS		0.5	_			99% removal > 10micron  99% removal > 10micron
Compression	NE		s		02		CO <sub>2</sub> Dehydration Filter Coalescer	Disposable Catridge	03	0	0 n/a	_	_			37.9		36			47 -5	_	_	m3/hr		316L SS		2.7	8.1	70.4		99.999% removal > 0.3micron
Compression	NE		S		05	A/B	CO <sub>2</sub> Dehydration Outlet Filter	Basket	03	0	0 n/a	_				36.6	+	36	$\vdash$		47 -5	+	-	m3/hr		316L SS		3.1		46.4		Alternative DT= -79°C for Rapid Depressurisation > 5micron
Compression	NE				09	A/B	CO <sub>2</sub> Dehydration Regeneration Gas	Basket	03	0	0 n/a	_	+			36.6	+	36	+		47 -5	+	-	m3/hr	ł	316L SS		2.3				Alternative DT= -79°C for Rapid Depressurisation > 5micron
Cooling Water	NE				10	A-D	Discharge Filters Cooling Water Filters	Basket	- 55	0	0 n/a			-	$\vdash$	10	-	17.5	$\vdash$			5 85		T/hr		CS	4.0		3.5			Alternative DT= -79°C for Rapid Depressurisation > 50 micron (4 x 33% units)
235mig Water			$^{-}$	+			- Journal of Filters	200.00		Ť	, in	+ "	+				+	1	$\vdash$		<del></del>	- 55	20004	.,,,,,			7.0		5.5			
Tanks																																
Carbon Capture	NE		т	1	01		Lean Amine Tank	Vertical - API 650	02	0	0 n/a	a n/	/a			Atm		Amb			0.15 -5	5 85	3187	m <sup>3</sup>		316L SS		14.2	22.0			Pressure at top is 0.04 barg (vent connected to absorber)     Double walled tank
Carbon Capture	NE		Т	0	03		Fresh Amine Tank	Vertical - API 620		0	0 n/a	a n/	/a								0.2 -5	5 85	6516	m <sup>3</sup>		316L SS		20.0	22.0			* Lined carbon steel could be considered as a lower cost alternative  * Pressure at top is 0.04 barg (vent connected to absorber)  * Dip Tubes
Carbon Capture	NE				07		Amine Drain Tank	Horizontal		0	0 n/a	_					+	-	$\vdash$			5 160		m <sup>3</sup>		316L SS	9.0		$\dashv$			* Sized for 5 trains Underground Horizontal Tank
Carbon Capture	NE		T		08		Degraded Amine Drain Tank	Horizontal		0	0 n/a	_	_			0.06		20		-0.5	1 -5			m <sup>3</sup>		316L SS	3.7	10.5		12.4		Underground Horizontal Tank  Underground Horizontal Tank, Includes a mixer.
Carbon Capture	NE				09		Waste Wash Water Tank	Vertical		0	0 n/a					Atm		Amb			ATM -5	5 85	13512	m <sup>3</sup>		CS + 3mm CA		26.7	24.1			Sized for 5 trains
			_							_		$\perp$					_	L	$\sqcup$			_	1	_								
Carbon Capture Carbon Capture	NE NE		-+		15 10		Amine Maintenance Tank  Chemical Sewer Tank	Vertical Horizontal		0	0 n/a	a n/ a n/	-	_	1	Atm Atm	+	Amb Amb	_		ATM -5	5 85 5 100	_	m3 m³		316L SS CS Lined	9.0	26.0 3.9	-	133 105.6		Sized to hold inventory of 1 train during maintenance Underground Horizontal Tank
Carbon Capture	NE		T		14		Thermal Reclaimer No 1 Feed Tank	Vertical		0	0 n/a	_	_			Atm		Amb			0.29 -5	_		m <sup>3</sup>		316L SS	3.0	8.4	$\overline{}$	.55.6		Pressure at top = 0.04 barg (Vent connected to Absorber)
Utilities	NE		Т		05		Aqueous Ammonia Tank	Horizontal		0		a n/				Atm		Amb	_			5 85		m <sup>3</sup>		CS	12.0	4.0				Originally sized for 2 off GTs - resized for 5
Utilities	NE		Т	0	04		Demineralised Water Tank	Vertical - API 650		0	0 n/a	a n/	/a			Atm		Amb			Atm -5	5 85	7000	m³		CS Lined		22.5	20.0			Sized for 5 trains
Utilities	NE		Т	0	06		Raw / Fire Water Tank	Vertical - API 650	<del>                                     </del>	0	0 n/a	a n/	/a	+		Atm	+	Amb	$\vdash$		Atm -5	5 85	75500	m <sup>3</sup>		CS Lined	<u> </u>	70.0	20.0	$\dashv$		Sized for 5 trains
Utilities	NE				11		47WT% Caustic Storage Tank	Vertical - API 650	<u> </u>	0	0 n/a	_				Atm	1	Amb			ATM -5	_		m <sup>3</sup>		CS Lined		12.0	_			Sized for 7 days storage



PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00005

PLANT AREA		EQ	UIPME	NT NUM	IBER		ITEM DESCRIPTION	TYPE	PFD Number		ELECTRIC	CAL POW	/ER		PERATING PRESSURE		PERATIN MPERATI		DESIGN PRESSUR	E TE	ESIGN MPER- TURE	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DII	MENSION	IS	WEIGH	HT REMARKS
	ASSET CODE	AREA / UNIT CODE		TRAIN	SEQUENCE	REDUNDANCY TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)  VOLTAGE (HV, MV,	CCS STANDBY (kW)	DUTY - INTERMITTENT (kW) DUTY - STANDBY	MIN (barg)	NORMAL (barg) MAX (barg)		NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)
Utilities	NE		Г	0	12		Concentrated Sulphuric Acid Tank	Vertical - API 650		0	0 n/a	n/a			Atm		Amb		AT	TM -5	85	100	m <sup>3</sup>		CS + 6mm CA		4.0	8.0		MOC: In accordance with NACE SP0294. Sized for 7 days storage
Utilities	NE	-	Г	0	02		Towns Water Break Tank	Vertical - API 650		0	0 n/a	n/a			Atm		Amb		AT	TM -5	85	208	m <sup>3</sup>		CS Lined		6.0	8.0		
											_									_								_		
Packages Power	NE		J	1	13		Anti Icing Skid				LV	n/a		+														-		
Power	NE		,		14		CO <sub>2</sub> / N <sub>2</sub> Storage Skid			0	0 n/a	n/a		+				$\vdash$	-		+	<u> </u>						$\dashv$	_	Fire Fighting for Gas Turbines
Power	NE		,		07		Condensate Polishing Plant		01	0	0 LV	n/a		+	10		30		1	19 90		311	T/hr		316L SS			-		Polishing of Condensate Return from Carbon Capture Unit
Power	NE		J		09		HRSG Chemical Feed Skid	API 675 Pumps		2	5 LV	n/a		1			20		_	12 -5	85				316L SS	8.0	3.0	2.7	7.0	Boiler Feedwater Dosing Chemicals - O2 Scavenger, Alkaline, Corrosion
Carbon Capture	NE		J	<del></del>	03		Thermal Reclaimer Unit	Ta voto t amp	02		15 LV	7								5.5 -5	335	206	m <sup>3</sup> /hr		316L SS	38.7		_		Inhibitor
			_		_	Δ/Ε	Thermal Reclaimer Vacuum								0.1		0.5				+						. 5.0	$\overline{}$	2.0	
Carbon Capture	NE		J	0	15	A/B	Packages			18	44 LV	18			-0.1		35		FV 3.	.5 -5	85 / 170	206	m³/hr		316L SS				3.0	
Carbon Capture	NE		J	_	04		Ion Exchange Package		02		8 LV	4										22	m³/hr		316L SS	11.1	11.1			
Compression	NE				01		CO <sub>2</sub> Compression Package	Integral Geared	03		13.74 LV	106		-	0.2/183		123			00 -5	150	230	T/hr		316L SS	25.0	18.0	9.0		
Compression	NE				02		CO <sub>2</sub> Dehydration Package	Mole Sieve	03	0	0 n/a	0		-	37.9			$\vdash$		17 -5	150	269	T/hr		316L SS	N/A			N/A	Equipment elsewhere - line item for price for design and mole sieve
Compression	NE	-	J		10		Tracer Dosing Package	API 675 Pumps			0.1 LV	0		-						00 -5	85	100	ppbv		316L SS	2.2	1.2	_	0.9	Addition to give CO <sub>2</sub> smell to allow leakage detection
Cooling Water	NE		-	-+	11		Chemical Dosing Package	API 675 Pumps		33	37 LV	n/a		+					1.	12 -5	85	<del> </del>				11.0	3.5	4.0	30.0	Cooling Water Dosing Chemicals Includes CCGT + Ion Exchange + Waste Wash Water + Acid Wash Effluent
Water Treatment	NE				05		Water Treatment Plant				671.8 MV	3760		-			20	$\vdash$		-5	85	13844	m³/hr		Various	644.2	128.8		_	Treatment 3 x 50% machines
Utilities	NE	ι	J	0	06	A/B/C	Instrument Air Compression Package	Centrifugal		1690	2700 MV	n/a			8.5		20		1	10 -5	85	145	m³/min	FAD		8.1	2.4		22.7	Sized for Carbon Capture and CCGT (Refer to Utilities Schedule)
Utilities	NE		_		12		Demineralisation Package	RO + Ion Exchange			360 LV	n/a		_								448	m <sup>3</sup> /hr			40.6	12.7			Sized for 5 trains
Utilities	NE	l	J	0	80		Ammonia Tanker Unloading			0	0 LV	n/a		-				$\vdash$	FV 9	9 -5	85	<u> </u>			CS				0.8	
																												_		
Power	NE	١ ,	,	1	01		HP Steam Drum	Horizontal	01	0	0 n/a	n/a			173.3		353.9		20	06 -5	420				15NiCuMoNb5-6-4	17.0	1.9		130	Part of HRSG
Power	NE		-		02		IP Steam Drum	Horizontal	01	0	0 n/a	n/a		+	36.6		245.1	<del>   </del>	-		1.20				CS					Part of HRSG
Power	NE				03		LP Steam Drum	Horizontal	01	0	0 n/a	n/a		+	3.792		141.7					<u> </u>			CS					Part of HRSG
Power	NE	١ ١	/		31		Oil / Water Separator	Horizontal		0	55 LV	n/a	45	1								136	m³/hr		cs	2.0	2.0	2.0	2.2	
Power	NE	١ ١	/	1	23		Blowdown Vessel / Tank	Vertical		0	0 n/a	n/a			ATM		100		FV 3	3.5 -5	180	5	m <sup>3</sup>		CS		1.3	4.0	2.2	
Power	NE	\	/	1	27		Fuel Gas Scrubber	Vertical		0	0 n/a	n/a			48 65	1	25	38	8	35 -29	55	2	m <sup>3</sup>		CS		1.0	2.4	2.9	
Power	NE	\	/	1	05		Feedwater Tank	Horiz / Vertical	01	0	0 n/a	n/a			3		46		8	8 -5	200	659	T/hr		Alloy Steel	20.5	4.3	8.3	85.0	Including Deaerator
Power	NE	١ ١	/	1	25	A/B	Flash Tanks (Start-Up & Shut Down)	Vertical		0	0 n/a	n/a			1.3		575		7	7 -5	600	16	m <sup>3</sup>		Alloy Steel		2.0	4.8	18.5	
Power	NE	'	/	1	26		Drain Vessel	Vertical		0	0 n/a	n/a			1.3		575		7	7 -5	600	16	m <sup>3</sup>		Alloy Steel		2.0	4.8	18.5	
Power	NE	١	/	1	22		Instrument Air Buffer Vessel - CCGT	Vertical		0	0 n/a	n/a			8.5		25		1	10 -5	85	90	m <sup>3</sup>		316L SS		3.2	10.0	25.2	
Power	NE	١	/	1	24		Flash Drum	Vertical		0	0 n/a	n/a			17		200		FV 1	19 -5	230	6	m <sup>3</sup>		CS		1.4	3.4	3.4	
Natural Gas	NE	'	/	0	04		Natural Gas Pig Receiver	Horizontal	01	0	0 n/a	n/a		45	65	1		38	8	35 -29	55	158	Nm³/hr		cs	5.1	1.3	1.3	13.9	
Natural Gas	NE	\	/	0	32		Natural Gas Pig Launcher	Horizontal		0	0 n/a	n/a		45	65	1		38	8	35 -29	55	158	Nm³/hr		cs	5.1	1.3	1.3	13.9	Located at NTS connection
Carbon Capture	NE	\	/	1	06		Direct Contact Cooler	Rectangular Tower	02	0	0 n/a	n/a			0.063		70		0.0	085 -5	85	254	T/hr (CO <sub>2</sub> )		Lined Concrete 304SS Internals	18.1	17.0	28.2		Column lining design temperature 120°C which could be subject to 110°C flue gas during start-up Scale up using flue gas flow rate: refer to 181869-0001-T-EM-CAL-AAA-00-00004 rev A02
Carbon Capture	NE	,	/	1	07		CO <sub>2</sub> Absorber	Rectangular Tower	02	0	0 n/a	n/a			0.026		30		0.0	085 -5	85	254	T/hr (CO <sub>2</sub> )		Lined Concrete 304/316SS Internals	34.0	17.0	64.3		* High efficiency mist eliminator at the top of the water wash * Knit mesh mist eliminator at the top of acid wash section * High quality gravity distributor * Leak & splash proof chimney tray * Structured packing * Shoepentouter inlet devices (two off) * Top =dia 5.9m, Middle = dia 10m, Top = dia 8m.
Carbon Capture	NE	,	/	1	08		Amine Stripper	Vertical	02	0	0 n/a	n/a			1		122.3		3.	i.5 -5	160	228	T/hr (CO <sub>2</sub> )		CS with 316L Cladding		9.6	34.6	261.0	* Upper rectification: predistributor, distributor (with chimney tray), splash plate, demister mat * Stripping: predistributor, distributor (with chimney tray), demisters * Structured packing
Carbon Capture	NE	\	/	1	09		Amine Reflux Drum	Vertical	02	0	0 n/a	n/a			1		26.3		3.	.5 -5	105	228	T/hr (CO <sub>2</sub> )		316L SS		4.5	8.0	31.0	* Half open pipe inlet device * Mesh * Mish Eliminator
Carbon Capture	NE	<del>                                     </del>	/	1	21		Vent KO Drum	Horizontal		0	0 n/a	n/a	<del>                                     </del>	+	<del>                                     </del>		$\vdash$		FV 1	10 -79	160	15	m <sup>3</sup>		316L SS		1.9	4.5	2.8	* Mist Eliminator  Kept pressurised with Instrument Air
Carbon Capture	NE				38		CC Unit Condensate Drum	Vertical		0	0 n/a	_		1			$\vdash$			5 -5	+	<del>                                     </del>			CS + 3mm CA				7.4	Includes inlet hood and wear plate
Carbon Capture	NE	,	/		28		Thermal Reclaimer Column No 1	Vertical			0 n/a									5.5 -5		36	m <sup>3</sup>		316L SS		1.7	8.9	3.9	* Packed section * Predistribution, distributor (with chimney tray) * Vane collector * Structured packing
Carbon Capture	NE	,	/	0	29		Thermal Reclaimer Column No 2	Vertical		0	0 n/a	n/a							FV 3.	5.5 -5	215	46	m <sup>3</sup>		316L SS		1.9	9.4	4.4	Packed section Predistribution, distributor (with chimney tray) Vane collector Structured packing



PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00005

PLANT AREA		EQ	JIPMEN	IT NUME	ER		ITEM DESCRIPTION	ТҮРЕ	PFD Number	ı	ELECTRICA	AL POW	/ER		OPERATING PRESSURE		OPERA TEMPERA		DESI PRESS		DESIG TEMPE ATUR	R-	\=	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	Di	IMENSION	s	WEIG	ЭНТ	REMARKS
	ASSET CODE	AREA / UNIT CODE		I KAIN	REDLINDANCY	TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW) INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (KW)	DUTY - INTERMITTENT (KW) DUTY - STANDBY	MIN (barg)	NORMAL (barg)	MAX (barg)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)		m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Carbon Capture	NE	,	′	0 3	0		Thermal Reclaimer Column No 3	Vertical		0 0	n/a	n/a			П				FV	3.5	-5	335 69	m <sup>3</sup>		316L SS		2.3	9.1	5.6		* Packed section * Predistribution, distributor (with chimney tray) * Vane collector * Structured packing
Carbon Capture	NE	١	/	0 3	3		Instrument Air Buffer Vessel	Vertical		0 0	n/a	n/a			8.5		25	5		10	-5	85			316L SS		3.4	10.1	23.8		
Compression	NE	١ ١	/	1 1	1		1st Stage CO <sub>2</sub> Compressor KO Drum	Vertical	03	0 0	n/a	n/a			0.15		25	5		3.5	-7	105 22	T/hr (CO <sub>2</sub>	.)	316L SS		3.4	5.5	11.5		Includes * Intlet hood and mist eliminator
Compression	NE	\	/	1 1	2		2nd Stage Integrated KO Drum	Vertical	03	0 0	n/a	n/a			1.95		122/	36				22	T/hr (CO <sub>2</sub>	,	316L SS						Part of Package U-101 Includes integral water cooled tube bundle
Compression	NE	,	,	1 1	3		3rd Stage Integrated KO Drum	Vertical	03	0 0	n/a	n/a			5.925		123/3	36				22	T/br		316L SS						Part of Package U-101
Compression	NE		,		4		4th Stage Integrated KO Drum	Vertical	03	0 0		n/a		+	15.52		121.	.8/	+	-	+	26	T/br		316L SS	+	+ +	+			Includes integral water cooled tube bundle Part of Package U-101
				_	_				+ +		+			+	+		36 116.	6	+			-+				1		-			Includes integral water cooled tube bundle Part of Package U-101
Compression	NE		/	_	5	_	5th Stage Integrated KO Drum	Vertical	03	0 0	n/a	n/a		_	38		36	5				26	(CO2		316L SS			_			Includes integral water cooled tube bundle
Compression	NE	\	/	0 1	7		CO <sub>2</sub> Pipeline Pig Launcher	Horizontal	03	0 0	n/a	n/a			181.7		36	3		200	-46	85 22	(CO <sub>2</sub>	2)	LTCS	11.4	1.1	1.3	15.6	19.0	
Compression	NE	\\	/	0 3	4		CO <sub>2</sub> Pipeline Pig Receiver	Horizontal		0 0	n/a	n/a		$\perp$	181.7		36	6		200	-46	85 22	T/hr (CO <sub>2</sub>	2)	LTCS	11.4	1.1	1.3	15.6	19.0	Located at Shore Crossing (except Teesside)
Compression	NE	\	/	0 3	5		CO <sub>2</sub> Pipeline Pig Launcher	Horizontal		0 0	n/a	n/a			181.7		36	5		200	-46	85 22	T/br		LTCS	11.4	1.1	1.3	15.6	19.0	Located at Shore Crossing (except Teesside)
Compression	NE	,	,	1 1	8 A/	/B	CO <sub>2</sub> Dehydration Absorber	Vertical	03	0 0	n/a	n/a		1	37.7					47	-5	150 269	T/br		316L SS		3.3	9.0			Internals = molecular sieves, cermaic balls, supports, grid support
Compression	NE	<b> </b>	,	1 1	9		Dehydration KO Drum	Vertical	03	0 0	n/a	n/a		+	35.4		36	<del>.   -</del>	1 1	47	-5	300 22	T/hr		316L SS	1	0.9	3.0			Material: CS clad with SS also acceptable Includes Inlet Hood and Mist Eliminator
Utilities	NE			0 3			Demin Water Expansion Vessel	Vertical	00	0 0		n/a		+	33.4		30	<u> </u>	+	5		85	(CO <sub>2</sub>	2)	CS + 3mm CA	1	$\perp$	4.0	3.0		Depressurisation = -79°C at 0 barg
Utilities	NE			0 3			Instrument Air Dry Air Receiver	Vertical		0 0	n/a	n/a		+	8.5		25	5	1 1		_	85 76	l m <sup>3</sup>		316L SS	1	1.0	4.0	0.0		
Miscellaneous																															
Power	NE	×	J	1 0	1		Steam Jet Air Ejector			0 0	n/a	n/a		+	+ +		-		+							1		-			Part of Water Cooled Condenser
Electrical Equipment																															
							Low Voltage Equipment														$\neg$							$\neg$			
Power	NE			1			Low Voltage Equipment			366	LV	n/a			+ +				+									_			Transformers, Circuit Breakers, Switchgear, MCCs, etc
Carbon Capture	NE		SG	_	1		LV Switchboard			342 446.		205																			Doubling GBC = 144 loads LV switchgear. Single TRU reduced number by 14 loads (EXCEPT FOR TRAIN 3)
Carbon Capture	NE		iG	1 0			LV Emergency Switchboard			147 290		88		+	+		_		+		_	_						-			
Compression  Compression	NE NE		iG iG	1 C	_		LV Switchboard  LV Emergency Switchboard			557 681. 145 260		334 87		+	+ +		_		+ +					+		1					Non-Process Equipment Loads
Utilities	NE		iG .		5		LV Switchboard			557 681.		n/a		1														-			
Utilities	NE	ES	iG	0 0	6		LV Emergency Switchboard			145 260	) LV	n/a																			
Facilities	NE	ES	SG	0 0	7		LV Switchboard			145 260	LV	n/a		_	++				$\perp$	$\perp$	_					1		_			
			+	_	-		Transmission Wellers T		-				<del>                                     </del>	+	++	_	+	+	+	+	_			1		1	$\vdash$	_	$\dashv$		
Power	NE		R	1 C	8		Transmission Voltage Equipment  Export Transformer		++	3660	HV	n/a	<del>                                     </del>	+	++		-	+	+	+	_		-	+		+	+	_	$\dashv$		
Power	NE		R	1 0	_	_	Unit Transformer		1	3000	HV	n/a	<del>                                     </del>	+	++		+	+	+	+		-		+		+		_	+		1
Power	NE		В	_	0		Circuit Breakers				HV	n/a																			
Power	NE			1			Miscellaneous PEACE Electrical Equipment				HV	n/a		T															$\Box$		Cost Bookmark
							·																								
			$\perp$				Generating Voltage Equipment							$\perp$				$\perp$													
Power	NE						Generator Buswork				MV	n/a	$\Box$		$+ \overline{1}$				$+\Box$	$\perp$				1			$\Box$		耳		
Power	NE	E	В	1 1	1		Circuit Breakers Miscellaneous PEACE Electrical		1		MV	n/a	<del>                                     </del>	+	++		_	+	+	$\dashv$	_			+		+	+ +	$\dashv$	_		
Power	NE		+	1	_		Equipment Equipment				MV	n/a		+	++		$\perp$	+	+	_				+		<del>                                     </del>			$\dashv$		Cost Bookmark
			+	-	+		Medium Voltage Equipment		++		+		$\vdash$	+	++		+	+	+	+	_		_	+		+	+	-+	$\dashv$		
Power	NE			1		_	Miscellaneous PEACE Auxiliaries		1	2902	MV	n/a		+	+ +		+	+	+ +	+	_			+		+	<del>   </del>	$\dashv$			1
Power	NE		_	1		_	Medium Voltage Equipment				MV	_		1						_+											Transformers, Circuit Breakers, Switchgear, MCCs, etc
Power	NE			-			HP Feedwater Pumps VFD				MV	n/a																			
Entire Plant	NE		SG .	_	_	_	MV Main Switchboard		$oxed{oxed}$		MV	n/a	$\Box$	_	$\perp$				$\perp$					1		1					
Carbon Capture	NE	ES	iG	1 1	3		MV Switchboard		I I	I	MV	n/a		I	1 1			l				I		1	I	1	1 1	I			I



PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00005

PLANT AREA			EQUIF	PMENT I	NUMBE	ER		ITEM DESCRIPTION	TYPE	PFD Number		ELECT	TRICAL	POWER		PR	ERATING ESSURE		OPERATI EMPERAT		DESI PRESS		DESIG TEMPE ATUR	R-	OUTY er Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	IMENSI	ONS	Wi	EIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	LV)	CCS STANDBY (kW)	INTERMITTENT (kW)  DUTY - STANDBY (kW)	MIN (barg)	NORMAL (barg)	MAX (barg) MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Carbon Capture	NE			1				Booster Fan VFD				1	MV	n/a																				Part of K-101 Supply
Compression	NE		ESG	1	14			MV Switchboard				1	MV	n/a																				
Compression	NE		ESG	1	15			Switchgear				1	MV	n/a															2.3	0.7	1.7	1.3		2 off - inlet and outlet. Part of Package U-101
Compression	NE		ETR	1	16			Transformer				1	MV	n/a																				Part of Package U-101
Compression	NE			1				CO <sub>2</sub> Com pressor VFD				1	MV	n/a															2.2	9.4	1.0	5.0		Part of Package U-101
uildings																																		
Facilities	NE		BLD	0	01			Warehouse			3	3	LV	n/a			+ve	5		35	N/A	N/A	N/A	N/A 8	8550 r	m <sup>3</sup>			47.5	30.0	6.0			Height to Eaves
Facilities	NE		BLD	0	02			Workshop			5	5 1	LV	n/a			+ve	5		35	N/A	N/A	N/A	N/A 1	14250 r	m <sup>3</sup>			47.5	30.0	10.0			Height to Eaves
Facilities	NE		BLD	0	03			Admin & Control Building			22	22	LV	n/a			+ve	20		25	N/A	N/A	N/A	N/A 2	2160 r	m <sup>3</sup>			40.0	12.0	4.5			Height to Eaves
Facilities	NE		BLD	0	04			Office Block			164	164	LV	n/a			+ve	20		25	N/A	N/A	N/A	N/A 1	16500 r	m <sup>3</sup>			33.0	25.0	20.0			Height to Top of Roof
Facilities	NE		BLD	0	05			Lockers, Welfare, & Training			49	49	LV	n/a			+ve	20		25	N/A	N/A	N/A	N/A 4	4950 r	m <sup>3</sup>			33.0	25.0	6.0			Height to Eaves
Facilities	NE		BLD	0	06			Guardhouse			1	1	LV	n/a			+ve	20		25	N/A	N/A	N/A	N/A	135 r	m <sup>3</sup>			10.0	3.0	4.5			Height to Eaves
Facilities	NE		BLD	0	07			Compression Electrical Substation			34	34	LV	n/a			+ve	10		40	N/A	N/A	N/A	N/A 1	11813 r	m <sup>3</sup>			75.0	35.0	4.5			Height to Eaves
Facilities	NE		BLD	1	08			Carbon Capture Electrical Substation			4	4	LV	n/a			+ve	10		40	N/A	N/A	N/A	N/A 1	1350 r	m <sup>3</sup>			25.0	12.0	4.5			Height to Eaves
Facilities	NE		BLD	1	09			Steam Turbine Building			34	34	LV	n/a			+ve	5		35	N/A	N/A	N/A	N/A 11	15200 r	m <sup>3</sup>			72.0	40.0	40.0			Height to Top of Roof
Facilities	NE		BLD	-	10	_		Cooling Water Power Distribution		1	2			n/a			+ve	10		40	N/A				720 r	m <sup>3</sup>			16.0	1	4.5			Height to Eaves
Facilities	NE		BLD	1	11			Centre HRSG Power Distribution Centre			1	1	LV	n/a			+ve	10	+	40	N/A	N/A	N/A	N/A	225 r	m <sup>3</sup>			10.0	5.0	4.5		+	Height to Eaves
Facilities	NE		BLD	1	12			Power Generation Power Distribution		1	2	2	LV	n/a			+ve	10		40	N/A	N/A	N/A	N/A	720 r	m <sup>3</sup>			20.0	8.0	4.5			Height to Eaves
Facilities	NE		BLD	1	13			Centre HV / LV Power Distribution Centre			2	2 1	LV	n/a		1 1	+ve	10	+	40	N/A	N/A	N/A	N/A	720 r	m <sup>3</sup>			20.0	8.0	4.5		1	Height to Eaves
	<del>†                                    </del>	1	+-	+	Ť	+		301110		1	Ė					1 1		<del>-  </del>	+						- '	+				T		$\vdash$	+	
										1					+	<del>   </del>			+							$\dashv$							+	
								Auxiliary Load and Losses	Total		76454		8	634		1 1										$\dashv$								Note: Matt back checked against total for the Power Gen before adding other
								Common			8999			761																				areas
								Common / 5			1800			752																				
								Loads Per Train			69255		5	625																				



SNC-Lavalin UK Limited Woodcote Grove Ashley Road, Epsom, Surrey KT18 5BW, United Kingdom

#### **Attachment 2.5 - Combined Case**



PROJECT No.
PROJECT NAME
LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE 181869-0001-T-EM-MEL-AAA-00-00006

A02

NOVEMBER 2017

PLANT AREA		EQ	UIPME	NT NUM	BER		ITEM DESCRIPTION	TYPE	PFD Number		EL	ECTRICAL	. POWER			PERATING RESSURE		PERATIN		DESI PRESS		DESIG	ER-	DUTY	SLIN	BARE HEAT TRANSFER AREA or ΔP	MATERIAL OF CONSTRUCTION	DIMEN	SIONS	WEIGH	T REMARKS
									Number						'			=				ATU	RE	(Per Unit)	5	(Per Unit)	MATE				
	ASSET CODE		EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY TRIM OR AUX ELEC	PECCOL		181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (KW) DUTY -	DUTY - STANDBY (kW)	MIN (barg)	NORMAL (barg) MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)			m²	) (m/TT/IVI)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)
Steam Generation Equ	uipment																														
Power	NE		В	1	01		Heat Recovery Steam Generator	Horizontal Drum	01	0	0	n/a	n/a			173.3		647.6			190	-5	600	600718	kW		CS (TP409 / T91 / T22 on high temp side) 4(	0.0 25	i.0 31	.0	Includes SCR catalyst, CO calayst, and Ammonia System
Power	NE		В	1	02		Auxiliary Boiler	Package		112	167	LV	n/a			7		220			10	-5	250	23	T/hr		CS (SA 192 Tubes)	8.3	1.3 4	.7 103 1	51.0 Assume 1 Auxiliary Boiler per Train
-		_			_																	_									
Compression Compression	NE		С	1	01		CO <sub>2</sub> Compressor	Centrifugal	03	23/123	25800	MV	0			See Pkg	Below														Part of Package U-101
Compression	INE			-	01		O2 compressor	Centunugui	00	20420	20000					OCC TRG	DCION														Motor sizing includes 10% API 617 Margin
Stack																															
Power	NE		D	1	01		Stack	Self Supporting	02	0	0	n/a	n/a			0.013	]	87.77	]	Ī		-5	750	3551	T/hr		CS - outer 316Ti - liner	10	0.0	0.0	Includes baseplate, anchor bolting, inner liner, outer shell, top cover, insulation, Flue Gas Inlet, Access/cleaning doors, condensation drain,
Power	NE	+	D	1	03	_	Auxiliary Boiler Stack	Self Supporting		0	0	n/a	n/a		+	0.02	$\vdash$	184	$\vdash$		+	-5	750		$\dashv$		CS	+	.0 3	0.0	ladders, platforms, AWLs, sample points, earth points, lifting lugs,
Carbon Capture	NE	_	D		02		CO <sub>2</sub> Vent Stack	Self Supporting		0	0		n/a			0.72		-10					250	229306	kg/hr		316L SS	30			Sch 10S
Heat Exchangers Power	NE		E	1	02		Condenser (Water Cooled)	2 pass	01	0	0	n/a	n/a			-0.93		39.16		FV	1	-5	110	355487	kW	12055	304 SS Tubes 20	0.7	5.1	510.0	Including steam ejectors for vaccuum
Power	NE		E		03		Fuel Gas Heater	Shell & Tube	01	0	0		n/a			49.1 / 36.6		204.4 / 242.9				-5	310		kW	500			).9	23.9	Feedwater - Tubeside, Fuel Gas - Shellside
Power	NE		E	1	04		Gland Steam Condenser	Shell & Tube	01	0	0	n/a	n/a		1					FV/0	.45/34	-5	270 / 100	378	kW	14	SS Tubes 4	4.5 1	.7 ;	3.1 3.5	Part of Steam Turbine Supply
Power	NE		E	1	22		Electric Superheater	Electric Heater		0	4415	MV	n/a			49.1		70			55	-5	310	2677	kW		316L SS / Alloy 800 pockets	5.5 1	.3		Start Up Heater (sized to provide superheat only), includes pressure vessel, thyristor control panel (safe area)
Power	NE		E	1	23	A-E	GT + Generator Lube Oil Cooler	Plate & Frame		0	0	n/a	n/a			3		37.5			6	-5	50	1417	kW						Part of RS-101
Power	NE		E			A-F	GT Generator Cooler	Plate & Frame		0			n/a		-	3		37.5			-	-5	50	-	kW			_	_	$\perp$	Part of R-101
Power	NE NE		E E	_		A/B A/B	ST + Generator Lube Oil Cooler ST Generator Cooler	Plate & Frame Plate & Frame		0	0		n/a n/a	<del> </del>	+	3		37.5 37.5	$\vdash$			-5 -5	50 50		kW			+	+	+	Part of RS-102 Part of R-102
Carbon Capture	NE		E		01		Gas-Gas Heat Exchanger	Rotary	02	15	15	LV	0		1			01.0				-5	130		kW	13521	Weathering Steel 15	5.6 15	i.6 4	1.5 340.2	Purge and Scavenge Fan shall be part of this package
Carbon Capture	NE		Е	1	09	A/B/C	Lean / Rich Amine Exchanger	Welded Plate	02	0	0	n/a	n/a			5.1 / 5.9		122.3 / 111			18	-20	140	46828	kW	8709	316L SS 2	2.5	3.5 18	3.0 400.0 4	e.g. Packinox type or equal. Duty was for 2 units - now split into 3 units Assume no change - would be minor difference but not affecting unit pricing
Carbon Capture	NE	+	E	1	10	A-F	CO <sub>2</sub> Stripper Reboilers	Welded Plate	02	0	0	n/a	n/a			2.1		122.3			5	-5	150	34232	kW	785	316L SS 2	2.2	.4	6.4	
Carbon Capture	NE		E	1		A/B	Overhead Condenser	Welded Plate	02	0			n/a			2		26				-5	160	27456	kW	571		2.4	.3	4.5	
Carbon Capture  Carbon Capture	NE NE			1	_	A/B	Wash Water Cooler  Lean Amine Cooler	Welded Plate Welded Plate	02 02	0		n/a n/a	n/a								10	-5	85		kW	937		4.6	.3 ;	3.0 0.0 - 15.0	
Carbon Capture	NE	_	_	1	_	A/B/C	DCC Cooler	Plate & Frame	02		0		n/a								_	-5	85		kW	0	316L SS -			- 0.0	Duty was for 2 units - now split into 3 units
Carbon Capture	NE		_		15		CO <sub>2</sub> Vent Vapouriser	Inverted Kettle			0	n/a								FV	10 / 27	-79		-	kW	67		3.7 (	).9	3.3	
Carbon Capture	NE	-	-	1	_	A/B	CC Unit Condensate Cooler	Plate & Frame				n/a										-	160	_	kW	170		3.3	-	1.0 0.7	
Carbon Capture  Carbon Capture	NE NE	-	-		18 19		Thermal Reclaimer Pre-Heater  IX Amine Cooler	Welded Plate Welded Plate		_	_	n/a n/a	_									-5 -5	160 85	_	kW kW	225 219		4.1 1 4.1 1	-	2.0 4.6	5.5
Carbon Capture	NE	_	_	1 :	_		IX Demin Water Cooler	Plate & Frame				n/a									9	$\overline{}$	$\overline{}$	_	kW	35		2.6	_		
Compression	NE		E	1	05		6th Stage Cooler	Shell & Tube	03	0	0	n/a	n/a			74.4		106.3 / 36						7889	kW		cs				Part of Package U-101
Compression	NE		E	1	06		7th Stage Cooler	Shell & Tube	03	0	0	n/a	n/a			150.7		89.1 / 36						10060	kW		cs				Part of Package U-101
Compression	NE		E	1	07		CO <sub>2</sub> Dehydration Electric Heater	Electric Heater	03	3488	3800	MV	0			37.4		22.9 / 290			47	-5	310	3488	kW		316L SS 5	5.6 1	.6	2.4 4.0	Alternative DT= -79°C for Rapid Depressurisation
Compression	NE				08		Dehydration Cooler	Shell & Tube	03	0	0		n/a			36.6			Ш			-5	310		kW	166	316L SS				Alternative DT= -79°C for Rapid Depressurisation
Cooling Plant Utilities	NE NE	-	E E		21 17	A-T	Cooling Towers  47WT% Caustic Storage Tank Electric Heater	Wet Electric Heater		3	5		n/a n/a			15		13 / 23 ATM			6 ATM	-5 -5	50 85	35849 3	kW	856 kg/s		_	0.2	0.0	Dimensions each cell
I	\																														
Instrumentation and C	NE NE		DC	1	06	A-H	Sampling	Analyser		8	8	LV	n/a														304 SS	2.0	2.0 :	3.0 2.3	Feedwater and Steam Sampling
Power	NE		DC		03		Continuous Emissions Monitoring	Analyser		Ė	Ť		n/a		1				$\vdash \vdash$			$\dashv$	$\neg$		$\dashv$					<del>                                     </del>	Measurements NOx, SO₂, CO₂, O₂, H₂O, °C, and flow
Natural Gas	NE				01		System (CEMS) Natural Gas Metering	Orifice	01	0			n/a	T	1	65-85	1		38		85	-5	85	158	Nm <sup>3</sup> /s		Carbon Steel 3	5.0	6.0	5.9 122.7	Metering - size based on similar scope pipeline meter
Natural Gas	NE		СР		01		Natural Gas Panel	Panel		1	1		n/a															_	0.8		Safe Area Panel
Natural Gas	NE	J	DC	0	01		Natural Gas Analyser House	I	l		]	LV	n/a						<b> </b>	I			I					2.0	2.0	2.7 2.3	Analyser House and Speciality Bottle House



PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00006

PLANT AREA			EQUIPI	MENT N	UMBER	ł		ITEM DESCRIPTION	ТҮРЕ	PFD Number		ELE	CTRICAL	L POWE	ER			RATING SSURE		PERATIN MPERATI		DESIGN PRESSURE	_ TE	ESIGN EMPER- ATURE	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP	MATERIAL OF CONSTRUCTION	DII	MENSIO	NS	WEIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (kW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (kW)	DUTY - INTERMITTENT (KW)	(kw)	<u> </u>	NORMAL (barg) MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg) MAX (barg)	MIN (°C)	MAX (°C)			m²	-0	Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes) OPERATING (tonnes)	
Compression	NE		JDF	0	02			CO <sub>2</sub> Metering	Coriolis	03	0		LV	0			1	50.5		36		16	5 -5	100	1140	T/hr		316L SS	35.0	6.0	7.0	122.7	Metering - size based on similar scope pipeline meter
Compression	NE		JCP	0	02			CO <sub>2</sub> Metering Panel	Panel		1	-	LV	1		_									<u> </u>				7.2			0.7	Safe Area Panel
Compression	NE		JDC	0	02			CO <sub>2</sub> Metering Analyser House					LV	_		_													2.0	2.0	2.7	2.3	Analyser House and Speciality Bottle House
Utilities	NE		JDC	0	05			DCS (ICSS)	Panel		110	110	LV																36.8	0.8	2.1	31.5 31.5	Price includes F&G and well as HIPPS
Fans																																	
Carbon Capture	NE		K	1	01			Booster Fan	Axial	02	13122	13900	MV	0		_	1.0	013 /		87.8					3551	T/hr	Δ 0.08bar	Steel Plate	9.9	9.3	8.1	111.4	
Carbon Capture	NE		KF	1	01	A-H	+	Booster Fan Motor Cooling Fans	Axial	02	24	$\vdash$	LV	0		$\dashv$	1.	093	+	07.0	$\vdash$		-	-	3331	1/111	Д 0.00bai	Steel Flate	3.3	5.5	0.1	111.4	Included in Pecetar Fone Cumply
Carbon Capture	NE		KU	1	01	A/B	+	Booster Fan Lube Oil Skids	Axidi		15		LV	15		$\dashv$	-+	+	+		$\vdash$		+	+	<del> </del>	+							Included in Booster Fans Supply  Included in Booster Fans Supply
Carbon Capture	NE		K	1	02			Damper Sealing Air Fan	Centrifugal		293		MV	0											1			Weathering Steel	4.0	2.2	3.2	10.7	Included in package with Gas Gas Heat Exchanger
Carbon Capture	NE		K	1	03			Damper Purge & Scavenge Air Fans	Centrifugal		6	7.5	LV	6											1500	m³/hr	800 mmWG	Weathering Steel	1.0	1.0	2.5	0.3	Included in package with Gas Gas Heat Exchanger
Cooling Plant	NE		EF	1	01	A-T		Cooling Tower Fans	Axial		2107	2600		632		$\dashv$	A	TM	1	10			-5		1578	T/hr							Total duty for CCGT + CCC
													$\neg$			一									1								
Mechanical Handling I	Equipmen	nt																															
Power	NE		L	1	01			Gas Turbine Overhead Crane	Double Girder Gantry		0	164	LV	n/a		164							-5		100	Т		cs					
Power	NE		L	1	02			Steam Turbine Overhead Crane	Double Girder Gantry		0	-		n/a		115							-5		70	T	40m Span	CS					
Power	NE		L.	1	03		-	Steam Turbine Auxiliary Crane	Double Girder Gantry		0			n/a		20		_	_		$\vdash$		-5		16	T	10m Span	CS					
Compression Water Treatment	NE NE		L	0	04 05		-	CO <sub>2</sub> Compressor Overhead Crane	Single Girder		0	_	LV	n/a n/a		20 10	_	_	-		$\vdash$	_	-5 -5	_	35 8	T		cs cs					
Water Treatment Water Treatment	NE		L	0	06			Demin Plant Hoist  Waste Water Treatment Plant Hoist	Single Girder Single Girder		0	-	_	n/a		10		_	+		$\vdash$		-5 -5		8	'   T		CS					
Utilities	NE		L	0	07			Fire Fighting Pump Station Hoist	Single Girder		0	-		n/a		6							-5		4	т Т		cs					
Facilities	NE		L	0	08			Workshop building Crane	Single Girder		0	-	LV	n/a		21							-5	_	10	Т	30m Span	cs					
Facilities	NE		L	0	09	A/B		Weighbridge			0	1	LV	n/a		1							-5		60	Т		cs	20.0	3.0		12.5	
Mixer																_																	
Carbon Capture	NE		М	0	14			Thermal Reclaimer No 1 Feed Tank Mixer			17	22	LV	22			А	tm		Amb		0.2	9 -5	85				316L SS		1.0		0.8	
Carbon Capture	NE		М	1	08			Amine Degraded Tank Mixer			17	22	LV	22		_	0	.06		20		1	-5	160				316L SS		1.0		0.8	
_																$\dashv$																	
Pumps	NE		Р	1	01	A/P		Condensate Duma	Contrifugal	01	426	950	MV	n/o				4		20.7		40		00	574	T/hr	@36.92m	Chromo Stool	4.0	1.0	4.0	10.0	Describes accessive for LD Clare in Operator of LD Foodwater Dump
Power	NE		P	1	02	A/B A/B		Condensate Pump  HP Feedwater Pump	Centrifugal Ring Section	01 01	5143	-	_	n/a n/a		$\dashv$		50.5	+	39.7 147	$\vdash$	400		_	589	m <sup>3</sup> /hr	@2438.4m	Chrome Steel Chrome Steel	4.0 6.4	1.8 2.3	1.8 3.3	21.4	Provides pressure for LP Stage - i.e. Operates as LP Feedwater Pump
Power	NE		P	1		A/B/C	+	IP Feedwater Pump	Ring Section	01	281	<del>                                     </del>	_	n/a		$\dashv$		8.5	+	143	<del>   </del>	1400	-5		71	m³/hr	@548.6m	Chrome Steel	6.0			7.0	<u> </u>
Power	NE		P	1	11	A/B	_	LTE Recirculation Pump	Centrifugal	Ŭ.	1		LV			$\dashv$		.023	+	104.4	<del>                                     </del>	-	-5	_	32	m³/hr	@1.2m	Chrome Steel		0.9			
Power	NE		P	1	12	A/B	+	Auxiliary Boiler Feedwater Pumps	Centrifugal		0		_	n/a	14	$\dashv$		7	+	104.4		10			25	m³/hr	@7.2m	Chrome Steel	1.8	1.1	0.7	1.1	
Power	NE		Р	1	13	A/B	+	GT + Generator Lube Oil Pump	Centrifugal			-		n/a		$\dashv$			1					1	1								
Power	NE		Р	1	14	A/B		GT Generator Control Oil Pump	Centrifugal				LV	n/a																			
Power	NE		Р	1	15	A/B		ST + Generator Lube Oil Pump	Centrifugal		0	0	n/a	n/a			(	6.5		40					248	m³/hr							Shaft Driven
Power	NE		Р	1	17	A/B	+	ST Generator Control Oil Pump	Centrifugal		30	-		n/a							$\sqcup$		$\perp$		<u> </u>	4							
Power	NE		P	1	20	A/B		Clean Drains Return Pump	Centrifugal		26	-		n/a		$\dashv$		2.7	_	20	$\vdash$	3.5	_		316	m³/hr	@15.2m	cs		1.1	1.0	1.6	
Cooling Plant Carbon Capture	NE NE		P P	1	16 04	A-F A/B	+	Cooling Water Pump  Absorber Feed Pumps	Centrifugal Centrifugal	02	4984 629	6267 1400		1495 377		$\dashv$		3	+	17.5 53	$\vdash$	6 10		_	12321 2829	T/hr	@23.7m @69.5m	CS 316 SS	7.2 5.0	1.9		18.0 11.0	5 pumps operating, 1 spare
Carbon Capture	NE NE		P	1	05	A/B	+	Absorber Feed Pumps  Lean Amine Pumps	Centrifugal	02	371		MV			+		4.1	+	122.4	$\vdash$	10		_	3042	m <sup>3</sup> /hr m <sup>3</sup> /hr	@69.5m @39.3m	316 SS 316 SS		1.7		9.1	
Carbon Capture	NE		P	1	06	A/B/C		Rich Amine Pumps	Centrifugal	02	711	-	_	427		$\dashv$		5.6	+	41	<del>   </del>	13.	_		1417	m³/hr	@129.4m	316 SS	3.5			13.0	3 x 50%
Carbon Capture	NE		Р	1	07	A/B	-	Stripper Reflux Pumps	Centrifugal	02	21	-	_	12	-+	$\dashv$		1	1	26		10	_		78	m³/hr	@61.1m	316 SS	_	1.1		1.1	1 Pump is a Spare for IX Transfer Pump
Carbon Capture	NE		Р	0	17	A/B		Waste Wash Water Pumps	Centrifugal		10	-	LV	6								10		_	64	m³/hr	@22.8m	cs	1.8		1.0	1.0	
Carbon Capture	NE		Р	1	19			Chemical Sewer Tank Pump	Centrifugal		8	11	LV	5								10	) -5	85	46	m³/hr	@19.5m	316 SS					
Carbon Capture	NE			1	18	_		CC Unit Condensate Pumps	Centrifugal		75		LV	_			7.5	8.5		50			-5	_	355	m³/hr	@44.6m	CS / SS Impeller		1.1		2.0	
Carbon Capture	NE		P	1	08	A-D		Direct Contact Cooler Pumps	Centrifugal	02	501		MV			_		5.5	_	41	$\sqcup$	10		_	2120	m³/hr	@ 61.4m	CS		1.2		5.5	
Carbon Capture	NE		P P	1	09	A/B		Acid Wash Pumps	Centrifugal	02	81	-	LV MV	_		$\dashv$		7.4	_	85	$\vdash$	10			1195	m <sup>3</sup> /hr	@18.7m	316 SS	3.5			6.0	<u> </u>
Carbon Capture  Carbon Capture	NE NE		P	0	10 28	A/B A/B	+	Water Wash Pumps Fresh Amine Transfer Pumps	Centrifugal Centrifugal	02	530	1200 5.5		318 0	-+	$\dashv$		2.2	+	46 25		10 35	_		4205 28	m <sup>3</sup> /hr m <sup>3</sup> /hr	@34.9m @22.8m	316 SS 316 SS	5.0 1.8	1.7 0.8	0.7	11.0 0.6	
Carbon Capture	NE		P	0	29	1 7/6		Amine Container Pump	Centrifugal		1	2.2		0		$\dashv$		1	+	25		35		_	20	m³/hr	@11.3m	316 SS		0.8		0.6	
Carbon Capture	NE		P		25			IX Amine Pump	Centrifugal		130	-	LV			_		3.8		85			-5	_	433	m³/hr	@74.3m	316 SS		1.1	1.0	3.1	



PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00006

PLANT AREA		I	EQUIPM	IENT N	JMBER			ITEM DESCRIPTION	ТҮРЕ	PFD Number		E	ELECTRIC	CAL POWER	R		OPERATIN PRESSUR			ERATING PERATUR		DESIGN PRESSURE	DESIGN TEMPER ATURE	DUTY (Per Unit	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	MENSIC	ons	WEIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (kW)	DUTY - INTERMITTENT (KW)	DUTY - STANDBY (kW)	MIN (barg) NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MIN (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	
Carbon Capture	NE		P	1	26			Amine Drain Pump	Centrifugal		10	15		0			4.4			160		10		43	m³/hr	@49.7m	316 SS	1.8	0.9	0.8	8 0.5	
Carbon Capture	NE		Р	0	27		_	IX Transfer Pump Thermal Reclaimer NO. 1	Centrifugal		82	_	-	90	_		8.9			110	$\rightarrow$	10	_	329	m <sup>3</sup> /hr	@60.8m	316 SS	2.5		1.0		
Carbon Capture	NE		Р	0	21	A/B		MP Condensate Pumps	Centrifugal		6	+	LV	6	_		22			250	_	FV 27			m³/hr	@21m	CS	1.8	_	0.9		
Carbon Capture	NE		Р	0	22	A/B		Thermal Reclaimer NO. 2 MP Condensate Pumps Thermal Reclaimer NO. 3	Centrifugal		1	3	LV	1	_		22			250	_	FV 27	-5 2		m³/hr	@19.8m	CS	1.8		0.7		
Carbon Capture	NE		Р	0	23	A/B		MP Condensate Pumps	Centrifugal		2	3	LV	2			22			250	_	FV 27	-5 2	0 6	m <sup>3</sup> /hr	@19.7m	cs	1.8	0.9	0.7	7 0.7	
Compression	NE		Р	1	24	A/B		Process Condensate Return Pumps	Centrifugal	03	1	1.5	LV	0			1			20		35	-5	2.0	m³/hr	@32m	316 SS	1.0	0.5	0.5	5 0.2	
Utilities	NE		Р	0	13	A/B/C		Demineralised Water Pumps	Centrifugal		30	135	LV	n/a		90	5		5	8	20	10	-5 8	5 150	m³/hr	@50m	316 SS	2.1	1.2	1.0	0 1.3	1 Normal Operation - 3 pumps in operation at start-up
Utilities	NE		Р	0	14			Fire Water Pumps	NFPA 20		0		LV	n/a			11		5		20	15	-5 8	5 1000	m³/hr	@1500kpag	CS / SS Impeller	6.6	1.5	3.0	0 8.7	Diesel Engine Driven
Utilities	NE		Р	0	15	A/B	1	Fire Water Jockey Pumps	Centrifugal		38	+-	_	n/a		$\dashv$	7		5		20	15	-5 8	_	m³/hr	@73m	CS / SS Impeller	1.8	<b>!</b>	1.0		Keep fire water main pressurised
Utilities	NE		Р	0	30	A/B	-	47WT% Caustic Transfer Pump Concentrated Sulphuric Acid Transfer	Centrifugal	-	7	11		n/a	_	$\dashv$	5.5			15	$\dashv$	10	-5 8	_	m³/hr		CS 240 CS	1.3	0.5	0.5	5 0.3	
Utilities	NE		P P	0	31	A/B	-	Pump	Positive Displacement		0.02			n/a		_	5		-		20			0.2	m <sup>3</sup> /hr	@34.4m	316 SS	4.0		<b>.</b>	1 12	ļ
Utilities Utilities	NE NE		P	0	19 32	A/B A/B	-	Service (Raw) Water Pumps Towns Water Pump	Centrifugal Centrifugal		9.20	+	LV	n/a n/a	_	$\dashv$	5.4		5		20	10	-5 8 -5 8	_	m <sup>3</sup> /hr m <sup>3</sup> /hr	@31m @ 56.7m	CS / SS Impeller 316 SS	1.8	-	1.1 0.5		
Ountes	INL		•	0	32	A/D		Towns water rump	Centinugai		40	110		IVA			5.4		,	-	20	10	1 3 1 0	31	m /nr	@ 30.7111	310 33	1.5	0.5	0.0	0.5	
Power Generation																																
Power	NE		R	1	01			Generator		01	0	0	n/a	n/a										500	MWe							
Power	NE		R	1	02			Generator		01	0	0	n/a	n/a									$\perp$	232	MWe						369.0	Unabated Performance
Utilities	NE		R	1	03			Standby Emergency Power Generator			0	0	n/a	n/a										2680	kVA			Incl	Incl	Incl	Incl	
Power	NE		RG	1	01			Gas Turbine	Class H/J	01	1001		LV	n/a										500	MW			33.0	6.0	6.0	1,050	Includes auxiliary equipment such as Lube Oil Consoles (Dims turbine only)
Power	NE		RS	1	02			Steam Turbine	Multi-Casing with Steam Extraction	01	123		LV	n/a										232	MW			40.0	15.0	23.0	752	Advice from Vendors that would be multi casing or multi shaft machine for steam extraction. Includes auxiliary equipment such as Lube Oil Consoles
Litilities	NE		RE	1	03		-	Standby Emergency Power				13.2	LV	2/0	_	$\dashv$					$\dashv$	_	+	-	+			12.0	3.0		4 43.0	(Dims turbine only)
Utilities	INE		KE	'	03			Generation Engine	Diesel Engine		3	13.2	LV	n/a	-	-					$\dashv$	_	+		+			12.0	3.0	3.4	4 43.0	
Filters																																
Power	NE		S	1	01			Inlet Air Filter		01	0	0	n/a	n/a			ATM			ATM		ATM	-10 3	3342	T/hr		CS / PTFE	20.0	7.5	15.0	0	
Power	NE		S	1	07	A/B		Condensate Filter	Basket	01	0	0	n/a	n/a			4			40		30	-5 8	5 574	T/hr		CS	0.9	0.9	1.6	6 0.5	
Power	NE		s	1	06			Fuel Gas Coalescing Filter	Coalescing Elements		0	0	n/a	n/a			40			25		85	-5 8	5 92	T/hr	0.87 m <sup>3</sup>	CS / 316L Internals		0.8	3.7	7 4.0	Removal of solid particles 100% > 3 micron and entrained liquids
Carbon Capture	NE		S	1	04	A/B		Amine Filter	Cartridge	02	0	0	n/a	n/a			7.1			40		12	-5 8	5 118	m3/hr		316L SS		0.5	2.3	3	99% removal > 10micron
Carbon Capture	NE		S	1	80			Amine Drain Filter	Cartridge		0	0	n/a	n/a			3.6			40		7	-5 16	0 33	m3/hr		316L SS		0.3	2.3	3	99% removal > 10micron
Compression	NE		S	1	02			CO <sub>2</sub> Dehydration Filter Coalescer	Disposable Catridge	03	0	0	n/a	n/a			37.9			36		47	-5 16	0 3186	m3/hr		316L SS		2.7	8.1	1 70.4	99.999% removal > 0.3micron Alternative DT= -79°C for Rapid Depressurisation
Compression	NE		S	1	05	A/B		CO <sub>2</sub> Dehydration Outlet Filter	Basket	03	0	0	n/a	n/a			36.6			36		47	-5 16	0 2884	m3/hr		316L SS		3.1	2.6	6 46.4	> 5micron Alternative DT= -79°C for Rapid Depressurisation
Compression	NE		S	1	09	A/B		CO <sub>2</sub> Dehydration Regeneration Gas Discharge Filters	Basket	03	0	0	n/a	n/a	T		36.6			36	T	47	-5 3 <sup>-</sup>	0 1162	m3/hr		316L SS		2.3	2.6	6 21.3	> 5micron Alternative DT= -79°C for Rapid Depressurisation
Cooling Water	NE		S	1	10	A-D		Cooling Water Filters	Basket		0	0	n/a	n/a			10			17.5		12	-5 8	5 20534	T/hr		CS	4.0	7.0	3.5	5 11.0	> 50 micron (4 x 33% units)
													$\perp$	$\Box$							$\Box$		$\perp \perp$									
Tanks																																* Pressure at top is 0.04 barg (vent connected to absorber)
Carbon Capture	NE		Т	1	01			Lean Amine Tank	Vertical - API 650	02	0	0	n/a	n/a			Atm			Amb		0.15	-5 8	3187	m <sup>3</sup>		316L SS		14.2	22.0	o	* Double walled tank
Oratha Cont	\						<del>                                     </del>				<u> </u>	_	+.		-+	$\dashv$					$\dashv$	<del>   </del>	<del>                                     </del>		,		040' 22				1	* Lined carbon steel could be considered as a lower cost alternative  * Pressure at top is 0.04 barg (vent connected to absorber)
Carbon Capture	NE		T	0	03			Fresh Amine Tank	Vertical - API 620		0	0	n/a	n/a								0.2	-5 8	5 6516	m <sup>3</sup>		316L SS		20.0	22.0		* Dip Tubes * Sized for 5 trains
Carbon Capture	NE		T	1	07			Amine Drain Tank	Horizontal		0	_	_	n/a							_	1	-5 16		m <sup>3</sup>		316L SS	9.0				Underground Horizontal Tank
Carbon Capture	NE		T	1	08			Degraded Amine Drain Tank	Horizontal		0	0	n/a	n/a			0.06			20		-0.5 1	-5 16	0 91	m <sup>3</sup>		316L SS	3.7	10.5		12.4 103.7	Underground Horizontal Tank. Includes a mixer.
Carbon Capture	NE		Т	0	09			Waste Wash Water Tank	Vertical		0	0	n/a	n/a			Atm			Amb		АТМ	-5 8	5 13512	m <sup>3</sup>		CS + 3mm CA		26.7	24.1		Sized for 5 trains
Carbon Capture	NE		T	0	15			Amine Maintenance Tank	Vertical		0	0	n/a	n/a			Atm			Amb		ATM		_	m3		316L SS		26.0	12.2		Sized to hold inventory of 1 train during maintenance
Carbon Capture	NE		T	1	10			Chemical Sewer Tank	Horizontal		0	_	n/a	n/a			Atm			Amb	_	ATM		_	m <sup>3</sup>		CS Lined	9.0	_		105.6	Underground Horizontal Tank
Carbon Capture	NE NE		T	0	14 05			Thermal Reclaimer No 1 Feed Tank	Vertical Horizontal		0	_	_	n/a n/a			Atm Atm			Amb Amb		0.29		_	m <sup>3</sup>		316L SS CS	12.0	8.4 4.0	6.8	В	Pressure at top = 0.04 barg (Vent connected to Absorber)  Originally sized for 2 off GTs - resized for 5
Utilities	NE		1	U	US		+	Aqueous Ammonia Tank	Horizontal		U	U	n/a	ıva	-+	-	Atm			AIIIO	$\dashv$	Atm	-5   8	150	m <sup>3</sup>		US	12.0	4.0		+ +	Originally sized for 2 off GTs - resized for 5
Utilities	NE		Т	0	04			Demineralised Water Tank	Vertical - API 650		0	0	n/a	n/a			Atm			Amb		Atm	-5 8	7000	m <sup>3</sup>		CS Lined		22.5	20.0		Sized for 5 trains



PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00006

PLANT AREA		E	EQUIPN	IENT NU	MBER			ITEM DESCRIPTION	TYPE	PFD Number		E	ELECTRIC	CAL POWE	R		OPERAT PRESSU			PERATIN		DESIGN PRESSURE	DESIG TEMPE ATURI	R-	UTY r Unit)	UNITS	BARE HEAT TRANSFER AREA or $\Delta P$ (Per Unit)	MATERIAL OF CONSTRUCTION	DII	MENSIO	NS	WEIGHT	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY	TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	VOLTAGE (HV, MV, LV)	CCS STANDBY (kW)	DUTY - INTERMITTENT (KW)	DUTY - STANDBY (KW)	MIN (barg) NORMAL (barg)	MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg) MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes) OPERATING (tonnes)	
Utilities	NE		T	0	06			Raw / Fire Water Tank	Vertical - API 650		0	+-	n/a	n/a		_	Atm			Amb		Atm		_		m <sup>3</sup>		CS Lined		70.0	20.0		Sized for 5 trains
Utilities Utilities	NE NE		T	0	11 12			47WT% Caustic Storage Tank	Vertical - API 650 Vertical - API 650		0		n/a n/a	n/a n/a	-		Atm Atm	_		Amb Amb		ATM ATM		_		m <sup>3</sup>		CS Lined CS + 6mm CA		12.0	14.0		Sized for 7 days storage  MOC: In accordance with NACE SP0294. Sized for 7 days storage
Utilities	NE		<del>'</del>	0	02			Concentrated Sulphuric Acid Tank Towns Water Break Tank	Vertical - API 650		0	+	n/a	+ +	-+	$\dashv$	Atm	_		Amb		ATM		_		m <sup>3</sup>		CS Lined		6.0	8.0		INOC. In accordance with NACE SP0294. Sized for 7 days storage
											+ -																						†
Packages																																	
Power	NE		U	1	13			Anti Icing Skid					LV	n/a																			
Power	NE		U	1	14			CO <sub>2</sub> / N <sub>2</sub> Storage Skid		<u> </u>	0	+-	n/a	n/a									$\perp$			_							Fire Fighting for Gas Turbines
Power	NE		U	1	07			Condensate Polishing Plant		01	0	+	+	_			10	-		30		19	+ +		311	T/hr		316L SS					Polishing of Condensate Return from Carbon Capture Unit  Boiler Feedwater Dosing Chemicals - O2 Scavenger, Alkaline, Corrosion
Power	NE		U	1	09			HRSG Chemical Feed Skid	API 675 Pumps		2		LV							20		12		85				316L SS	8.0		2.7		Inhibitor
Carbon Capture	NE		U	0	03			Thermal Reclaimer Unit		02	11	15	LV	7	$\rightarrow$	-						FV 3.5	-5	335 2	206 n	n <sup>3</sup> /hr		316L SS	38.7	19.3	25.0		
Carbon Capture	NE		U	0	15	A/B		Thermal Reclaimer Vacuum Packages			18	44	LV	18			-0.1			35		FV 3.5	-5 85	/ 170 2	206 n	n <sup>3</sup> /hr		316L SS				3.0	
Carbon Capture	NE		U	0	04			Ion Exchange Package		02	7	8	LV	4											22 n	n³/hr		316L SS	11.1	11.1	5.0		
Compression	NE		U	1	01			CO <sub>2</sub> Compression Package	Integral Geared	03	106	189	LV	64			0.2 / 150.7			123		165	-5	150 2	230	T/hr		316L SS	25.0	18.0	9.0	356.0	No change to package / utilities as is same frame size compressor - just one less stage
Compression	NE		U	1	02			CO <sub>2</sub> Dehydration Package	Mole Sieve	03	0	0	n/a	0			37.9					47	-5	150 2	269	T/hr		316L SS	N/A	N/A	N/A	N/A	Equipment elsewhere - line item for price for design and mole sieve
Compression	NE		U	_	10			Tracer Dosing Package	API 675 Pumps		_	0.1	_	_	_		150.5			36		165		_	100 p	pbv		316L SS	2.2			0.9	Addition to give CO <sub>2</sub> smell to allow leakage detection
Cooling Water	NE		U	0	11			Chemical Dosing Package	API 675 Pumps		33		+	+ +	_			_				12		85					11.0		4.0	30.0	Cooling Water Dosing Chemicals
Water Treatment	NE		U	0	05			Water Treatment Plant			6267	7 8671	.8 MV	3760						20			-5	85 13	3844 n	n <sup>3</sup> /hr		Various	644.2	128.8			Includes CCGT + Ion Exchange + Waste Wash Water + Acid Wash Effluent Treatment
Utilities	NE		U	0	06	A/B/C		Instrument Air Compression Package	Centrifugal		1690	0 270	MV	n/a				8.5		20		10	-5	85 1	145 m	<sup>3</sup> /min	FAD		8.1	2.4		22.7	3 x 50% machines Sized for Carbon Capture and CCGT (Refer to Utilities Schedule)
Utilities	NE		U	0	12			Demineralisation Package	RO + Ion Exchange		60			n/a										4	448 n	n³/hr			40.6	12.7			Sized for 5 trains
Utilities	NE		U	0	80			Ammonia Tanker Unloading			0	0	LV	n/a	_			_				FV 9	-5	85				CS				0.8	
Drums and Vessels											+																						
Power	NE		V	1	01			HP Steam Drum	Horizontal	01	0	0	n/a	n/a	-	-	173.3			353.9		206	-5	120				15NiCuMoNb5-6-4	17.0	1.9		130	Part of HRSG
Power	NE		V	1	02			IP Steam Drum	Horizontal	01	0		n/a	+ +			36.6	+		245.1								CS					Part of HRSG
Power	NE		V	1	03			LP Steam Drum	Horizontal	01	0	0	n/a	n/a			3.792			141.7								cs					Part of HRSG
Power	NE		V	1	31			Oil / Water Separator	Horizontal		0	55	LV	n/a		45								1	136 n	n <sup>3</sup> /hr		cs	2.0	2.0	2.0	2.2	
Power	NE		V	1	23			Blowdown Vessel / Tank	Vertical	<u> </u>	0	_	n/a	n/a			ATM			100		FV 3.5				m <sup>3</sup>		CS		1.3	4.0		
Power	NE NE		V	1	27 05			Fuel Gas Scrubber	Vertical	04	0		n/a	_	-	$\dashv$	48	65	1	25 46	38	85 8				m <sup>3</sup> T/hr		CS	20.5	1.0	2.4 8.3	2.9	Includios December
Power	NE		V	1	25	A/B		Feedwater Tank	Horiz / Vertical	01	0	+	n/a n/a	n/a n/a	+	$\dashv$	1.3	-		575	-	7	+ +	_		m <sup>3</sup>		Alloy Steel	20.5	2.0	4.8		Including Deaerator
Power	NE		V	1	26	A/D		Flash Tanks (Start-Up & Shut Down)  Drain Vessel	Vertical Vertical	-	0	_	n/a	-	-		1.3			575		7				m <sup>3</sup>		Alloy Steel		2.0	4.8		
Power	NE		V	1	22			Instrument Air Buffer Vessel - CCGT	Vertical		0	_	n/a	+ +	-		8.5	_		25		10	+ +	_		m³		316L SS		3.2		25.2	
Power	NE NE		V		24			Area Flash Drum	Vertical		0		+	+-+	_		17	_	$\vdash$	200		FV 19		_		m <sup>3</sup>		CS		1.4		3.4	+
Natural Gas	NE		v	0	04			Natural Gas Pig Receiver	Horizontal	01	0		n/a	+ +	$\dashv$	$\dashv$	45	65	1	200	38	85		_		m³/hr		cs	5.1		1.3		+
Natural Gas	NE		V		32			Natural Gas Pig Launcher	Horizontal		0		_	-	$\dashv$	$\dashv$	45	65	1		38	85		_		m³/hr		cs	5.1			13.9	Located at NTS connection
Carbon Capture	NE		V	1	06			Direct Contact Cooler	Rectangular Tower	02	0	0	n/a	n/a			0.063			70		0.085	5 -5	85 2		T/hr CO <sub>2</sub> )		Lined Concrete 304SS Internals	18.1	17.0	28.2		Column lining design temperature 120°C which could be subject to 110°C flue gas during start-up Scale up using flue gas flow rate: refer to 181869-0001-T-EM-CAL-AAA-00-00004 rev A02
Carbon Capture	NE		V	1	07			CO₂ Absorber	Rectangular Tower	02	0	0	n/a	n/a			0.026			30		0.088	5 -5	85 2	254 (0	T/hr CO <sub>2</sub> )		Lined Concrete 304/316SS Internals	34.0	17.0	64.3		High efficiency mist eliminator at the top of the water wash     Knit mesh mist eliminator at the top of acid wash section     High quality gravity distributor     Leak & splash proof chimney tray     Structured packing     Shoepentouter inlet devices (two off)
Carbon Capture	NE		V	1	08			Amine Stripper	Vertical	02	0	0	n/a	n/a			1			122.3		3.5	-5	160 2	228 (0	T/hr CO <sub>2</sub> )		CS with 316L Cladding		9.6	34.6	261.0	* Top =dia 5.9m, Middle = dia 10m, Top = dia 8m.  * Upper rectification: predistributor, distributor (with chimney tray), splash plate, demister mat  * Stripping: predistributor, distributor (with chimney tray), demisters  * Structured packing
Carbon Capture	NE		٧	1	09			Amine Reflux Drum	Vertical	02	0		n/a	$\perp$			1			26.3		3.5	$\perp$		228 (0	T/hr CO <sub>2</sub> )		316L SS		4.5	8.0		* Half open pipe inlet device  * Mesh * Mist Eliminator
Carbon Capture	NE		V	1	21			Vent KO Drum	Horizontal		0							-				FV 10		_	15	m <sup>3</sup>		316L SS		1.9	4.5		Kept pressurised with Instrument Air
Carbon Capture	NE		V	1	38			CC Unit Condensate Drum	Vertical		0	0	n/a	n/a								FV 5	-5	160				CS + 3mm CA		2.6	5.0	7.4	Includes inlet hood and wear plate  * Packed section
Carbon Capture	NE		٧	0	28			Thermal Reclaimer Column No 1	Vertical		0	0	n/a	n/a								FV 3.5	-5	160	36	m <sup>3</sup>		316L SS		1.7	8.9	3.9	* Predistribution, distributor (with chimney tray)  * Vane collector  * Structured packing





PROJECT No.
PROJECT NAME
LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE 181869-0001-T-EM-MEL-AAA-00-00006

A02

NOVEMBER 2017

PLANT AREA		EC	UIPMEI	NT NUM	BER		ITEM DESCRIPTION	TYPE	PFD Number		ELECTRI	CAL PO	WER			RATING SSURE		PERATIN MPERATI		DESIG PRESSI		DESIG TEMPE ATUR	R-	OUTY or Unit)	BARE HEAT TRANSFER AREA or ΔP	MATERIAL OF CONSTRUCTION	DI	IMENSION	ıs	WEIG	БНТ	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	TRAIN	SEQUENCE	REDUNDANCY TRIM OR AUX ELEC EQUIPMENT			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW) VOLTAGE (HV, MV,	CCS STANDBY (kW)	DUTY - INTERMITTENT (KW)		MIN (barg)	NORMAL (barg) MAX (barg)	MIN (°C)	NORMAL (°C)	MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)		m²	- 8	Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	OPERATING (tonnes)	
Carbon Capture	NE		v	0	29		Thermal Reclaimer Column No 2	Vertical		0	0 n/a	n/a								FV	3.5	-5	215	46 n	13	316L SS		1.9	9.4	4.4		Pracked section Predistribution, distributor (with chimney tray) Vane collector Structured packing
Carbon Capture	NE		v	0	30		Thermal Reclaimer Column No 3	Vertical		0	0 n/a	n/a								FV	3.5	-5	335	69 n	1 <sup>3</sup>	316L SS		2.3	9.1	5.6		Packed section Predistribution, distributor (with chimney tray) Vane collector Structured packing
Carbon Capture	NE		V	0	33		Instrument Air Buffer Vessel	Vertical		0	0 n/a	n/a			8	8.5		25			10	-5	85			316L SS		3.4	10.1	23.8		Эписиней раскинд
Compression	NE		٧	1	11		1st Stage CO <sub>2</sub> Compressor KO Drum	Vertical	03	0	0 n/a	n/a			0	.15		25			3.5	-7	105	228 T/	hr O <sub>2</sub> )	316L SS		3.4	5.5	11.5		Includes * Intlet hood and mist eliminator
Compression	NE		V	1	12		2nd Stage Integrated KO Drum	Vertical	03	0	0 n/a	n/a			1	.95		122/36						228 T/	hr Do)	316L SS						Part of Package U-101 Includes integral water cooled tube bundle
Compression	NE		v	1	13		3rd Stage Integrated KO Drum	Vertical	03	0	0 n/a	n/a		十	5.	925		123/36						228 T/	hr	316L SS			$\neg$			Part of Package U-101 Includes integral water cooled tube bundle
Compression	NE		v	1	14		4th Stage Integrated KO Drum	Vertical	03	0	0 n/a	n/a	1 1	$\top$	15	5.52	1	121.8/				+			hr	316L SS			$\dashv$			Part of Package U-101
Compression	NE		v	_	15		5th Stage Integrated KO Drum	Vertical	03	0	0 n/a	n/a	+	+		38	+	116.7/	$\vdash$			+		200 T/	hr	316L SS	<del>                                     </del>		$\dashv$	$\dashv$		Includes integral water cooled tube bundle Part of Package U-101
Compression	NE		V		17		CO <sub>2</sub> Pipeline Pig Launcher	Horizontal	03	0	0 n/a	n/a			_	150		36 36			165	-46	_	1140 (C)	_	LTCS	11.4	11	1.3	14.7	18.1	Includes integral water cooled tube bundle
	NE		_	_	34				- 55	0		+	+	+	-	150		36				_	_	1140 (C)	O <sub>2</sub> )		11.4	$\vdash$	$\overline{}$	$\overline{}$		Landad at Chara Canadian (Consult Tours He)
Compression			+	_	_		CO <sub>2</sub> Pipeline Pig Receiver	Horizontal				n/a	+	+			$\vdash$					_	_	(C	O <sub>2</sub> )	LTCS	-		1.3	_	18.1	Located at Shore Crossing (except Teesside)
Compression	NE				35		CO <sub>2</sub> Pipeline Pig Launcher	Horizontal		0	0 n/a	n/a		_	_	150		36				_		1140 (C	O <sub>2</sub> )	LTCS	11.4			14.7	18.1	Located at Shore Crossing (except Teesside)
Compression	NE		V	1	18	A/B	CO <sub>2</sub> Dehydration Absorber	Vertical	03	0	0 n/a	n/a			3	7.7					47	-5	150	269 T/	O <sub>2</sub> )	316L SS	ļ	3.3	9.0			Internals = molecular sieves, cermaic balls, supports, grid support Material: CS clad with SS also acceptable
Compression	NE		V	1	19		Dehydration KO Drum	Vertical	03	0	0 n/a	n/a			3	5.4		36			47	-5	300	228 T/(C	hr O <sub>2</sub> )	316L SS		0.9	3.0			Includes Inlet Hood and Mist Eliminator Depressurisation = -79°C at 0 barg
Utilities	NE				36		Demin Water Expansion Vessel	Vertical	-	0	0 n/a	n/a	-	$\perp$			+	05			-	-	85	704	2	CS + 3mm CA	-	1.9	4.0	3.9		
Utilities	NE		V	0	37		Instrument Air Dry Air Receiver	Vertical		0	0 n/a	n/a		-		8.5	+	25			10	-5	85	764 n	า	316L SS				+		
Miscellaneous																																
Power	NE		XJ	1	01		Steam Jet Air Ejector			0	0 n/a	n/a																				Part of Water Cooled Condenser
Electrical Equipment																																
							Low Voltage Equipment																									
Power	NE	_	_	1			Low Voltage Equipment			366	LV	n/a		_	_																	Transformers, Circuit Breakers, Switchgear, MCCs, etc  Doubling GBC = 144 loads LV switchgear. Single TRU reduced number by
Carbon Capture  Carbon Capture	NE NE		00		01		LV Switchboard			342 147	446.9 LV 290 LV	205 88																				14 loads (EXCEPT FOR TRAIN 3)
Compression	NE				03		LV Emergency Switchboard  LV Switchboard		+		681.9 LV	_		$\dashv$			+						+						_	+		Non-Process Equipment Loads
Compression	NE				04		LV Emergency Switchboard				260 LV																					
Utilities	NE				05		LV Switchboard				681.9 LV			_								_	_			ļ			_			
Utilities Facilities	NE NE		_		06 07		LV Emergency Switchboard  LV Switchboard		1	145 145	260 LV 260 LV	n/a n/a	-	+	+	-	+		<del>   </del>	$\vdash$	-	_	+				<del>                                     </del>	<del>                                     </del>	$\dashv$	+		
														_			L															
							Transmission Voltage Equipment																									
Power	NE		TR	_	08		Export Transformer			3660	HV			$\perp$																		
Power	NE NE		TR CB		09 10		Unit Transformer Circuit Breakers		1		HV	n/a n/a		_	+		+-		$\vdash$	$\vdash$	_	_	_				-		$\dashv$			
Power	NE			1	.0		Miscellaneous PEACE Electrical		1		HV	+	+ +	$\dashv$	+		+		+	+	_	_	-			1	1	<del>   </del>	$\overline{}$			Cost Bookmark
			$\dashv$		$\dashv$		Equipment		1			+	+	+	+		+		+		_	$\dashv$	$\dashv$						$\dashv$	+		
			$\top$				Generating Voltage Equipment							$\top$																		
Power	NE			1			Generator Buswork				MV	_																				
Power	NE	E	-+		11	_	Circuit Breakers Miscellaneous PEACE Electrical		+		MV	n/a		+	_	_	-		$\vdash$	$\vdash$			$-\!\!\!\!+\!\!\!\!\!-$				<u> </u>	$\vdash$				
Power	NE		+	1	_		Equipment		1		MV	n/a	+	+	+	+	+		$\vdash$	$\vdash$	-+	+	+					$\vdash$	+			Cost Bookmark
			$\dashv$	_	$\dashv$		Medium Voltage Equipment		1			+	+ +	+	+	+	+			+	_		$\dashv$					<del>   </del>	+	_		
Power	NE			1			Miscellaneous PEACE Auxiliaries			2902	MV	n/a																				
Power	NE			1			Medium Voltage Equipment				MV	_	-																			Transformers, Circuit Breakers, Switchgear, MCCs, etc
Power	NE		1	1	I	I	HP Feedwater Pumps VFD	l	I	I	MV	n/a	1	1		I	I		1 I		I		I		I	I	1	1 1	I	I		<b>I</b>



PROJECT No. PROJECT NAME LOCATION

181869

Thermal Power with CCS: Generic Business Case

UK

DOCUMENT No. REVISION DATE

181869-0001-T-EM-MEL-AAA-00-00006

PLANT AREA		E	EQUIPMENT	Г NUMBE	ER		ITEM DESCRIPTION	TYPE	PFD Number		ELEC	TRICAL P	OWER			ERATING RESSURE			RATING RATURE		SIGN SSURE	DESI TEMP ATU	ER-	DUTY (Per Unit)	UNITS	BARE HEAT TRANSFER AREA or ΔP (Per Unit)	MATERIAL OF CONSTRUCTION	DI	IMENSIO	DNS	WEIGH	REMARKS
	ASSET CODE	AREA / UNIT CODE	EQUIPMENT CODING	SEQUENCE	REDIINDANCY	TRIM OR AUX ELEC			181869-0001-D-EM- PFD-AAA-00-00001- XX	ABSORBED (KW)	INSTALLED (KW)	LV) LV) CCS STANDBY (FW)	- YTUG	DUTY - STANDBY (KW)	MIN (barg)	NORMAL (barg)	MAX (barg)	(O) NIMI	NORMAL (°C) MAX (°C)	MIN (barg)	MAX (barg)	MIN (°C)	MAX (°C)			m²		Length-OVL/TT (m)	Width Or DIA (m)	Height-OVL / TT (m)	DRY (tonnes)	
Entire Plant	NE		ESG 1	12			MV Main Switchboard					MV n/																				
Carbon Capture	NE		ESG 1	13			MV Switchboard					MV n/	а																			
Carbon Capture	NE		1				Booster Fan VFD					MV n/	а																			Part of K-101 Supply
Compression	NE		ESG 1	14			MV Switchboard					MV n/	а																			
Compression	NE		ESG 1	15			Switchgear					MV n/	а															2.3	0.7	1.7	1.3	2 off - inlet and outlet. Part of Package U-101
Compression	NE		ETR 1	16			Transformer					MV n/	а																			Part of Package U-101
Compression	NE		1				CO <sub>2</sub> Compressor VFD					MV n/	а		$\perp$													2.2	9.4	1.0	5.0	Part of Package U-101
				_	_							_	_				_	$\perp$		_												
uildings																																
Facilities	NE		BLD 0	<u> </u>	_	_	Warehouse			3		LV n/	_	_	$\perp$	+ve			35	N/A	-	N/A	N/A	8550	m <sup>3</sup>			47.5				Height to Eaves
Facilities	NE		BLD 0	- 02	_		Workshop		-	5		LV n/	_		+	+ve			35	N/A	N/A	N/A	N/A	14250	m <sup>3</sup>			47.5				Height to Eaves
Facilities	NE	+ +	BLD 0		_	_	Admin & Control Building		-	22		LV n/		_	+	+ve		20	25	N/A	-	N/A	N/A	2160	m <sup>3</sup>			40.0				Height to Eaves
Facilities	NE		BLD 0		_	_	Office Block		-	164		LV n/		_	+	+ve	_	20	25	N/A		N/A	N/A	16500	m <sup>3</sup>			33.0				Height to Top of Roof
Facilities	NE		BLD 0		_	_	Lockers, Welfare, & Training		-	49		LV n/		_	+	+ve	2	_	25	N/A	-		N/A	4950	m <sup>3</sup>			33.0	<del>                                     </del>			Height to Eaves
Facilities	NE		BLD 0		_	_	Guardhouse		-	1		LV n/		_	+	+ve		20	25	-			N/A	135	m <sup>3</sup>			10.0		<del>                                     </del>		Height to Eaves
Facilities	NE	+ +	BLD 0	+	+	_	Compression Electrical Substation		1	34		LV n/	_	_	+	+ve		0	40	N/A	<del>                                     </del>	N/A	N/A	11813	m <sup>3</sup>			75.0	+	4.5	<del>                                     </del>	Height to Eaves
Facilities	NE		BLD 1	08			Carbon Capture Electrical Substation			4	4	LV n/	а			+ve	1	0	40	N/A	N/A	N/A	N/A	1350	m <sup>3</sup>			25.0	12.0	4.5		Height to Eaves
Facilities	NE		BLD 1	09			Steam Turbine Building			34	34	LV n/	а			+ve	5	5	35	N/A	N/A	N/A	N/A	115200	m <sup>3</sup>			72.0	40.0	40.0		Height to Top of Roof
Facilities	NE		BLD 1	10			Cooling Water Power Distribution Centre			2	2	LV n/	a			+ve	1	0	40	N/A	N/A	N/A	N/A	720	m <sup>3</sup>			16.0	10.0	4.5		Height to Eaves
Facilities	NE		BLD 1	11			HRSG Power Distribution Centre			1	1	LV n/	а			+ve	1	0	40	N/A	N/A	N/A	N/A	225	m <sup>3</sup>			10.0	5.0	4.5		Height to Eaves
Facilities	NE		BLD 1	12			Power Generation Power Distribution Centre			2	2	LV n/	а			+ve	1	0	40	N/A	N/A	N/A	N/A	720	m <sup>3</sup>			20.0	8.0	4.5		Height to Eaves
Facilities	NE	1 1	BLD 1	13			HV / LV Power Distribution Centre			2	2	LV n/	а		1 1	+ve	1	0	40	N/A	N/A	N/A	N/A	720	m <sup>3</sup>			20.0	8.0	4.5		Height to Eaves
		1 1													1 1					1												
-												_	_	_	1 1			-		1	$\vdash$								<b>†</b>			<u> </u>



SNC-Lavalin UK Limited Woodcote Grove Ashley Road, Epsom, Surrey KT18 5BW, United Kingdom

## <u>ATTACHMENT 3 - H&MB (CC only - not in Licensor area)</u> <u>Attachment 3.1 – 2 CCGT into 1 CC Case</u>



HEAT AND MASS BALANCE 2 INTO 1 OPTIMISATION CARBON CAPTURE H&MB

PROJECT No. 181869

PROJECT NAME THERMAL POWER WITH CCS

LOCATION UK

DOCUMENT No. 181869-0001-D-EM-HMB-AAA-00-00002-01

REVISION A01

TE NOVEMBER 2017

_				T	ı		 	_		 				T	1	1	
	Stream Description	Sour Gas Feed	Treated Gas to Stack	Treated Gas from Amine Reflux Drum	LP Steam to Reboiler	LP Condensate from Reboiler											
	PFD Stream Number	100	101	102	103	104											
	Vapour Fraction	1.000	1.000	1.000	1.000	0.000											
	Temperature (C)	87.80	64.60	26.30	138.7	126.1											i l
	Pressure (bar)	1.010	1.009	2.000	2.400	2.400											
	Actual Volume Flow (m3/h)	7429011.0	6340531.1	130165.9	467491.3	639.6											
	Mass Flow (tonne/h)	7101.0	6430.3	460.4	599.8	599.8											
	Molar Flow (kgmole/h)	250166.2	227919.3	10572.8	33294.4	33294.4											
=	Mass Density (kg/m3)	0.956	1.014	3.537	1.3	937.8											
Vers	Molecular Weight	28.39	28.21	43.55	18.0	18.0											
Ó	Mass Heat Capacity (kJ/kg-C)	1.06	1.04	0.86	1.9	4.6											
	Std Gas Flow (STD_m3/h)	5915039.9	5389022.4	249988.4	787227.1	787227.1											1
I	Std Ideal Liq Vol Flow (m3/h)	12584.1	11813.7	559.7	601.0	601.0											1
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141	0.2165											
	Actual Volume Flow (m3/h)	7429011.0	6340531.1	130165.9	467491.3												
I	Mass Flow (tonne/h)	7101.0	6430.3	460.4	599.8												
ě	Molar Flow (kgmole/h)	250166.2	227919.3	10572.8	33294.4												1
has	Mass Density (kg/m3)	0.96	1.01	3.54	1.28												
- E	Molecular Weight	28.39	28.21	43.55	18.02												
ode	Cp/Cv	1.38	1.40	1.30	1.34												
×	Std Gas Flow (STD_m3/h)	5915039.9	5389022.4	249988.4	787227.1												
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141												
	Z Factor	0.9994	0.9996	0.9890	0.9841												
	Actual Volume Flow (m3/h)																
	Mass Flow (tonne/h)																
se	Molar Flow (kgmole/h)																
F	Mass Density (kg/m3)																
Liquid	Molecular Weight																
Lig	Std Ideal Liq Vol Flow (m3/h)																
	Surface Tension (dyne/cm)																
	Viscosity (cP)																1
	Actual Volume Flow (m3/h)					639.6											
ıse	Mass Flow (tonne/h)					599.8											
Pha	Molar Flow (kgmole/h)					33294.4											
snc	Mass Density (kg/m3)					937.8											
nec	Molecular Weight					18.02											
٩	Std Ideal Liq Vol Flow (m3/h)					600.96											
	Viscosity (cP)					0.216											
	H2O	0.09166	0.04858	0.01749	1.000000	1.000000											
I	CO2	0.04606	0.00505	0.98090	0.000000	0.000000											
Ē	H2S	0.00000	0.00000	0.00000	0.000000	0.000000											
ition (Mol )	Oxygen	0.11157	0.12246	0.00002	0.000000	0.000000							·				
ion	Nitrogen	0.74178	0.81417	0.00026	0.000000	0.000000							·				
osit	SO2	0.00000	0.00000	0.00001	0.000000	0.000000											Ī
Ē	Ammonia	0.00000	0.00000	0.00000	0.000000	0.000000											
ပိ	Argon	0.00893	0.00974	0.00127	0.000000	0.000000											
I	NO2	0.00000	0.00000	0.00000	0.000000	0.000000											
	Total	1.000	1.000	1.000	1.000	1.000											



HEAT AND MASS BALANCE 2 INTO 1 OPTIMISATION COMPRESSION H&MB

PROJECT No. 181869

PROJECT NAME THERMAL POWER WITH CCS

UK

LOCATION

DOCUMENT No. 181869-0001-D-EM-HMB-AAA-00-00002-01

REVISION A01

DATE NOVEMBER 2017

	Stream Description	Gas to 1st Stage CO <sub>2</sub> Compressor KO Drum	Liquid from 1st Stage CO <sub>2</sub> Compressor KO Drum	Gas to 1st Stage CO <sub>2</sub> Compressor	Gas to 2nd Stage CO <sub>2</sub> Compressor KO Drum	Gas to 2nd Stage CO <sub>2</sub> Compressor	Liquid from 2nd Stage CO <sub>2</sub> Compressor KO Drum	Liquid to 1st Stage CO <sub>2</sub> Compressor KO Drum	Gas to 3rd Stage CO <sub>2</sub> Compressor KO Drum	Gas to 3rd Stage CO <sub>2</sub> Compressor	Liquid from 3rd Stage CO <sub>2</sub> Compressor KO Drum	Liquid to 2nd Stage CO <sub>2</sub> Compressor KO Drum	Gas to 4th Stage CO <sub>2</sub> Compressor KO Drum	Gas to 4th Stage CO <sub>2</sub> Compressor	Liquid from 4th Stage CO <sub>2</sub> Compressor KO Drum	Liquid to 3rd Stage CO <sub>2</sub> Compressor KO Drum	Gas to 5th Stage CO <sub>2</sub> Compressor KO Drum	Gas to CO <sub>2</sub> Dehydration	Liquid from 5th Stage CO <sub>2</sub> Compressor KO Drum	Liquid to 4rd Stage CO <sub>2</sub> Compressor KO Drum	Gas to 6th Stage CO <sub>2</sub> Compressor	Liquid from Process Condensate Return Pump	Liquid from Dehydration KO Drum	Gas from Dehydration KO Drum	
	PFD Stream Number	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	
	/apour Fraction	1.000	0.000	1.000	1.000	1.000	0.000	0.001	1.000	1.000	0.000	0.002	1.000	1.000	0.000	0.004	1.000	1.000	0.000	0.007	1.000	0.000	0.006	1.000	
	Temperature (C)	25.3	20.1	20.1	122.3	35.6	35.6	35.6	123.1	35.7	35.7	35.8	121.7	32.9	32.9	32.9	116.8	36.0	36.0	36.2	38.0	20.2	14.1	14.3	
	Pressure (bar)	1.150	1.050	1.050	3.150	2.850	2.850	1.150	7.125	6.825	6.825	2.950	16.721	16.421	16.421	6.925	39.200	38.900	38.900	16.521	37.400	2.000	6.925	16.621	
	Actual Volume Flow (m3/h)	226698.8	3.3	245230.5	110129.5	94188.6	4.3	7.8	48300.5	38100.3	4.0	6.8	19841.1	17355.2	1.2	2.0	9259.5	6372.0	0.2	0.4	5767.7	3.3	1.2	2353.2	
	Mass Flow (tonne/h)	460.4	3.3	461.4	461.4	461.2	4.3	4.3	461.2	458.8	4.0	4.0	458.8	538.6	1.2	1.2	538.6	538.4	0.2	0.2	457.0	3.3	0.6	80.7	
	Molar Flow (kgmole/h)	10574.0	184.7	10626.0	10626.0	10612.0	237.6	237.6	10612.0	10488.0	222.8	222.8	10488.0	12268.0	65.9	66.0	12268.0	12256.0	12.5	12.5	10388.0	184.7	32.4	1835.2	
=	Mass Density (kg/m3)	2.03	1011.00	1.88	4.19	4.90	999.80	547.00	9.55	12.04	1000.00	591.00	23.13	31.03	1004.00	589.30	58.17	84.49	1005.00	650.50	79.25	1011.00	494.00	34.29	
/era	Molecular Weight	43.55	18.03	43.42	43.42	43.45	18.04	18.04	43.45	43.76	18.08	18.08	43.76	43.90	18.18	18.18	43.90	43.93	18.35	18.35	44.00	18.03	18.28	43.97	
ó	Mass Heat Capacity (kJ/kg-C)	0.8826	4.3110	0.8807	0.9540	0.8996	4.3080	4.3060	0.9652	0.9156	4.2980	4.2950	0.9884	0.9743	4.2740	4.2670	1.0660	1.2160	4.2320	4.2200	1.1790	4.3110	4.2410	0.9832	
	Std Gas Flow (STD_m3/h)	250000.0	4366.0	251200.0	251200.0	250800.0	5618.0	5618.0	250800.0	248000.0	5266.0	5266.0	248000.0	290000.0	1557.0	1561.6	290000.0	289800.0	295.0	295.0	245600.0	4366.0	765.0	43400.0	
	Std Ideal Liq Vol Flow (m3/h)	556.8	3.3	557.8	557.8	557.6	4.3	4.3	557.6	555.4	4.0	4.0	555.4	652.0	1.2	1.2	652.0	651.8	0.2	0.2	553.6	3.3	0.6	97.7	
	/iscosity (cP)	0.0145	0.9983	0.0141	0.0198	0.0150	0.7453	0.0000	0.0200	0.0153	0.7406	0.0000	0.0203	0.0156	0.7723	0.0000	0.0209	0.0170	0.7165	0.0000	0.0170	0.9981	0.0000	0.0147	
	Actual Volume Flow (m3/h)	226698.8	0.0	245230.5	110129.5	94188.6	0.0	3.6	48300.5	38100.3	0.0	2.8	19841.1	17355.2	0.0	0.9	9259.5	6372.0	0.0	0.1	5767.7		0.6	2353.2	
	Mass Flow (tonne/h)	460.4	0.0	461.4	461.4	461.2	0.0	0.0	461.2	458.8	0.0	0.0	458.8	538.6	0.0	0.0	538.6	538.4	0.0	0.0	457.0		0.0	80.7	
e e	Molar Flow (kgmole/h)	10574.0	0.0	10626.0	10626.0	10612.0	0.0	0.2	10612.0	10488.0	0.0	0.3	10488.0	12268.0	0.0	0.2	12268.0	12256.0	0.0	0.1	10388.0		0.2	1835.2	
has	Mass Density (kg/m3)	2.03	1.88	1.88	4.19	4.90	4.90	1.92	9.55	12.04	12.04	5.07	23.13	31.03	31.03	12.37	58.17	84.49	84.49	30.80	79.25		13.33	34.29	
7	Molecular Weight	43.55	43.42	43.42	43.42	43.45	43.45	42.69	43.45	43.76	43.76	43.48	43.76	43.90	43.90	43.81	43.90	43.93	43.93	43.89	44.00		43.94	43.97	
bode	Cp/Cv	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.3	1.4	1.7	1.7	1.4	1.6		1.3	1.4	
8	Std Gas Flow (STD_m3/h)	250000.0	0.0	251200.0	251200.0	250800.0	0.0	3.8	250800.0	248000.0	0.0	7.7	248000.0	290000.0	0.0	5.7	290000.0	289800.0	0.0	2.1	245600.0		4.5	43400.0	
	/iscosity (cP)	0.0145	0.0141	0.0141	0.0198	0.0150	0.0150	0.0146	0.0200	0.0153	0.0153	0.0150	0.0203	0.0156	0.0156	0.0152	0.0209	0.0170	0.0170	0.0158	0.0170		0.0142	0.0147	
	Z Factor	0.9935	0.9937	0.9937	0.9930	0.9854	0.9854	0.9938	0.9843	0.9655	0.9655	0.9849	0.9636	0.9130	0.9130	0.9639	0.9124	0.7868	0.7868	0.9153	0.8026		0.9563	0.8918	
	Actual Volume Flow (m3/h)																								
	Mass Flow (tonne/h)																								
se	Molar Flow (kgmole/h)																								
Ph	Mass Density (kg/m3)																								
nid	Molecular Weight																								
Liq	Std Ideal Liq Vol Flow (m3/h)																								
	Surface Tension (dyne/cm)																								
	/iscosity (cP)																								
	Actual Volume Flow (m3/h)		3.3	0.0		0.0	4.3	4.3		0.0	4.0	4.0		0.0	1.2	1.2		0.0	0.2	0.2		3.3	0.6		
ase	Mass Flow (tonne/h)		3.3	0.0		0.0	4.3	4.3		0.0	4.0	4.0		0.0	1.2	1.2		0.0	0.2	0.2		3.3	0.6		-
Ph	Molar Flow (kgmole/h)		184.7	0.0		0.0	237.6	237.4		0.0	222.8	222.4		0.0	65.9	65.8		0.0	12.5	12.4		184.7	32.2		
Snc	Mass Density (kg/m3)		1011.0	1011.0		999.8	999.8	999.5		1000.0	1000.0	999.7		1004.0	1004.0	1003.0		1005.0	1005.0	1002.0		1011.0	1018.0		
nec	Molecular Weight		18.03	18.03		18.04	18.04	18.03		18.08	18.08	18.04		18.18	18.18	18.09		18.35	18.35	18.17		18.03	18.13		
A	Std Ideal Liq Vol Flow (m3/h)		3.34	0.00		0.00	4.30	4.29		0.00	4.04	4.02		0.00	1.20	1.19		0.00	0.23	0.23		3.34	0.59		
	/iscosity (cP)		0.998	0.998		0.745	0.745	0.710		0.741	0.741	0.743		0.772	0.772	0.780		0.717	0.717	0.728		0.998	1.121		
	CO2)	0.980901	0.000552	0.976031	0.976031	0.977429	0.001055	0.001055	0.977429	0.989035	0.002526	0.002526	0.989035	0.994518	0.006325	0.006325	0.994518	0.995517	0.013030	0.013030	0.998312	0.000552	0.010139	0.997061	
	Nitrogen)	0.000256	0.000000	0.000255	0.000255	0.000255	0.000000	0.000000	0.000255	0.000258	0.000000	0.000000	0.000258	0.000260	0.000000	0.000000	0.000260	0.000260	0.000000	0.000000	0.000261	0.000000	0.000000	0.000260	
( To	Oxygen)	0.000073	0.000000	0.000020	0.000020	0.000020	0.000000	0.000000	0.000020	0.000020	0.000000	0.000000	0.000020	0.000020	0.000000	0.000000	0.000020	0.000020	0.000000	0.000000	0.000020	0.000000	0.000000	0.000020	
osition (Mol	H2S)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	
tion	H2O)	0.017490	0.999447	0.022368	0.022368	0.020968	0.998944	0.998944	0.020968	0.009343	0.997472	0.997472	0.009343	0.003851	0.993671	0.993671	0.003851	0.002850	0.986963	0.986963	0.000050	0.999447	0.989842	0.001302	
osi	Ammonia)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001	0.000001	0.000000	0.000000	0.000002	0.000002	0.000000	0.000000	0.000015	0.000001	
μ̈	SO2)	0.000008	0.000000	0.000008	0.000008	0.000008	0.000001	0.000001	0.000008	0.000008	0.000001	0.000001	0.000008	0.000008	0.000003	0.000003	0.000008	0.000008	0.000005	0.000005	0.000008	0.000000	0.000004	0.000008	
ပိ	Argon)	0.001272	0.000000	0.001266	0.001266	0.001267	0.000000	0.000000	0.001267	0.001282	0.000000	0.000000	0.001282	0.001290	0.000000	0.000000	0.001290	0.001291	0.000000	0.000000	0.001295	0.000000	0.000000	0.001293	
	NO2)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	



SNC-Lavalin UK Limited Woodcote Grove Ashley Road, Epsom, Surrey KT18 5BW, United Kingdom

# Attachment 3.2.1 – Brochure Efficiency Reboiler Case 2.7 GJ/tonne CO<sub>2</sub> case



PROJECT No. 181869

THERMAL POWER WITH CCS PROJECT NAME UK

LOCATION

181869-0001-D-EM-HMB-AAA-00-00002-01 DOCUMENT No.

A02 REVISION

DATE NOVEMBER 2017

	Stream Description	Air to Inlet Air Filter	Air from Inlet Air Filter	Fuel Gas to Fuel Gas Heater	Fuel Gas to Gas Turbine	Flue Gas from Gas Turbine	Flue Gas to RH3	Flue Gas to HPS1	Flue Gas to RH1	Flue Gas to HPS0	Flue Gas to HPB1	Flue Gas to HPE3	Flue Gas to LPS	Flue Gas to IPS1	Flue Gas to HPE2	Flue Gas to IPB	Flue Gas to HPE0/ IPE2	Flue Gas to IPE2	Flue Gas to HPE0	Flue Gas from IPE2	Flue Gas from HPE0	Flue Gas to LPB	Flue Gas to LPE	Flue Gas to LTE	Flue Gas to CCP
	PFD Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Vapour Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Temperature (C)	10.00	10.00	25.00	204.44	646.54	633.96	609.13	595.70	552.52	466.71	363.86	331.24	326.96	323.90	276.92	250.71	250.71	185.28	250.71	185.28	185.28	155.48	129.33	89.69
	Pressure (bar)	1.013	1.013	49.110	49.110	1.045	1.044	1.043	1.043	1.042	1.039	1.029	1.025	1.025	1.025	1.021	1.020	1.020	1.017	1.020	1.017	1.017	1.015	1.014	1.013
	Actual Volume Flow (m3/h)	2777444.6	2777444.6	2254.2	4074.0	9158759.5	9039549.0	8798874.5	8668271.3	8243029.0	7404797.7	6441519.4	6133576.6	6090713.0	6061413.1	5602182.1	5343374.3	1091905.5	958357.3	4251468.8	3731480.4	4689839.8	4389130.4	4126381.1	3721592.0
	Mass Flow (tonne/h)	3455.8	3455.8	94.7	94.7	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	725.5	725.5	2825.0	2825.0	3550.5	3550.5	3550.5	3550.5
	Molar Flow (kgmole/h)	119636.8	119636.8	5115.6	5115.6	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	25560.6	25560.6	99523.5	99523.5	125084.2	125084.2	125084.2	125084.2
l _	Mass Density (kg/m3)	1.24	1.24	41.99	23.24	0.39	0.39	0.40	0.41	0.43	0.48	0.55	0.58	0.58	0.59	0.63	0.66	0.66	0.76	0.66	0.76	0.76	0.81	0.86	0.95
era	Molecular Weight	28.89	28.89	18.50	18.50	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38
ò	Mass Heat Capacity (kJ/kg-C)	1.01	1.01	2.46	2.74	1.20	1.20	1.19	1.19	1.18	1.16	1.14	1.13	1.13	1.13	1.12	1.11	1.11	1.09	1.11	1.09	1.09	1.09	1.08	1.07
	Std Gas Flow (STD_m3/h)	2829000.0	2829000.0	121000.0	121000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	604400.0	604400.0	2353000.0	2353000.0	2958000.0	2958000.0	2958000.0	2958000.0
	Std Ideal Liq Vol Flow (m3/h)	3972.0	3972.0	289.1	289.1	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	850.6	850.6	3312.0	3312.0	4163.0	4163.0	4163.0	4163.0
	Viscosity (cP)	0.0180	0.0180	0.0125	0.0173	0.0407	0.0403	0.0393	0.0388	0.0372	0.0341	0.0305	0.0293	0.0292	0.0291	0.0274	0.0265	0.0265	0.0241	0.0265	0.0241	0.0241	0.0230	0.0219	0.0203
	Actual Volume Flow (m3/h)	2777444.6	2777444.6	2254.2	4074.0	9158759.5	9039549.0	8798874.5	8668271.3	8243029.0	7404797.7	6441519.4	6133576.6	6090713.0	6061413.1	5602182.1	5343374.3	1091905.5	958357.3	4251468.8	3731480.4	4689839.8	4389130.4	4126381.1	3721592.0
	Mass Flow (tonne/h)	3455.8	3455.8	94.7	94.7	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	725.5	725.5	2825.0	2825.0	3550.5	3550.5	3550.5	3550.5
	Molar Flow (kgmole/h)	119636.8	119636.8	5115.6	5115.6	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	25560.6	25560.6	99523.5	99523.5	125084.2	125084.2	125084.2	125084.2
ase	Mass Density (kg/m3)	1.24	1.24	41.99	23.24	0.39	0.39	0.40	0.41	0.43	0.48	0.55	0.58	0.58	0.59	0.63	0.66	0.66	0.76	0.66	0.76	0.76	0.81	0.86	0.95
<u> </u>	Molecular Weight	28.89	28.89	18.50	18.50	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38
noc	Cp/Cv	1.40	1.40	1.49	1.24	1.32	1.32	1.33	1.33	1.33	1.34	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.37	1.36	1.37	1.37	1.37	1.37	1.38
\ \	Std Gas Flow (STD m3/h)	2829000.0	2829000.0	121000.0	121000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	604400.0	604400.0	2353000.0	2353000.0	2958000.0	2958000.0	2958000.0	2958000.0
	Viscosity (cP)	0.0180	0.0180	0.0125	0.0173	0.0407	0.0403	0.0393	0.0388	0.0372	0.0341	0.0305	0.0293	0.0292	0.0291	0.0274	0.0265	0.0265	0.0241	0.0265	0.0241	0.0241	0.0230	0.0219	0.0203
	Z Factor	0.9992	0.9992	0.8730	0.9849	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9999	0.9999	0.9998	0.9996	0.9993
	Actual Volume Flow (m3/h)	0.9992	0.9992	0.8730	0.9649	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9999	0.5555	0.9998	0.5550	0.9993
	Mass Flow (tonne/h)																								
0	Molar Flow (kgmole/h)																								
has	,								-										<b>+</b>		+				
D D	Mass Density (kg/m3)								-										<b>+</b>		+				-
idn	Molecular Weight Std Ideal Liq Vol Flow (m3/h)																								
-	, ,																								
	Surface Tension (dyne/cm)																								
	Viscosity (cP)																								-
	Actual Volume Flow (m3/h)																								
Jase	Mass Flow (tonne/h)																								
S P	Molar Flow (kgmole/h)																								
noa	Mass Density (kg/m3)																								
ď	Molecular Weight																								
`	Std Ideal Liq Vol Flow (m3/h)																								
	Viscosity (cP)	0.00000	0.00000	0.04040	0.04040	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000
	(CO2)	0.00030	0.00030	0.01910	0.01910	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606
	(Nitrogen)	0.77512	0.77512	0.00990	0.00990	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178
	(Oxygen)	0.20797	0.20797	0.00004	0.00004	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157
	(H2S)	0.00707	0.00707	0.00004	0.00004	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400
	(H2O)	0.00727	0.00727			0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166
9	(Ammonia)					0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
u o	(SO2)	0.00004	0.00004			0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
sitie	(Argon)	0.00934	0.00934			0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893
l odu	(NO2)			0.07447	0.07447																				
S	(Methane)			0.87447	0.87447																				
	(Ethane)			0.06980	0.06980																				
	(Propane)			0.02190	0.02190																				
	(n-Butane)			0.00410	0.00410																				
	(n-Pentane)			0.00050	0.00050																				
	(n-Hexane)	4.5	4.6	0.00020	0.00020	4.5		4 6						4.5		4.555								40	4.0
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000



**PROJECT No.** 181869

PROJECT NAME THERMAL POWER WITH CCS

LOCATION

DOCUMENT No. 181869-0001-D-EM-HMB-AAA-00-00002-01

NOVEMBER 2017

REVISION A02

DATE

Stream Description	Steam to HP Casing	Steam from HP Casing	Reheat Steam to HP	MP Steam from HP	MP Steam	MP Steam to		Steam from IP Casing	Steam from LPS	Steam to IP/LP Casing	Steam from IP/LP Casing	LP Steam	LP Steam to	LP Steam to	Condensate from Turbine	Condensate from	Cooling Water	Cooling Water Return	Condensate from Gland	Condensate from Fuel	Condensate from	Condensate from CCP	Condensate to Feedwater	r Water to
			Casing	Casing												Condenser	Supply		Steam	Gas Heater	E-103/104		Tank	+
PFD Stream Number	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Vapour Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Temperature (C)	573.89	342.37	573.89	522.71	522.71	235.00	522.71	270.72	291.90	272.66	234.41	234.41	138.70	234.41	39.16	39.15	17.50	35.50	39.67	104.44	51.47	49.50	50.58	50.5
Pressure (bar)	165.000	34.390	30.000	21.510	21.510	21.510	21.510	3.375	3.375	3.375	2.400	2.400	2.400	2.400	0.071	0.429	2.986	2.308	4.023	33.890	4.023	4.023	4.023	4.02
Actual Volume Flow (m3/h)	10366.3	35853.9	67016.9	89891.2	1744.0	1323.6	88147.2	385993.3	40439.5	426436.1	561423.6	244739.0	213808.1	316673.0	6706149.8	331.3	10670.8	10723.3	331.3	71.0	401.7	293.3	695.1	668
Mass Flow (tonne/h)	482.2	465.5	522.9	534.5	10.4	13.4	524.1	524.1	52.8	576.9	580.5	253.1	276.5	327.4	328.7	328.7	10656.1	10656.1	328.7	67.9	396.6	289.9	686.5	660
Molar Flow (kgmole/h)	26766.4	25839.4	29025.7	29669.6	575.6	745.4	29093.9	29093.9	2929.8	32023.7	32223.0	14043.3	15341.5	18170.9	18248.0	18248.0	591510.4	591510.4	18243.1	3767.5	22016.5	16086.7	38097.3	3664
Mass Density (kg/m3)	46.52	12.98	7.80	5.95	5.95	10.15	5.95	1.36	1.31	1.35	1.03	1.03	1.29	1.03	0.05	992.32	998.62	993.74	992.30	956.20	987.26	988.20	987.70	987.
Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.
Mass Heat Capacity (kJ/kg-C)	2.69	2.45	2.26	2.21	2.21	2.83	2.21	2.04	2.04	2.04	2.03	2.03	2.12	2.03	1.88	4.18	4.18	4.18	4.18	4.22	4.18	4.18	4.18	4.1
Std Gas Flow (STD m3/h)	632900.0	611000.0	686300.0	701500.0	13610.0	17630.0	687900.0	687900.0	69270.0	757200.0	761900.0	332153.1	362880.5	429744.9	431464.1	431464.1	13985929.5	13985929.5	431444.5	89100.0	441.2	380424.6	901054.1	8665
Std Ideal Liq Vol Flow (m3/h)	483.2	466.4	524.0	535.6	10.4	13.5	525.2	525.2	52.9	578.1	581.7	253.6	277.0	328.1	329.4	329.4	10677.6	10677.6	329.4	68.0	59994.2	290.4	687.9	661
Viscosity (cP)	0.0332	0.0222	0.0317	0.0295	0.0295	0.0171	0.0295	0.0190	0.0199	0.0191	0.0175	0.0175	0.0136	0.0175	0.0096	0.6621	1.0656	0.7113	0.6555	0.2665	0.5309	0.5488	0.5389	0.53
Actual Volume Flow (m3/h)	10366.3	35853.9	67016.9	89891.2	1744.0	1323.6	88147.2	385993.3	40439.5	426436.1	561423.6	244739.0	213808.1	316673.0	6706149.8	0.0021	1.0000	0.7110	0.0000	0.2000	0.0000	0.0400	0.0000	- 0.00
, ,	482.2	465.5	522.9	534.5	10.4	13.4	524.1	524.1	52.8	576.9	580.5	253.1	276.5	327.4	328.7									+
Mass Flow (tonne/h)		1	<b>!</b>						<b>+</b>	<b>4</b>		<b>!</b>	-	<b>+</b>						1				+
Molar Flow (kgmole/h)	26766.4	25839.4	29025.7	29669.6	575.6	745.4	29093.9	29093.9	2929.8	32023.7	32223.0	14043.3	15341.5	18170.9	18248.0			+						+
Mass Density (kg/m3)	46.52	12.98	7.80	5.95	5.95	10.15	5.95	1.36	1.31	1.35	1.03	1.03	1.29	1.03	0.05			1		1				+
Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02									-
Cp/Cv	1.42	1.39	1.29	1.30	1.30	1.45	1.30	1.32	1.31	1.31	1.32	1.32	1.35	1.32	1.33			1						
Std Gas Flow (STD_m3/h)	632900.0	611000.0	686300.0	701500.0	13610.0	17630.0	687900.0	687900.0	69270.0	757200.0	761900.0	332153.1	362880.5	429744.9	431464.1									
Viscosity (cP)	0.0332	0.0222	0.0317	0.0295	0.0295	0.0171	0.0295	0.0190	0.0199	0.0191	0.0175	0.0175	0.0136	0.0175	0.0096									
Z Factor	0.9074	0.9324	0.9835	0.9849	0.9849	0.9040	0.9849	0.9902	0.9916	0.9904	0.9909	0.9909	0.9764	0.9909	0.9978									
Actual Volume Flow (m3/h)																								
Mass Flow (tonne/h)																								
Molar Flow (kgmole/h)																								
Mass Density (kg/m3)																								
Molecular Weight																								-
Std Ideal Liq Vol Flow (m3/h)									1											<del> </del>				+
Surface Tension (dyne/cm)													1											+
Viscosity (cP)																								+
• • • • • • • • • • • • • • • • • • • •			-		-	-			+	-			-	-	+	331.3	40070.0	40700.0	331.3	74.0	401.7	293.3	COE 4	668
Actual Volume Flow (m3/h)									<del> </del>	1			-	<u> </u>	-		10670.8	10723.3		71.0	+		695.1	_
Mass Flow (tonne/h)									-					-		328.7	10656.1	10656.1	328.7	67.9	396.6	289.9	686.5	660
Molar Flow (kgmole/h)																18248.0	591510.4	591510.4	18243.1	3767.5	22016.5	16086.7	38097.3	3664
Mass Density (kg/m3)																992.3	998.6	993.7	992.3	956.2	987.3	988.2	987.7	987
Molecular Weight																18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.
Std Ideal Liq Vol Flow (m3/h)																329.40	10677.62	10677.62	329.38	68.03	59994.16	290.44	687.91	661
Viscosity (cP)																0.662	1.066	0.711	0.656	0.267	0.531	0.549	0.539	0.5
(CO2)																								
(Nitrogen)																								
(Oxygen)																								
(H2S)																								1
(H2O)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00
(Ammonia)					1					1				1				112222		1100000	1			+
(SO2)						<u> </u>			<del>                                     </del>						+			+						+
' '																		1						+
(Argon) (NO2)			+						+									+						+
· · · · ·			<del> </del>			<b> </b>									+			+						+
(Methane)																		1						+
(Ethane)									1									1						
(Propane)																								1
(n-Butane)																								
(n-Pentane)																								
(n-Hexane)																								
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0



**PROJECT No.** 181869

PROJECT NAME THERMAL POWER WITH CCS

UK

LOCATION

DOCUMENT No. 181869-0001-D-EM-HMB-AAA-00-00002-01

REVISION A02

DATE NOVEMBER 2017

	Stream Description	Water to LPE	Water to LPB/IP/HP Pumps	Water to LPB (V-103)	Water to HP Feedwater Pump	Water to IP Feedwater Pump	Steam to LPS	Steam from LPS	Water to HPE0	Water to IPB/ Fuel Gas Heater	Water to Fuel Gas Heater	Water to IPB (V-102)	Water to IPS1	Steam from IPS1	Water to IPE2	Water to HPE2	Water to HPE3	Water to HPB1 (V-101)	Steam from HPB1 (V-101)	Steam from HPS0	Steam from HPS3	Steam to RH1	Steam to RH3	Steam from RH3	
	PFD Stream Number	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	69	70	71	72	
	Vapour Fraction	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	
	Temperature (C)	104.44	139.71	139.71	139.71	139.71	141.71	293.33	140.99	238.48	238.48	238.48	240.69	310.62	145.67	238.47	313.91	351.63	353.86	495.65	575.65	336.95	486.44	575.33	
	Pressure (bar)	3.906	3.792	3.792	3.792	3.792	3.792	3.611	34.900	33.890	33.890	33.890	33.890	33.220	178.540	176.560	174.660	173.340	173.340	168.860	164.480	33.220	31.850	31.050	
	Actual Volume Flow (m3/h)	691.5	713.0	57.0	520.8	135.3	25658.8	37872.3	135.2	153.6	83.2	70.3	70.6	4271.2	518.4	581.1	688.7	842.7	3893.6	8647.4	10433.2	41326.8	55995.4	64830.0	
	Mass Flow (tonne/h)	660.2	660.2	52.8	482.2	125.3	52.8	52.8	125.3	125.3	67.9	57.4	57.4	57.4	482.2	482.2	482.2	482.2	482.2	482.2	482.2	522.9	522.9	522.9	
	Molar Flow (kgmole/h)	36647.0	36647.0	2929.8	26764.8	6952.5	2929.8	2929.8	6952.5	6952.5	3768.5	3184.0	3184.0	3184.0	26764.8	26764.8	26764.8	26764.8	26764.8	26764.8	26764.8	29025.7	29025.7	29025.7	
l _	Mass Density (kg/m3)	954.70	925.90	925.90	925.90	925.90	2.06	1.39	926.50	815.70	815.70	815.70	812.40	13.43	930.20	829.70	700.10	572.20	123.80	55.76	46.22	12.65	9.34	8.07	
era	Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	
ò	Mass Heat Capacity (kJ/kg-C)	4.22	4.29	4.29	4.29	4.29	2.25	2.05	4.28	4.76	4.76	4.76	4.78	2.59	4.25	4.62	5.79	10.62	18.86	3.02	2.68	2.45	2.24	2.26	
	Std Gas Flow (STD_m3/h)	866500.0	866500.0	69270.0	632800.0	164400.0	69270.0	69270.0	164400.0	164400.0	89100.0	75280.0	75280.0	75280.0	632800.0	632800.0	632800.0	632800.0	632800.0	632800.0	632800.0	686300.0	686300.0	686300.0	
	Std Ideal Liq Vol Flow (m3/h)	661.5	661.5	52.9	483.1	125.5	52.9	52.9	125.5	125.5	68.0	57.5	57.5	57.5	483.1	483.1	483.1	483.1	483.1	483.1	483.1	524.0	524.0	524.0	-
	Viscosity (cP)	0.2665	0.1954	0.1954	0.1954	0.1954	0.0136	0.0200	0.1935	0.1121	0.1121	0.1121	0.1111	0.0207	0.1869	0.1121	0.0858	0.0726	0.0467	0.0304	0.0333	0.0219	0.0282	0.0318	
	Actual Volume Flow (m3/h)						25658.8	37872.3						4271.2					3893.6	8647.4	10433.2	41326.8	55995.4	64830.0	
	Mass Flow (tonne/h)						52.8	52.8						57.4					482.2	482.2	482.2	522.9	522.9	522.9	
	Molar Flow (kgmole/h)	1					2929.8	2929.8						3184.0					26764.8	26764.8	26764.8	29025.7	29025.7	29025.7	
Jase	Mass Density (kg/m3)	1					2.06	1.39						13.43					123.80	55.76	46.22	12.65	9.34	8.07	-
Ē	Molecular Weight	1					18.02	18.02						18.02					18.02	18.02	18.02	18.02	18.02	18.02	
nod	Cp/Cv	1					1.37	1.31						1.41					5.07	1.54	1.42	1.39	1.32	1.29	-
\ a	Std Gas Flow (STD_m3/h)	1					69270.0	69270.0						75280.0					632800.0	632800.0	632800.0	686300.0	686300.0	686300.0	
	Viscosity (cP)						0.0136	0.0200						0.0207					0.0467	0.0304	0.0333	0.0219	0.0282	0.0318	
	Z Factor						0.9628	0.9911						0.9181					0.4837	0.8535	0.9085	0.9324	0.9729	0.9831	
	Actual Volume Flow (m3/h)	1					0.0020	0.0011						0.0.0.					0.1007	0.0000	0.0000	0.0021	0.0720	0.000	
	Mass Flow (tonne/h)																								
ø,	Molar Flow (kgmole/h)																								
has	Mass Density (kg/m3)																								
<u>5</u>	Molecular Weight																								
-ig	Std Ideal Liq Vol Flow (m3/h)																								-
-	Surface Tension (dyne/cm)																								
	Viscosity (cP)																								
	Actual Volume Flow (m3/h)	691.5	713.0	57.0	520.8	135.3			135.2	153.6	83.2	70.3	70.6		518.4	581.1	688.7	842.7							-
Φ	Mass Flow (tonne/h)	660.2	660.2	52.8	482.2	125.3			125.3	125.3	67.9	57.4	57.4		482.2	482.2	482.2	482.2							
has	Molar Flow (kgmole/h)	36647.0	36647.0	2929.8	26764.8	6952.5			6952.5	6952.5	3768.5	3184.0	3184.0		26764.8	26764.8	26764.8	26764.8							
S P	Mass Density (kg/m3)	954.7	925.9	925.9	925.9	925.9			926.5	815.7	815.7	815.7	812.4		930.2	829.7	700.1	572.2							
eon	Molecular Weight	18.02	18.02	18.02	18.02	18.02			18.02	18.02	18.02	18.02	18.02		18.02	18.02	18.02	18.02							
Aqu	Std Ideal Liq Vol Flow (m3/h)	661.50	661.50	52.89	483.10	125.50			125.50	125.50	68.03	57.48	57.48		483.10	483.10	483.10	483.10							
	Viscosity (cP)	0.267	0.195	0.195	0.195	0.195			0.194	0.112	0.112	0.112	0.111		0.187	0.112	0.086	0.073							
	(CO2)	5.201	000	000	000	3.700			554	5IZ	J.712	V12	V11		0.107	U.112	3.300	5.570							
	(Nitrogen)	+ -																							
	(Oxygen)	+ -																							
	(H2S)																								
	(H2O)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		
	(Ammonia)	1.50000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		
ĕ	(SO2)	+ -																							
io	(Argon)																								
sit	(NO2)	+ -																							
ш	(Methane)																								
និ	(Ethane)																								
1	(Propane)	+																							
	(n-Butane)	+																							
	(n-Pentane)	+ -																							
1	(n-Hexane)	+																							
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000					
	I Ulai	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000					



HEAT AND MASS BALANCE BROCHURE EFFICIENCY REBOILER CARBON CAPTURE H&MB

PROJECT No. 181869

PROJECT NAME THERMAL POWER WITH CCS

LOCATION UK

 DOCUMENT No.
 181869-0001-D-EM-HMB-AAA-00-00002-01

 REVISION
 A02

NOVEMBER 2017

							 		r						1	1	
	Stream Description	Sour Gas Feed	Treated Gas to Stack	Treated Gas from Amine Reflux Drum	LP Steam to Reboiler	LP Condensate from Reboiler											
	PFD Stream Number	100	101	102	103	104											
	Vapour Fraction	1.000	1.000	1.000	1.000	0.000											
	Temperature (C)	87.80	64.60	26.30	138.70	126.14											
	Pressure (bar)	1.010	1.009	2.000	2.400	2.400											
	Actual Volume Flow (m3/h)	3714505.5	3170265.6	65083.0	217108.4	297.0											
	Mass Flow (tonne/h)	3550.5	3215.1	230.2	278.6	278.6											
	Molar Flow (kgmole/h)	125083.1	113959.6	5286.4	15462.3	15462.3											
<b>=</b>	Mass Density (kg/m3)	0.956	1.014	3.537	1.283	937.811											
vers	Molecular Weight	28.39	28.21	43.55	18.02	18.02											
Ó	Mass Heat Capacity (kJ/kg-C)	1.06	1.04	0.86	1.94	4.56											
	Std Gas Flow (STD_m3/h)	2957520.0	2694511.2	124994.2	365597.5	365597.5											
	Std Ideal Liq Vol Flow (m3/h)	6292.1	5906.8	279.8	279.1	279.1											
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141	0.2165											
	Actual Volume Flow (m3/h)	3714505.5	3170265.6	65083.0	217108.4												
	Mass Flow (tonne/h)	3550.5	3215.1	230.2	278.6												
eg.	Molar Flow (kgmole/h)	125083.1	113959.6	5286.4	1546.2												
has	Mass Density (kg/m3)	0.96	1.01	3.54	1.28												
Ä	Molecular Weight	28.39	28.21	43.55	18.02												
abo	Cp/Cv	1.38	1.40	1.30	1.34												
>	Std Gas Flow (STD_m3/h)	2957520.0	2694511.2	124994.2	365597.5												
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141												
	Z Factor	0.9994	0.9996	0.9890	0.9841												
	Actual Volume Flow (m3/h)																
	Mass Flow (tonne/h)																
ase	Molar Flow (kgmole/h)																
표	Mass Density (kg/m3)																
Di Di	Molecular Weight																
Lig	Std Ideal Liq Vol Flow (m3/h)																
	Surface Tension (dyne/cm)																
	Viscosity (cP)																
	Actual Volume Flow (m3/h)					297.0											
ase	Mass Flow (tonne/h)					278.6											
F.	Molar Flow (kgmole/h)					15462.3											
sno	Mass Density (kg/m3)					937.8											
ane	Molecular Weight					18.02											
Ĭ	Std Ideal Liq Vol Flow (m3/h)					279.09											
	Viscosity (cP)					0.216											
I	H2O	0.09166	0.04858	0.01749	1.00000	1.00000											
Ī	CO2	0.04606	0.00505	0.98090	0.00000	0.00000											
(Mol)	H2S	0.00000	0.00000	0.00000	0.00000	0.00000											
Ē	Oxygen	0.11157	0.12246	0.00002	0.00000	0.00000											
ition	Nitrogen	0.74178	0.81417	0.00026	0.00000	0.00000											
osi	SO2	0.00000	0.00000	0.00001	0.00000	0.00000											
Ĕ	Ammonia	0.00000	0.00000	0.00000	0.00000	0.00000											
ŭ	Argon	0.00893	0.00974	0.00127	0.00000	0.00000											
	NO2	0.00000	0.00000	0.00000	0.00000	0.00000				<b> </b>							
	Total	1.000	1.000	1.000	1.000	1.000											



SNC-Lavalin UK Limited Woodcote Grove Ashley Road, Epsom, Surrey KT18 5BW, United Kingdom

# Attachment 3.2.2 – Brochure Efficiency Reboiler Case 2.4 GJ/tonne CO<sub>2</sub> case



PROJECT No. 181869

THERMAL POWER WITH CCS PROJECT NAME UK

LOCATION

181869-0001-D-EM-HMB-AAA-00-00002-01 DOCUMENT No. REVISION

A01

DATE OCTOBER 2017

	Stream Description	Air to Inlet Air Filter	Air from Inlet Air Filter	Fuel Gas to Fuel Gas Heater	Fuel Gas to Gas Turbine	Flue Gas from Gas Turbine	Flue Gas to RH3	Flue Gas to HPS1	Flue Gas to RH1	Flue Gas to HPS0	Flue Gas to HPB1	Flue Gas to HPE3	Flue Gas to LPS	Flue Gas to	Flue Gas to HPE2	Flue Gas to IPB	Flue Gas to HPE0/ IPE2	Flue Gas to IPE2	Flue Gas to HPE0	Flue Gas from IPE2	Flue Gas from HPE0	Flue Gas to LPB	Flue Gas to LPE	Flue Gas to LTE	Flue Gas to CCP
	PFD Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Vapour Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Temperature (C)	10.00	10.00	25.00	204.44	646.54	633.96	609.13	595.70	552.52	466.71	363.86	331.24	326.96	323.90	276.92	250.71	250.71	185.28	250.71	185.28	185.28	155.48	129.33	89.69
	Pressure (bar)	1.013	1.013	49.110	49.110	1.045	1.044	1.043	1.043	1.042	1.039	1.029	1.025	1.025	1.025	1.021	1.020	1.020	1.017	1.020	1.017	1.017	1.015	1.014	1.013
	Actual Volume Flow (m3/h)	2777444.6	2777444.6	2254.2	4074.0	9158759.5	9039549.0	8798874.5	8668271.3	8243029.0	7404797.7	6441519.4	6133576.6	6090713.0	6061413.1	5602182.1	5343374.3	1091905.5	958357.3	4251468.8	3731480.4	4689839.8	4389130.4	4126381.1	3721592.0
	Mass Flow (tonne/h)	3455.8	3455.8	94.7	94.7	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	725.5	725.5	2825.0	2825.0	3550.5	3550.5	3550.5	3550.5
	Molar Flow (kgmole/h)	119636.8	119636.8	5115.6	5115.6	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	25560.6	25560.6	99523.5	99523.5	125084.2	125084.2	125084.2	125084.2
l _	Mass Density (kg/m3)	1.24	1.24	41.99	23.24	0.39	0.39	0.40	0.41	0.43	0.48	0.55	0.58	0.58	0.59	0.63	0.66	0.66	0.76	0.66	0.76	0.76	0.81	0.86	0.95
era	Molecular Weight	28.89	28.89	18.50	18.50	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38
ò	Mass Heat Capacity (kJ/kg-C)	1.01	1.01	2.46	2.74	1.20	1.20	1.19	1.19	1.18	1.16	1.14	1.13	1.13	1.13	1.12	1.11	1.11	1.09	1.11	1.09	1.09	1.09	1.08	1.07
	Std Gas Flow (STD_m3/h)	2829000.0	2829000.0	121000.0	121000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	604400.0	604400.0	2353000.0	2353000.0	2958000.0	2958000.0	2958000.0	2958000.0
	Std Ideal Liq Vol Flow (m3/h)	3972.0	3972.0	289.1	289.1	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	850.6	850.6	3312.0	3312.0	4163.0	4163.0	4163.0	4163.0
	Viscosity (cP)	0.0180	0.0180	0.0125	0.0173	0.0407	0.0403	0.0393	0.0388	0.0372	0.0341	0.0305	0.0293	0.0292	0.0291	0.0274	0.0265	0.0265	0.0241	0.0265	0.0241	0.0241	0.0230	0.0219	0.0203
-	Actual Volume Flow (m3/h)	2777444.6	2777444.6	2254.2	4074.0	9158759.5	9039549.0	8798874.5	8668271.3	8243029.0	7404797.7	6441519.4	6133576.6	6090713.0	6061413.1	5602182.1	5343374.3	1091905.5	958357.3	4251468.8	3731480.4	4689839.8	4389130.4	4126381.1	3721592.0
	Mass Flow (tonne/h)	3455.8	3455.8	94.7	94.7	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	725.5	725.5	2825.0	2825.0	3550.5	3550.5	3550.5	3550.5
_	Molar Flow (kgmole/h)	119636.8	119636.8	5115.6	5115.6	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	25560.6	25560.6	99523.5	99523.5	125084.2	125084.2	125084.2	125084.2
ase	Mass Density (kg/m3)	1.24	1.24	41.99	23.24	0.39	0.39	0.40	0.41	0.43	0.48	0.55	0.58	0.58	0.59	0.63	0.66	0.66	0.76	0.66	0.76	0.76	0.81	0.86	0.95
된	Molecular Weight	28.89	28.89	18.50	18.50	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38
noc	Cp/Cv	1.40	1.40	1.49	1.24	1.32	1.32	1.33	1.33	1.33	1.34	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.37	1.36	1.37	1.37	1.37	1.37	1.38
Vap	Std Gas Flow (STD_m3/h)	2829000.0	2829000.0	121000.0	121000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	604400.0	604400.0	2353000.0	2353000.0	2958000.0	2958000.0	2958000.0	2958000.0
	Viscosity (cP)	0.0180	0.0180	0.0125	0.0173	0.0407	0.0403	0.0393	0.0388	0.0372	0.0341	0.0305	0.0293	0.0292	0.0291	0.0274	0.0265	0.0265	0.0241	0.0265	0.0241	0.0241	0.0230	0.0219	0.0203
	Z Factor	0.9992	0.9992	0.8730	0.9849	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9999	0.0241	0.0230	0.0219	0.0203
	Actual Volume Flow (m3/h)	0.9992	0.9992	0.8730	0.9049	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.5555	0.5555	0.5550	0.9990	0.9993
	,														-										<del>                                     </del>
ø	Mass Flow (tonne/h) Molar Flow (kgmole/h)														-										$\vdash$
has	, ,														-										$\vdash$
В	Mass Density (kg/m3)														-										$\vdash$
ig	Molecular Weight Std Ideal Liq Vol Flow (m3/h)														-										<del>                                     </del>
-	. , ,														-										$\vdash$
	Surface Tension (dyne/cm)															-									<del>                                     </del>
-	Viscosity (cP)														-	ļ	-								$\vdash$
	Actual Volume Flow (m3/h)														-										<del>                                     </del>
ase	Mass Flow (tonne/h)	-													-	1									<del>                                     </del>
- S	Molar Flow (kgmole/h)															-									<del>                                     </del>
noe	Mass Density (kg/m3)	-													-	1									1
'nb	Molecular Weight															-									<del>                                     </del>
1	Std Ideal Liq Vol Flow (m3/h)														-										<del>                                     </del>
<u> </u>	Viscosity (cP)	0.00000	0.00000	0.04040	0.04040	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000	0.04000
	(CO2)	0.00030	0.00030	0.01910	0.01910	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606
	(Nitrogen)	0.77512	0.77512	0.00990	0.00990	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178
	(Oxygen)	0.20797	0.20797	0.00004	0.00004	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157	0.11157
	(H2S)	0.00707	0.00707	0.00004	0.00004	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400	0.00400
	(H2O)	0.00727	0.00727			0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166
Θ	(Ammonia)					0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
u o	(SO2)	0.00004	0.00004			0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Siti	(Argon)	0.00934	0.00934			0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893
odu	(NO2)			0.07447	0.07447																				$\vdash$
ទ	(Methane)			0.87447	0.87447																				$\vdash$
	(Ethane)			0.06980	0.06980										-										
	(Propane)			0.02190	0.02190										-										
	(n-Butane)	1		0.00410	0.00410										1		-								
	(n-Pentane)			0.00050	0.00050										-										
	(n-Hexane)	4.000	4.000	0.00020	0.00020	4 000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000



PROJECT No. 181869

THERMAL POWER WITH CCS PROJECT NAME

LOCATION

DOCUMENT No. A01 REVISION

181869-0001-D-EM-HMB-AAA-00-00002-01

DATE OCTOBER 2017

	Stream Description	Steam to HP Casing	Steam from HP Casing	Reheat Steam to HP Casing	MP Steam from HP Casing	MP Steam	MP Steam to CCP (Note 3)		Steam from IP Casing	Steam from LPS	Steam to IP/LP Casing	Steam from IP/LP Casing	LP Steam	LP Steam to CCP (Note 3)	LP Steam to		Condensate from Condenser	Cooling Water Supply	Cooling Water Return	Condensate from Gland Steam	Condensate from Fuel Gas Heater	Condensate from E-103/104	Condensate from CCP	Condensate to Feedwater Tank	Water to LTE
	PFD Stream Number	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	Vapour Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Temperature (C)	573.89	342.37	573.89	522.71	522.71	235.00	522.71	270.72	291.90	272.66	234.41	234.41	138.70	234.41	39.16	39.15	17.50	35.50	39.67	104.44	51.47	49.50	50.58	50.58
	Pressure (bar)	165.000	34.390	30.000	21.510	21.510	21.510	21.510	3.375	3.375	3.375	2.400	2.400	2.400	2.400	0.071	0.429	2.986	2.308	4.023	33.890	4.023	4.023	4.023	4.023
	Actual Volume Flow (m3/h)	10366.3	35853.9	67016.9	89891.2	1744.0	1323.6	88147.2	385993.3	40439.5	426436.1	561423.6	217338.9	189870.8	344073.1	7284105.7	359.8	10670.8	10723.3	359.8	71.0	430.4	262.0	692.4	668.4
	Mass Flow (tonne/h)	482.2	465.5	522.9	534.5	10.4	13.4	524.1	524.1	52.8	576.9	580.5	224.7	245.5	355.8	357.1	357.1	10656.1	10656.1	357.1	67.9	425.0	258.9	683.9	660.2
	Molar Flow (kgmole/h)	26766.4	25839.4	29025.7	29669.6	575.6	745.4	29093.9	29093.9	2929.8	32023.7	32223.0	12471.1	13623.9	19743.2	19820.7	19820.7	591510.4	591510.4	19815.3	3767.5	23589.2	14369.1	37951.9	36647.0
		46.52	12.98	7.80					1.36	<b>.</b>		1.03	1.03	<b>+</b>		0.05			993.74		956.20	987.26	<b>+</b>	987.70	987.70
ra E	Mass Density (kg/m3)				5.95 18.02	5.95	10.15	5.95		1.31	1.35	18.02	<b>!</b>	1.29	1.03	1	992.32	998.62	1	992.30		<b> </b>	988.20		
Š	Molecular Weight	18.02	18.02	18.02		18.02	18.02	18.02	18.02	18.02	18.02		18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02
	Mass Heat Capacity (kJ/kg-C)	2.69	2.45	2.26	2.21	2.21	2.83	2.21	2.04	2.04	2.04	2.03	2.03	2.12	2.03	1.88	4.18	4.18	4.18	4.18	4.22	4.18	4.18	4.18	4.18
	Std Gas Flow (STD_m3/h)	632900.0	611000.0	686300.0	701500.0	13610.0	17630.0	687900.0	687900.0	69270.0	757200.0	761900.0	294966.3	322253.6	466928.6	468648.9	468648.9	13985929.5	13985929.5	468627.6	89100.0	472.7	339806.6	897616.6	866500.0
	Std Ideal Liq Vol Flow (m3/h)	483.2	466.4	524.0	535.6	10.4	13.5	525.2	525.2	52.9	578.1	581.7	225.2	246.0	356.5	357.8	357.8	10677.6	10677.6	357.8	68.0	64279.6	259.4	685.3	661.5
	Viscosity (cP)	0.0332	0.0222	0.0317	0.0295	0.0295	0.0171	0.0295	0.0190	0.0199	0.0191	0.0175	0.0175	0.0136	0.0175	0.0096	0.6621	1.0656	0.7113	0.6555	0.2665	0.5309	0.5488	0.5389	0.5389
	Actual Volume Flow (m3/h)	10366.3	35853.9	67016.9	89891.2	1744.0	1323.6	88147.2	385993.3	40439.5	426436.1	561423.6	217338.9	230317.1	297775.6	6307545.4									
1	Mass Flow (tonne/h)	482.2	465.5	522.9	534.5	10.4	13.4	524.1	524.1	52.8	576.9	580.5	224.7	297.8	307.9	309.2									
8	Molar Flow (kgmole/h)	26766.4	25839.4	29025.7	29669.6	575.6	745.4	29093.9	29093.9	2929.8	32023.7	32223.0	12471.1	16526.1	17086.6	17163.4									
'na	Mass Density (kg/m3)	46.52	12.98	7.80	5.95	5.95	10.15	5.95	1.36	1.31	1.35	1.03	1.03	1.29	1.03	0.05									
7	Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02				-					
og g	Cp/Cv	1.42	1.39	1.29	1.30	1.30	1.45	1.30	1.32	1.31	1.31	1.32	1.32	1.35	1.32	1.33									
>	Std Gas Flow (STD_m3/h)	632900.0	611000.0	686300.0	701500.0	13610.0	17630.0	687900.0	687900.0	69270.0	757200.0	761900.0	294966.3	390900.0	404100.0	405818.4									
	Viscosity (cP)	0.0332	0.0222	0.0317	0.0295	0.0295	0.0171	0.0295	0.0190	0.0199	0.0191	0.0175	0.0175	0.0136	0.0175	0.0096									
	Z Factor	0.9074	0.9324	0.9835	0.9849	0.9849	0.9040	0.9849	0.9902	0.9916	0.9904	0.9909	0.9909	0.9764	0.9909	0.9978									
	Actual Volume Flow (m3/h)																								
	Mass Flow (tonne/h)																								
ø	Molar Flow (kgmole/h)																								
has	, ,			1										<del> </del>	1										
В	Mass Density (kg/m3)			1		<b> </b>				1	-			+	-							+	+		<del>                                     </del>
ja	Molecular Weight			-										<del> </del>	<u> </u>	-			-				1		-
	Std Ideal Liq Vol Flow (m3/h)													-	-	-			1						-
	Surface Tension (dyne/cm)													-	-										
	Viscosity (cP)													-		ļ									
	Actual Volume Flow (m3/h)																359.8	10670.8	10723.3	359.8	71.0	430.4	262.0	692.4	668.4
ase	Mass Flow (tonne/h)																357.1	10656.1	10656.1	357.1	67.9	425.0	258.9	683.9	660.2
훕	Molar Flow (kgmole/h)																19820.7	591510.4	591510.4	19815.3	3767.5	23589.2	14369.1	37951.9	36647.0
snc	Mass Density (kg/m3)																992.3	998.6	993.7	992.3	956.2	987.3	988.2	987.7	987.7
lne	Molecular Weight																18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02
A	Std Ideal Liq Vol Flow (m3/h)													1			357.79	10677.62	10677.62	357.76	68.03	64279.62	259.43	685.28	661.50
L	Viscosity (cP)																0.662	1.066	0.711	0.656	0.267	0.531	0.549	0.539	0.539
	(CO2)																								
	(Nitrogen)																								
1	(Oxygen)																								
	(H2S)																								
1	(H2O)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
_	(Ammonia)															1									
Θ	(SO2)			+										<del>                                     </del>		1			<del> </del>						<del>                                     </del>
_ ⊆	(Argon)			+										<del>                                     </del>		1			<del> </del>						<del>                                     </del>
	(NO2)			+									-	+		1			1		-				$\vdash$
ubo	' '			+										-		+			<del> </del>						$\vdash$
9	(Methane)					-				-	-		-	-		1					-	-	-		$\vdash$
1	(Ethane)															1			1						1
	(Propane)															1			1						1
	(n-Butane)																								$\perp$
	(n-Pentane)																								
	(n-Hexane)																								<u> </u>
1	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000



PROJECT No. 181869

THERMAL POWER WITH CCS PROJECT NAME

UK LOCATION

181869-0001-D-EM-HMB-AAA-00-00002-01 DOCUMENT No. A01

REVISION

DATE OCTOBER 2017

	Stream Description	Water to LPE	Water to LPB/IP/HP Pumps	Water to LPB (V-103)	Water to HP Feedwater Pump	Water to IP Feedwater Pump	Steam to LPS	Steam from LPS	Water to HPE0	Water to IPB/ Fuel Gas Heater	Water to Fuel Gas Heater	Water to IPB (V-102)	Water to IPS1	Steam from IPS1	Water to IPE2	Water to HPE2	Water to HPE3	Water to HPB1 (V-101)	Steam from HPB1 (V-101)	Steam from HPS0	Steam from HPS3	Steam to RH1	Steam to RH3	Steam from RH3	
	PFD Stream Number	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	69	70	71	72	
	Vapour Fraction	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	
	Temperature (C)	104.44	139.71	139.71	139.71	139.71	141.71	293.33	140.99	238.48	238.48	238.48	240.69	310.62	145.67	238.47	313.91	351.63	353.86	495.65	575.65	336.95	486.44	575.33	
	Pressure (bar)	3.906	3.792	3.792	3.792	3.792	3.792	3.611	34.900	33.890	33.890	33.890	33.890	33.220	178.540	176.560	174.660	173.340	173.340	168.860	164.480	33.220	31.850	31.050	
	Actual Volume Flow (m3/h)	691.5	713.0	57.0	520.8	135.3	25658.8	37872.3	135.2	153.6	83.2	70.3	70.6	4271.2	518.4	581.1	688.7	842.7	3893.6	8647.4	10433.2	41326.8	55995.4	64830.0	
	Mass Flow (tonne/h)	660.2	660.2	52.8	482.2	125.3	52.8	52.8	125.3	125.3	67.9	57.4	57.4	57.4	482.2	482.2	482.2	482.2	482.2	482.2	482.2	522.9	522.9	522.9	
	Molar Flow (kgmole/h)	36647.0	36647.0	2929.8	26764.8	6952.5	2929.8	2929.8	6952.5	6952.5	3768.5	3184.0	3184.0	3184.0	26764.8	26764.8	26764.8	26764.8	26764.8	26764.8	26764.8	29025.7	29025.7	29025.7	
	Mass Density (kg/m3)	954.70	925.90	925.90	925.90	925.90	2.06	1.39	926.50	815.70	815.70	815.70	812.40	13.43	930.20	829.70	700.10	572.20	123.80	55.76	46.22	12.65	9.34	8.07	
ara	Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	
ŏ	Mass Heat Capacity (kJ/kg-C)	4.22	4.29	4.29	4.29	4.29	2.25	2.05	4.28	4.76	4.76	4.76	4.78	2.59	4.25	4.62	5.79	10.62	18.86	3.02	2.68	2.45	2.24	2.26	
	Std Gas Flow (STD m3/h)	866500.0	866500.0	69270.0	632800.0	164400.0	69270.0	69270.0	164400.0	164400.0	89100.0	75280.0	75280.0	75280.0	632800.0	632800.0	632800.0	632800.0	632800.0	632800.0	632800.0	686300.0	686300.0	686300.0	
	, - /			<b>I</b>						<b>-</b>						<b>I</b>	<b>.</b>	<b>.</b>		1					
	Std Ideal Liq Vol Flow (m3/h)	661.5	661.5	52.9	483.1	125.5	52.9	52.9	125.5	125.5	68.0	57.5	57.5	57.5	483.1	483.1	483.1	483.1	483.1	483.1	483.1	524.0	524.0	524.0	
-	Viscosity (cP)	0.2665	0.1954	0.1954	0.1954	0.1954	0.0136	0.0200	0.1935	0.1121	0.1121	0.1121	0.1111	0.0207	0.1869	0.1121	0.0858	0.0726	0.0467	0.0304	0.0333	0.0219	0.0282	0.0318	
	Actual Volume Flow (m3/h)						25658.8	37872.3						4271.2					3893.6	8647.4	10433.2	41326.8	55995.4	64830.0	
	Mass Flow (tonne/h)						52.8	52.8						57.4					482.2	482.2	482.2	522.9	522.9	522.9	
se	Molar Flow (kgmole/h)						2929.8	2929.8						3184.0					26764.8	26764.8	26764.8	29025.7	29025.7	29025.7	
Pha	Mass Density (kg/m3)						2.06	1.39						13.43					123.80	55.76	46.22	12.65	9.34	8.07	
our	Molecular Weight						18.02	18.02						18.02					18.02	18.02	18.02	18.02	18.02	18.02	
/ab	Cp/Cv						1.37	1.31						1.41					5.07	1.54	1.42	1.39	1.32	1.29	
_	Std Gas Flow (STD_m3/h)						69270.0	69270.0						75280.0					632800.0	632800.0	632800.0	686300.0	686300.0	686300.0	
	Viscosity (cP)						0.0136	0.0200						0.0207					0.0467	0.0304	0.0333	0.0219	0.0282	0.0318	
	Z Factor						0.9628	0.9911						0.9181					0.4837	0.8535	0.9085	0.9324	0.9729	0.9831	
	Actual Volume Flow (m3/h)																								
	Mass Flow (tonne/h)																								
ase	Molar Flow (kgmole/h)																								
룹	Mass Density (kg/m3)																								
Б	Molecular Weight																								
Ę	Std Ideal Liq Vol Flow (m3/h)																								
	Surface Tension (dyne/cm)																								
	Viscosity (cP)																								
	Actual Volume Flow (m3/h)	691.5	713.0	57.0	520.8	135.3			135.2	153.6	83.2	70.3	70.6		518.4	581.1	688.7	842.7							
se	Mass Flow (tonne/h)	660.2	660.2	52.8	482.2	125.3			125.3	125.3	67.9	57.4	57.4		482.2	482.2	482.2	482.2							
- Pa	Molar Flow (kgmole/h)	36647.0	36647.0	2929.8	26764.8	6952.5			6952.5	6952.5	3768.5	3184.0	3184.0		26764.8	26764.8	26764.8	26764.8							
l sn	Mass Density (kg/m3)	954.7	925.9	925.9	925.9	925.9			926.5	815.7	815.7	815.7	812.4		930.2	829.7	700.1	572.2							
oen	Molecular Weight	18.02	18.02	18.02	18.02	18.02			18.02	18.02	18.02	18.02	18.02		18.02	18.02	18.02	18.02							
Aq	Std Ideal Liq Vol Flow (m3/h)	661.50	661.50	52.89	483.10	125.50			125.50	125.50	68.03	57.48	57.48		483.10	483.10	483.10	483.10							
	Viscosity (cP)	0.267	0.195	0.195	0.195	0.195			0.194	0.112	0.112	0.112	0.111		0.187	0.112	0.086	0.073							
	(CO2)																								
1	(Nitrogen)																								
	(Oxygen)																								
	(H2S)																								
1	(H2O)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		
l _	(Ammonia)																								
₽	(SO2)																								
ţio	(Argon)																								
osit	(NO2)																								
Ĕ	(Methane)																								
ပိ	(Ethane)																								
	(Propane)																								
	(n-Butane)																								
	(n-Pentane)																								
1																									
	(n-Hexane)	1 000	1 000	1.000	1.000	1 000	1 000	1 000	1.000	1.000	1 000	1 000	1 000	1 000	1 000	1.000	1 000	1 000	1 000	1,000					
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000					



HEAT AND MASS BALANCE BROCHURE EFFICIENCY REBOILER CARBON CAPTURE H&MB

PROJECT No. 181869

PROJECT NAME THERMAL POWER WITH CCS

LOCATION UK

REVISION A01

DOCUMENT No.

181869-0001-D-EM-HMB-AAA-00-00002-01

		Sour Gas		Treated Gas	LP Steam to	LP Condensate									
	Stream Description	Feed	to Stack	from Amine Reflux Drum	Reboiler	from									
	PFD Stream Number	100	101	102	103	Reboiler 104							1		
	Vapour Fraction	1.000	1.000	1.000	1.000	0.000		1	1	1	1		İ		
	Temperature (C)	87.80	64.60	26.30	138.70	126.14									
	Pressure (bar)	1.010	1.009	2.000	2.400	2.400									
	Actual Volume Flow (m3/h)	3714505.5	3170265.6	65083.0	192985.2	264.0									
	Mass Flow (tonne/h)	3550.5	3215.1	230.2	247.6	247.6									
	Molar Flow (kgmole/h)	125083.1	113959.6	5286.4	13744.3	13744.3									
	Mass Density (kg/m3)	0.956	1.014	3.537	1.283	937.811									
	Molecular Weight	28.39	28.21	43.55	18.02	18.02									
Ó	Mass Heat Capacity (kJ/kg-C)	1.06	1.04	0.86	1.94	4.56									
	Std Gas Flow (STD_m3/h)	2957520.0	2694511.2	124994.2	324975.5	324975.5									
	Std Ideal Liq Vol Flow (m3/h)	6292.1	5906.8	279.8	248.1	248.1									
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141	0.2165									
	Actual Volume Flow (m3/h)	3714505.5	3170265.6	65083.0	192985.2										
	Mass Flow (tonne/h)	3550.5	3215.1	230.2	247.6										
g,	Molar Flow (kgmole/h)	125083.1	113959.6	5286.4	1374.4										
has	Mass Density (kg/m3)	0.96	1.01	3.54	1.28										
F P	Molecular Weight	28.39	28.21	43.55	18.02										
od	Cp/Cv	1.38	1.40	1.30	1.34										
>	Std Gas Flow (STD_m3/h)	2957520.0	2694511.2	124994.2	324975.5										
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141										
	Z Factor	0.9994	0.9996	0.9890	0.9841										
	Actual Volume Flow (m3/h)														
	Mass Flow (tonne/h)														
se	Molar Flow (kgmole/h)														
Ę.	Mass Density (kg/m3)														
	Molecular Weight														
Lig	Std Ideal Liq Vol Flow (m3/h)														
	Surface Tension (dyne/cm)														
	Viscosity (cP)														
	Actual Volume Flow (m3/h)					264.0									
se	Mass Flow (tonne/h)					247.6				1					
Pha	Molar Flow (kgmole/h)					13744.3									
sno	Mass Density (kg/m3)					937.8									
nec	Molecular Weight					18.02									
Aq	Std Ideal Liq Vol Flow (m3/h)					248.08									
	Viscosity (cP)					0.216									
	H2O	0.09166	0.04858	0.01749	1.00000	1.00000									
	CO2	0.04606	0.00505	0.98090	0.00000	0.00000									
Ē	H2S	0.00000	0.00000	0.00000	0.00000	0.00000									
	Oxygen	0.11157	0.12246	0.00002	0.00000	0.00000									
	Nitrogen	0.74178	0.81417	0.00026	0.00000	0.00000				1					
osit	SO2	0.00000	0.00000	0.00001	0.00000	0.00000									
ξ	Ammonia	0.00000	0.00000	0.00000	0.00000	0.00000									
ပိ	Argon	0.00893	0.00974	0.00127	0.00000	0.00000									
	NO2	0.00000	0.00000	0.00000	0.00000	0.00000									
	Total	1.000	1.000	1.000	1.000	1.000									



SNC-Lavalin UK Limited Woodcote Grove Ashley Road, Epsom, Surrey KT18 5BW, United Kingdom

### <u>Attachment 3.3 – 150 barg Compressor Case</u>



HEAT AND MASS BALANCE
150 barg Compressor Discharge
TEESSIDE TO ENDURANCE

PROJECT No.	181869

PROJECT NAME

LOCATION

THERMAL POWER WITH CCS

UK

 REVISION
 A02

 DATE
 NOVEMBER 2017

181869-0001-D-EM-HMB-AAA-00-00002-01

DOCUMENT No.

	Stream Description	Gas to 6th Stage Cooler	Stage CO <sub>2</sub>	Gas from 7th Stage CO <sub>2</sub> Compressor	Gas to 8th Stage Cooler	Gas from 7th Stage CO <sub>2</sub> Compressor	Gas to CO <sub>2</sub> Metering (Note 6)	CO <sub>2</sub> to Onshore Pipeline					
	PFD Stream Number	224	225	226	227	228	229	240					
	Vapour Fraction	1.000	1.000	1.000		0.000	0.000	0.000					
	Temperature (C)	106.3	36.0	89.1		36.0	36.0	36.0					
	Pressure (bar)	75.433	76.233	151.713		151.513	151.513	151.013					
	Actual Volume Flow (m3/h)	1776.0	850.0	619.1		292.4	1462.0	1463.0					
	Mass Flow (tonne/h)	228.5	228.5	228.5		228.5	1142.5	1142.5					
	Molar Flow (kgmole/h)	5194.0	5194.0	5194.0		5194.0	25970.0	25970.0					
l _	Mass Density (kg/m3)	128.70	268.90	369.10		781.60	781.60	781.10					
era	Molecular Weight	44.00	44.00	44.00		44.00	44.00	44.00					
	Mass Heat Capacity (kJ/kg-C)	1.2710	4.6220	2.3020		2.8310	2.8310	2.8360					
	Std Gas Flow (STD_m3/h)	122789.5	122789.5	122789.5		122789.5	613947.7	613947.7					
	Std Ideal Liq Vol Flow (m3/h)	277.2	277.2	277.2		277.2	1385.8	1385.8					
	Viscosity (cP)	0.0223	0.0223	0.0223		0.0052	0.0052	0.0052					
	Actual Volume Flow (m3/h)	1776.0	850.0	619.1									
	Mass Flow (tonne/h)	228.5	228.5	228.5									
ø	Molar Flow (kgmole/h)	5194.0	5194.0	5194.0									
has	Mass Density (kg/m3)	128.70	268.90	369.10									
-r -	Molecular Weight	44.00	44.00	44.00									
ode	Cp/Cv	1.6	5.9	2.7									
>	Std Gas Flow (STD_m3/h)	122789.5	122789.5	122789.5									
	Viscosity (cP)	0.0223	0.0223	0.0223									
	Z Factor	0.8174	0.4790	0.6005									
	Actual Volume Flow (m3/h)					292.4	1462.0	1463.0					
	Mass Flow (tonne/h)					228.5	1142.5	1142.5					
ıse	Molar Flow (kgmole/h)					5194.0	25970.0	25970.0					
Ph	Mass Density (kg/m3)					781.60	781.60	781.10					
nid	Molecular Weight					44.00	44.00	44.00					
Lig	Std Ideal Liq Vol Flow (m3/h)					277.2	1385.8	1385.8					
	Surface Tension (dyne/cm)					0.0037	0.0038	0.0037					
	Viscosity (cP)					0.0052	0.0052	0.0052					
	Actual Volume Flow (m3/h)												
se	Mass Flow (tonne/h)												
Pha	Molar Flow (kgmole/h)												
snc	Mass Density (kg/m3)												
nec	Molecular Weight												
Αć	Std Ideal Liq Vol Flow (m3/h)												
	Viscosity (cP)												
	(CO2)	0.998312	0.998312	0.998312		0.998312	0.998312	0.998312					
	(Nitrogen)	0.000261	0.000261	0.000261		0.000261	0.000261	0.000261					
<u> </u>	(Oxygen)	0.000020	0.000020	0.000020		0.000020	0.000020	0.000020					
$\sim$	(H2S)	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000					
ion	(H2O)	0.000050	0.000050	0.000050		0.000050	0.000050	0.000050					
	(Ammonia)	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000					
Ĕ	(SO2)	0.000008	0.000008	0.000008		0.000008	0.000008	0.000008					
ပိ	(Argon)	0.001295	0.001295	0.001295		0.001295	0.001295	0.001295					
	(NO2)	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000					
	Total	1.000	1.000	1.000		1.000	1.000	1.000					



SNC-Lavalin UK Limited Woodcote Grove Ashley Road, Epsom, Surrey KT18 5BW, United Kingdom

### <u>Attachment 3.4 – Single TRU Case</u>



HEAT AND MASS BALANCE SINGLE SOLVENT RECOVERY UNIT POWER GENERATION H&MB

ROJECT No.	181869

PROJECT NAME THERMAL POWER WITH CCS

LOCATION

 DOCUMENT No.
 181869-0001-D-EM-HMB-AAA-00-00002-01

 REVISION
 A01

 DATE
 NOVEMBER 2017

	Stream Description	Air to Inlet Air Filter	Air from Inlet Air Filter	Fuel Gas to Fuel Gas Heater	Fuel Gas to Gas Turbine	Flue Gas from Gas Turbine	Flue Gas to RH3	Flue Gas to HPS1	Flue Gas to RH1	Flue Gas to HPS0	Flue Gas to HPB1	Flue Gas to HPE3	Flue Gas to LPS	Flue Gas to	Flue Gas to HPE2	Flue Gas to IPB	Flue Gas to HPE0/ IPE2	Flue Gas to IPE2	Flue Gas to HPE0	Flue Gas from IPE2	Flue Gas from HPE0	Flue Gas to LPB	Flue Gas to LPE	Flue Gas to	Flue Gas to CCP
	PFD Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Vapour Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Temperature (C)	10.00	10.00	25.00	204.44	646.54	633.96	609.13	595.70	552.52	466.71	363.86	331.24	326.96	323.90	276.92	250.71	250.71	185.28	250.71	185.28	185.28	155.48	129.33	89.69
	Pressure (bar)	1.013	1.013	49.110	49.110	1.045	1.044	1.043	1.043	1.042	1.039	1.029	1.025	1.025	1.025	1.021	1.020	1.020	1.017	1.020	1.017	1.017	1.015	1.014	1.013
	Actual Volume Flow (m3/h)	2777444.6	2777444.6	2254.2	4074.0	9158759.5	9039549.0	8798874.5	8668271.3	8243029.0	7404797.7	6441519.4	6133576.6	6090713.0	6061413.1	5602182.1	5343374.3	1091905.5	958357.3	4251468.8	3731480.4	4689839.8	4389130.4	4126381.1	3721592.0
	Mass Flow (tonne/h)	3455.8	3455.8	94.7	94.7	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	725.5	725.5	2825.0	2825.0	3550.5	3550.5	3550.5	3550.5
	Molar Flow (kgmole/h)	119636.8	119636.8	5115.6	5115.6	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	25560.6	25560.6	99523.5	99523.5	125084.2	125084.2	125084.2	125084.2
≡	Mass Density (kg/m3)	1.24	1.24	41.99	23.24	0.39	0.39	0.40	0.41	0.43	0.48	0.55	0.58	0.58	0.59	0.63	0.66	0.66	0.76	0.66	0.76	0.76	0.81	0.86	0.95
Ver	Molecular Weight	28.89	28.89	18.50	18.50	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38
٥	Mass Heat Capacity (kJ/kg-C)	1.01	1.01	2.46	2.74	1.20	1.20	1.19	1.19	1.18	1.16	1.14	1.13	1.13	1.13	1.12	1.11	1.11	1.09	1.11	1.09	1.09	1.09	1.08	1.07
	Std Gas Flow (STD_m3/h)	2829000.0	2829000.0	121000.0	121000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	604400.0	604400.0	2353000.0	2353000.0	2958000.0	2958000.0	2958000.0	2958000.0
	Std Ideal Liq Vol Flow (m3/h)	3972.0	3972.0	289.1	289.1	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	850.6	850.6	3312.0	3312.0	4163.0	4163.0	4163.0	4163.0
	Viscosity (cP)	0.0180	0.0180	0.0125	0.0173	0.0407	0.0403	0.0393	0.0388	0.0372	0.0341	0.0305	0.0293	0.0292	0.0291	0.0274	0.0265	0.0265	0.0241	0.0265	0.0241	0.0241	0.0230	0.0219	0.0203
	Actual Volume Flow (m3/h)	2777444.6	2777444.6	2254.2	4074.0	9158759.5	9039549.0	8798874.5	8668271.3	8243029.0	7404797.7	6441519.4	6133576.6	6090713.0	6061413.1	5602182.1	5343374.3	1091905.5	958357.3	4251468.8	3731480.4	4689839.8	4389130.4	4126381.1	3721592.0
	Mass Flow (tonne/h)	3455.8	3455.8	94.7	94.7	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	725.5	725.5	2825.0	2825.0	3550.5	3550.5	3550.5	3550.5
se	Molar Flow (kgmole/h)	119636.8	119636.8	5115.6	5115.6	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	25560.6	25560.6	99523.5	99523.5	125084.2	125084.2	125084.2	125084.2
Pha	Mass Density (kg/m3)	1.24	1.24	41.99	23.24	0.39	0.39	0.40	0.41	0.43	0.48	0.55	0.58	0.58	0.59	0.63	0.66	0.66	0.76	0.66	0.76	0.76	0.81	0.86	0.95
<u> </u>	Molecular Weight	28.89	28.89	18.50	18.50	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38
'apc	Cp/Cv	1.40	1.40	1.49	1.24	1.32	1.32	1.33	1.33	1.33	1.34	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.37	1.36	1.37	1.37	1.37	1.37	1.38
>	Std Gas Flow (STD_m3/h)	2829000.0	2829000.0	121000.0	121000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	604400.0	604400.0	2353000.0	2353000.0	2958000.0	2958000.0	2958000.0	2958000.0
	Viscosity (cP)	0.0180	0.0180	0.0125	0.0173	0.0407	0.0403	0.0393	0.0388	0.0372	0.0341	0.0305	0.0293	0.0292	0.0291	0.0274	0.0265	0.0265	0.0241	0.0265	0.0241	0.0241	0.0230	0.0219	0.0203
	Z Factor	0.9992	0.9992	0.8730	0.9849	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9999	0.9999	0.9998	0.9996	0.9993
	Actual Volume Flow (m3/h)																								
١.	Mass Flow (tonne/h)																					<u> </u>			
ase	Molar Flow (kgmole/h)																					<u> </u>			
<u> </u>	Mass Density (kg/m3)																					<u> </u>			
l ğ	Molecular Weight																					<u> </u>			
=	Std Ideal Liq Vol Flow (m3/h)																					1			
	Surface Tension (dyne/cm)																					1			
	Viscosity (cP)																					<del>                                     </del>			
	Actual Volume Flow (m3/h)																					<u> </u>			
Jase	Mass Flow (tonne/h)																					<u> </u>			
F S	Molar Flow (kgmole/h)																					<del>                                     </del>			
noe	Mass Density (kg/m3)																					<del>                                     </del>			
)nb	Molecular Weight																					<del> </del>			
`	Std Ideal Liq Vol Flow (m3/h)																					<del>                                     </del>			
$\vdash$	Viscosity (cP) (CO2)	0.00030	0.00030	0.01910	0.01910	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606
1	(Nitrogen)	0.00030	0.00030	0.01910	0.01910	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606
1	(Oxygen)	0.77512	0.77512	0.00330	0.00330	0.74176	0.74176	0.74176	0.74178	0.74178	0.74176	0.74178	0.74176	0.74178	0.74178	0.74178	0.74176	0.74178	0.74176	0.74178	0.74178	0.74178	0.74178	0.74176	0.74178
1	(H2S)	0.20131	0.20131	0.00004	0.00004	0.11131	0.11137	0.11131	0.11131	0.11131	0.11131	0.11131	0.11131	0.11131	0.11137	0.11131	0.11131	0.11131	0.11131	0.11131	0.11101	0.11137	0.11101	0.11131	0.11101
1	(H2O)	0.00727	0.00727	0.00004	0.00004	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166
1_	(Ammonia)	0.00121	0.00121			0.00100	0.03100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100	0.00100
Θ	(SO2)					0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
io	(Argon)	0.00934	0.00934			0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893
osit	(NO2)	3.33007	0.00001			5.55555	0.0000	3.33000	0.0000	0.0000	0.0000	3.33000	0.0000	0.0000	0.0000	0.00000	0.0000	0.0000	0.0000	3.33000	0.0000	3.33000	3.33300	3.33000	3.33000
Ē	(Methane)			0.87447	0.87447																	1			
ပိ	(Ethane)			0.06980	0.06980																	1			
1	(Propane)	1		0.02190	0.02190																	<del>                                     </del>			
	(n-Butane)			0.00410	0.00410																	1			
	(n-Pentane)			0.00050	0.00050																	<del>                                     </del>			
1	(n-Hexane)			0.00020	0.00020																	<b>†</b>			
	, ,	1.000							<b> </b>					ı	1			l	l					l	



HEAT AND MASS BALANCE SINGLE SOLVENT RECOVERY UNIT POWER GENERATION H&MB

**PROJECT No.** 181869

PROJECT NAME THERMAL POWER WITH CCS

UK

LOCATION

DOCUMENT No. 181869-0001-D-EM-HMB-AAA-00-00002-01

REVISION A01

DATE NOVEMBER 2017

	Stream Description	Steam to HP	Steam from HP Casing	Reheat Steam to HP	MP Steam from HP	MP Steam	MP Steam to		Steam from IP Casing	Steam from LPS	Steam to	Steam from IP/LP Casing	LP Steam	LP Steam to	LP Steam to	Condensate from Turbine	Condensate from	Cooling Water Supply	Cooling Water Return	Condensate from Gland	Condensate from Fuel	Condensate from	Condensate from CCP	Condensate to Feedwater	Water to LTE
	PFD Stream Number	25	26	Casing 27	Casing 28	29	30	31	32	33	34	35	36	37	38	39	Condenser 40	41	42	Steam 43	Gas Heater 44	E-103/104 45	46	Tank 47	48
-	Vapour Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Temperature (C)	573.89	342.37	573.89	522.71	522.71	235.00	522.71	270.72	291.90	272.66	234.41	234.41	138.70	234.41	39.16	39.15	17.50	35.50	39.67	104.44	51.47	49.50	50.58	50.58
	. , ,	165.000	34.390	30.000	21.510	21.510	21.510	21.510	3.375	3.375	3.375	2.400	2.400	2.400	2.400	0.071	0.429	2.986	2.308	4.023	33.890	4.023	4.023	4.023	4.023
	Pressure (bar)	10366.3	35853.9	67016.9	89891.2	1744.0		88147.2	385993.3	40439.5	426436.1	561423.6	263641.8	230294.1	297781.8	6307545.4			9275.6	_		382.0		696.9	668.4
	Actual Volume Flow (m3/h)	482.2			534.5		1323.6 13.4	524.1			576.9			230294.1			311.6 309.2	9230.2	-	311.6	71.0	377.1	314.9 311.2		660.2
	Mass Flow (tonne/h)	1	465.5	522.9		10.4	1		524.1	52.8		580.5	272.6		307.9	309.2		9217.5	9217.5	309.2	67.9			688.3	36647.0
	Molar Flow (kgmole/h)	26766.4	25839.4	29025.7	29669.6	575.6	745.4	29093.9	29093.9	2929.8	32023.7	32223.0	15131.8	16530.6	17091.2	17163.4	17163.4	511654.1	511654.1	17163.4	3768.5	20931.9	17274.4	38206.3	-
<u></u>	Mass Density (kg/m3)	46.52	12.98	7.80	5.95	5.95	10.15	5.95	1.36	1.31	1.35	1.03	1.03	1.29	1.03	0.05	992.32	998.62	993.74	992.30	956.20	987.26	988.20	987.70	987.70
ő	Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02
*	Mass Heat Capacity (kJ/kg-C)	2.69	2.45	2.26	2.21	2.21	2.83	2.21	2.04	2.04	2.04	2.03	2.03	2.12	2.03	1.88	4.18	4.18	4.18	4.18	4.22	4.18	4.18	4.18	4.18
	Std Gas Flow (STD_m3/h)	632900.0	611000.0	686300.0	701500.0	13610.0	17630.0	687900.0	687900.0	69270.0	757200.0	761900.0	357800.0	390900.0	404100.0	405818.4	405818.4	12097772.8	12097772.8	405800.0	89100.0	419.5	408400.0	903400.0	866500.0
	Std Ideal Liq Vol Flow (m3/h)	483.2	466.4	524.0	535.6	10.4	13.5	525.2	525.2	52.9	578.1	581.7	273.2	298.4	308.5	309.8	309.8	9236.1	9236.1	309.8	68.0	57038.6	311.8	689.7	661.5
-	Viscosity (cP)	0.0332	0.0222	0.0317	0.0295	0.0295	0.0171	0.0295	0.0190	0.0199	0.0191	0.0175	0.0175	0.0136	0.0175	0.0096	0.6621	1.0656	0.7113	0.6555	0.2665	0.5309	0.5488	0.5389	0.5389
	Actual Volume Flow (m3/h)	10366.3	35853.9	67016.9	89891.2	1744.0	1323.6	88147.2	385993.3	40439.5	426436.1	561423.6	263641.8	230294.1	297781.8	6307545.4									
1	Mass Flow (tonne/h)	482.2	465.5	522.9	534.5	10.4	13.4	524.1	524.1	52.8	576.9	580.5	272.6	297.8	307.9	309.2									<b></b>
Se	Molar Flow (kgmole/h)	26766.4	25839.4	29025.7	29669.6	575.6	745.4	29093.9	29093.9	2929.8	32023.7	32223.0	15131.8	16530.6	17091.2	17163.4									1
Pha	Mass Density (kg/m3)	46.52	12.98	7.80	5.95	5.95	10.15	5.95	1.36	1.31	1.35	1.03	1.03	1.29	1.03	0.05									
ž	Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02									$\longleftarrow$
abo	Cp/Cv	1.42	1.39	1.29	1.30	1.30	1.45	1.30	1.32	1.31	1.31	1.32	1.32	1.35	1.32	1.33									
>	Std Gas Flow (STD_m3/h)	632900.0	611000.0	686300.0	701500.0	13610.0	17630.0	687900.0	687900.0	69270.0	757200.0	761900.0	357800.0	390900.0	404100.0	405818.4									
	Viscosity (cP)	0.0332	0.0222	0.0317	0.0295	0.0295	0.0171	0.0295	0.0190	0.0199	0.0191	0.0175	0.0175	0.0136	0.0175	0.0096									1
	Z Factor	0.9074	0.9324	0.9835	0.9849	0.9849	0.9040	0.9849	0.9902	0.9916	0.9904	0.9909	0.9909	0.9764	0.9909	0.9978									1
	Actual Volume Flow (m3/h)																								
	Mass Flow (tonne/h)																								1
se	Molar Flow (kgmole/h)																								1
Ph	Mass Density (kg/m3)																								
Ē	Molecular Weight																								
Ę	Std Ideal Liq Vol Flow (m3/h)																								
	Surface Tension (dyne/cm)																								
	Viscosity (cP)																								
	Actual Volume Flow (m3/h)																311.6	9230.2	9275.6	311.6	71.0	382.0	314.9	696.9	668.4
eg.	Mass Flow (tonne/h)																309.2	9217.5	9217.5	309.2	67.9	377.1	311.2	688.3	660.2
has	Molar Flow (kgmole/h)																17163.4	511654.1	511654.1	17163.4	3768.5	20931.9	17274.4	38206.3	36647.0
l su	Mass Density (kg/m3)																992.3	998.6	993.7	992.3	956.2	987.3	988.2	987.7	987.7
eo	Molecular Weight																18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02
Aqu	Std Ideal Liq Vol Flow (m3/h)																309.82	9236.10	9236.10	309.80	68.03	57038.57	311.80	689.70	661.50
	Viscosity (cP)						1 1										0.662	1.066	0.711	0.656	0.267	0.531	0.549	0.539	0.539
	(CO2)						<del>                                     </del>											<u> </u>							
	(Nitrogen)						+ -																		
	(Oxygen)						+																		
	(H2S)						+																		
	(H2O)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
	(Ammonia)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
	(SO2)																								
_	(Argon)																								
siti	(NO2)	1	+		-		+ -								-					+					<del>                                     </del>
l de																									
S	(Methane)					-	+																		<del>                                     </del>
	(Ethane)																	-							
1	(Propane)						+																		
1	(n-Butane)						+																		
1	(n-Pentane)						<del>                                     </del>																		
1	(n-Hexane)																								
Ш	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000



HEAT AND MASS BALANCE SINGLE SOLVENT RECOVERY UNIT POWER GENERATION H&MB

**PROJECT No.** 181869

PROJECT NAME THERMAL POWER WITH CCS

UK

LOCATION

DOCUMENT No. 181869-0001-D-EM-HMB-AAA-00-00002-01

REVISION A01

DATE NOVEMBER 2017

	Stream Description	Water to LPE	Water to LPB/IP/HP Pumps	Water to LPB (V-103)	Water to HP Feedwater Pump	Water to IP Feedwater Pump	Steam to LPS	Steam from LPS	Water to HPE0	Water to IPB/ Fuel Gas Heater	Water to Fuel Gas Heater	Water to IPB (V-102)	Water to IPS1	Steam from IPS1	Water to IPE2	Water to HPE2	Water to HPE3	Water to HPB1 (V-101)	Steam from HPB1 (V-101)	Steam from HPS0	Steam from HPS3	Steam to RH1	Steam to RH3	Steam from RH3	
	PFD Stream Number	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	69	70	71	72	
	Vapour Fraction	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	
	Temperature (C)	104.44	139.71	139.71	139.71	139.71	141.71	293.33	140.99	238.48	238.48	238.48	240.69	310.62	145.67	238.47	313.91	351.63	353.86	495.65	575.65	336.95	486.44	575.33	
	Pressure (bar)	3.906	3.792	3.792	3.792	3.792	3.792	3.611	34.900	33.890	33.890	33.890	33.890	33.220	178.540	176.560	174.660	173.340	173.340	168.860	164.480	33.220	31.850	31.050	
	Actual Volume Flow (m3/h)	691.5	713.0	57.0	520.8	135.3	25658.8	37872.3	135.2	153.6	83.2	70.3	70.6	4271.2	518.4	581.1	688.7	842.7	3893.6	8647.4	10433.2	41326.8	55995.4	64830.0	
	Mass Flow (tonne/h)	660.2	660.2	52.8	482.2	125.3	52.8	52.8	125.3	125.3	67.9	57.4	57.4	57.4	482.2	482.2	482.2	482.2	482.2	482.2	482.2	522.9	522.9	522.9	
	Molar Flow (kgmole/h)	36647.0	36647.0	2929.8	26764.8	6952.5	2929.8	2929.8	6952.5	6952.5	3768.5	3184.0	3184.0	3184.0	26764.8	26764.8	26764.8	26764.8	26764.8	26764.8	26764.8	29025.7	29025.7	29025.7	
l _	Mass Density (kg/m3)	954.70	925.90	925.90	925.90	925.90	2.06	1.39	926.50	815.70	815.70	815.70	812.40	13.43	930.20	829.70	700.10	572.20	123.80	55.76	46.22	12.65	9.34	8.07	
eral	Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	
ò	Mass Heat Capacity (kJ/kg-C)	4.22	4.29	4.29	4.29	4.29	2.25	2.05	4.28	4.76	4.76	4.76	4.78	2.59	4.25	4.62	5.79	10.62	18.86	3.02	2.68	2.45	2.24	2.26	
	Std Gas Flow (STD_m3/h)	866500.0	866500.0	69270.0	632800.0	164400.0	69270.0	69270.0	164400.0	164400.0	89100.0	75280.0	75280.0	75280.0	632800.0	632800.0	632800.0	632800.0	632800.0	632800.0	632800.0	686300.0	686300.0	686300.0	
	Std Ideal Lig Vol Flow (m3/h)	661.5	661.5	52.9	483.1	125.5	52.9	52.9	125.5	125.5	68.0	57.5	57.5	57.5	483.1	483.1	483.1	483.1	483.1	483.1	483.1	524.0	524.0	524.0	
	Viscosity (cP)	0.2665	0.1954	0.1954	0.1954	0.1954	0.0136	0.0200	0.1935	0.1121	0.1121	0.1121	0.1111	0.0207	0.1869	0.1121	0.0858	0.0726	0.0467	0.0304	0.0333	0.0219	0.0282	0.0318	
	Actual Volume Flow (m3/h)	0.2000	0.1007	0.1004	0.1004	0.1007	25658.8	37872.3	0.1000	0.1121	0.1121	V.1121	0.1111	4271.2	0.1000	0.1121	0.0000	0.0120	3893.6	8647.4	10433.2	41326.8	55995.4	64830.0	
	Mass Flow (tonne/h)	1					52.8	52.8						57.4					482.2	482.2	482.2	522.9	522.9	522.9	
	Molar Flow (kgmole/h)						2929.8	2929.8						3184.0					26764.8	26764.8	26764.8	29025.7	29025.7	29025.7	-
ase	Mass Density (kg/m3)						2.06	1.39						13.43					123.80	55.76	46.22	12.65	9.34	8.07	
Ę	Molecular Weight						18.02	18.02						18.02					18.02	18.02	18.02	18.02	18.02	18.02	
οď	Cp/Cv						1.37	1.31						1.41					5.07	1.54	1.42	1.39	1.32	1.29	
Vap	Std Gas Flow (STD m3/h)			-			69270.0	69270.0						75280.0					632800.0	632800.0	632800.0	686300.0	686300.0	686300.0	
	Viscosity (cP)			-			0.0136	0.0200						0.0207					0.0467	0.0304	0.0333	0.0219	0.0282	0.0318	
	Z Factor					-	0.9628	0.0200		1				0.0207		1			0.4837	0.8535	0.9085	0.0219	0.0282	0.9831	
	Actual Volume Flow (m3/h)	-		-	<del> </del>	<b>†</b>	0.9020	0.9911		<b>†</b>				0.9161	-	<del> </del>		-	0.4637	0.6555	0.9065	0.9324	0.9729	0.9631	
	, ,									<u> </u>															
ø	Mass Flow (tonne/h)																								
ē	Molar Flow (kgmole/h)																								
Ē	Mass Density (kg/m3)	_																							
id	Molecular Weight	-																							
-	Std Ideal Liq Vol Flow (m3/h)	-																							
	Surface Tension (dyne/cm)																								
<u> </u>	Viscosity (cP)	004.5	740.0	57.0	520.8	405.0			405.0	450.0	83.2	70.0	70.0		518.4	504.4	688.7	842.7							
	Actual Volume Flow (m3/h)	691.5	713.0	57.0		135.3			135.2	153.6		70.3	70.6			581.1									
nase	Mass Flow (tonne/h)	660.2	660.2	52.8	482.2	125.3			125.3	125.3	67.9	57.4	57.4		482.2	482.2	482.2	482.2							
S P	Molar Flow (kgmole/h)	36647.0	36647.0	2929.8	26764.8	6952.5			6952.5	6952.5	3768.5	3184.0	3184.0		26764.8	26764.8	26764.8	26764.8							
no.	Mass Density (kg/m3)	954.7	925.9	925.9	925.9	925.9			926.5	815.7	815.7	815.7	812.4		930.2	829.7	700.1	572.2							
nbı	Molecular Weight	18.02	18.02	18.02	18.02	18.02			18.02	18.02	18.02	18.02	18.02		18.02	18.02	18.02	18.02							
⁴	Std Ideal Liq Vol Flow (m3/h)	661.50	661.50	52.89	483.10	125.50			125.50	125.50	68.03	57.48	57.48		483.10	483.10	483.10	483.10			-				
<b>—</b>	Viscosity (cP)	0.267	0.195	0.195	0.195	0.195			0.194	0.112	0.112	0.112	0.111		0.187	0.112	0.086	0.073				-			
	(CO2)																								
	(Nitrogen)	_																							
	(Oxygen)																								
1	(H2S)	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	1.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000	4.00000		
	(H2O)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		
Mo	(Ammonia) (SO2)	_																							
_	,	_																							
	(Argon)	+																							
gu	(NO2)	_				-				-						-					-				
S	(Methane)	_				-				-						-					-				
	(Ethane)	-				-																			
	(Propane)																								
I	(n-Butane)					-																			
	(n-Pentane)																								
	(n-Hexane)																								
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000					



HEAT AND MASS BALANCE SINGLE SOLVENT RECOVERY UNIT CARBON CAPTURE H&MB

PROJECT No. 181869

PROJECT NAME THERMAL POWER WITH CCS

LOCATION UK

REVISION A01
DATE NOVEMBER 2017

DOCUMENT No.

181869-0001-D-EM-HMB-AAA-00-00002-01

						LP									T		
	Stream Description	Sour Gas	Treated Gas	Treated Gas	LP Steam to												
	Stream Description	Feed	to Stack	from Amine Reflux Drum	Reboiler	from											
-	PFD Stream Number	100	101	102	103	Reboiler 104				-			1				
-	Vapour Fraction	1.000	1.000	1.000	1.000	0.000											
	Temperature (C)	87.80	64.60	26.30	138.7	126.1											
	Pressure (bar)	1.010	1.009	2.000	2.400	2.400											
	Actual Volume Flow (m3/h)	3714505.5	3170265.6	65083.0	233745.6	319.8				1							
	Mass Flow (tonne/h)	3550.5	3215.1	230.2	299.9	299.9											
	Molar Flow (kgmole/h)	125083.1	113959.6	5286.4	16647.2	16647.2											
l _	Mass Density (kg/m3)	0.956	1.014	3.537	1.3	937.8											
eral	Molecular Weight	28.39	28.21	43.55	18.0	18.0											
ò	Mass Heat Capacity (kJ/kg-C)	1.06	1.04	0.86	1.9	4.6											
	Std Gas Flow (STD_m3/h)	2957520.0	2694511.2	124994.2	393613.6	393613.6											
	Std Ideal Liq Vol Flow (m3/h)	6292.1	5906.8	279.8	300.5	300.5											
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141	0.2165											
	Actual Volume Flow (m3/h)	3714505.5	3170265.6	65083.0	233745.6												
	Mass Flow (tonne/h)	3550.5	3215.1	230.2	299.9												
0	Molar Flow (kgmole/h)	125083.1	113959.6	5286.4	16647.2												
Jase	Mass Density (kg/m3)	0.96	1.01	3.54	1.28												
<u>-</u>	Molecular Weight	28.39	28.21	43.55	18.02												
pod	Cp/Cv	1.38	1.40	1.30	1.34												
\ 8	Std Gas Flow (STD_m3/h)	2957520.0	2694511.2	124994.2	393613.6												
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141												
	Z Factor	0.9994	0.9996	0.9890	0.9841												
	Actual Volume Flow (m3/h)																
	Mass Flow (tonne/h)																
ıse	Molar Flow (kgmole/h)																
Ph	Mass Density (kg/m3)																
Εġ	Molecular Weight																
Ę	Std Ideal Liq Vol Flow (m3/h)																
	Surface Tension (dyne/cm)																
	Viscosity (cP)																
	Actual Volume Flow (m3/h)					319.8											
se	Mass Flow (tonne/h)					299.9											
Ph	Molar Flow (kgmole/h)					16647.2											
snc	Mass Density (kg/m3)					937.8											
nec	Molecular Weight					18.02											
¥	Std Ideal Liq Vol Flow (m3/h)					300.48											
	Viscosity (cP)					0.216											
	H2O	0.09166	0.04858	0.01749	1.000000	1.000000											
	CO2	0.04606	0.00505	0.98090	0.000000	0.000000											
(Mol)	H2S	0.00000	0.00000	0.00000	0.000000	0.000000											
	Oxygen	0.11157	0.12246	0.00002	0.000000	0.000000											
ţi	Nitrogen	0.74178	0.81417	0.00026	0.000000	0.000000											
isoc	SO2	0.00000	0.00000	0.00001	0.000000	0.000000											
E O	Ammonia	0.00000	0.00000	0.00000	0.000000	0.000000											
ŭ	Argon	0.00893	0.00974	0.00127	0.000000	0.000000											
	NO2	0.00000	0.00000	0.00000	0.000000	0.000000											
1	Total	1.000	1.000	1.000	1.000	1.000	1		1		1	I	1			1	



SNC-Lavalin UK Limited Woodcote Grove Ashley Road, Epsom, Surrey KT18 5BW, United Kingdom

#### **Attachment 3.5 - Combined Case**



HEAT AND MASS BALANCE

COMBINED CASE
POWER GENERATION H&MB

PROJECT No. 181869

PROJECT NAME THERMAL POWER WITH CCS

UK

LOCATION

DOCUMENT No. 181869-0001-D-EM-HMB-AAA-00-00002-01

REVISION A02

DATE NOVEMBER 2017

	Stream Description	Air to Inlet Air Filter	Air from Inlet Air Filter	Fuel Gas to Fuel Gas Heater	Fuel Gas to Gas Turbine	Flue Gas from Gas Turbine	Flue Gas to RH3	Flue Gas to HPS1	Flue Gas to RH1	Flue Gas to HPS0	Flue Gas to HPB1	Flue Gas to HPE3	Flue Gas to LPS	Flue Gas to IPS1	Flue Gas to HPE2	Flue Gas to IPB	Flue Gas to HPE0/ IPE2	Flue Gas to IPE2	Flue Gas to HPE0	Flue Gas from IPE2	Flue Gas from HPE0	Flue Gas to LPB	Flue Gas to LPE	Flue Gas to LTE	Flue Gas to CCP
	PFD Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	apour Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	emperature (C)	10.00	10.00	25.00	204.44	646.54	633.96	609.13	595.70	552.52	466.71	363.86	331.24	326.96	323.90	276.92	250.71	250.71	185.28	250.71	185.28	185.28	155.48	129.33	89.69
	Pressure (bar)	1.013	1.013	49.110	49.110	1.045	1.044	1.043	1.043	1.042	1.039	1.029	1.025	1.025	1.025	1.021	1.020	1.020	1.017	1.020	1.017	1.017	1.015	1.014	1.013
	Actual Volume Flow (m3/h)	2777444.6	2777444.6	2254.2	4074.0	9158759.5	9039549.0	8798874.5	8668271.3	8243029.0	7404797.7	6441519.4	6133576.6	6090713.0	6061413.1	5602182.1	5343374.3	1091905.5	958357.3	4251468.8	3731480.4	4689839.8	4389130.4	4126381.1	3721592.0
	Mass Flow (tonne/h)	3455.8	3455.8	94.7	94.7	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	725.5	725.5	2825.0	2825.0	3550.5	3550.5	3550.5	3550.5
	Molar Flow (kgmole/h)	119636.8	119636.8	5115.6	5115.6	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	25560.6	25560.6	99523.5	99523.5	125084.2	125084.2	125084.2	125084.2
=	Mass Density (kg/m3)	1.24	1.24	41.99	23.24	0.39	0.39	0.40	0.41	0.43	0.48	0.55	0.58	0.58	0.59	0.63	0.66	0.66	0.76	0.66	0.76	0.76	0.81	0.86	0.95
/era	Molecular Weight	28.89	28.89	18.50	18.50	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38
ó	Mass Heat Capacity (kJ/kg-C)	1.01	1.01	2.46	2.74	1.20	1.20	1.19	1.19	1.18	1.16	1.14	1.13	1.13	1.13	1.12	1.11	1.11	1.09	1.11	1.09	1.09	1.09	1.08	1.07
	Std Gas Flow (STD_m3/h)	2829000.0	2829000.0	121000.0	121000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	604400.0	604400.0	2353000.0	2353000.0	2958000.0	2958000.0	2958000.0	2958000.0
	Std Ideal Liq Vol Flow (m3/h)	3972.0	3972.0	289.1	289.1	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	4163.0	850.6	850.6	3312.0	3312.0	4163.0	4163.0	4163.0	4163.0
	/iscosity (cP)	0.0180	0.0180	0.0125	0.0173	0.0407	0.0403	0.0393	0.0388	0.0372	0.0341	0.0305	0.0293	0.0292	0.0291	0.0274	0.0265	0.0265	0.0241	0.0265	0.0241	0.0241	0.0230	0.0219	0.0203
	Actual Volume Flow (m3/h)	2777444.6	2777444.6	2254.2	4074.0	9158759.5	9039549.0	8798874.5	8668271.3	8243029.0	7404797.7	6441519.4	6133576.6	6090713.0	6061413.1	5602182.1	5343374.3	1091905.5	958357.3	4251468.8	3731480.4	4689839.8	4389130.4	4126381.1	3721592.0
	Mass Flow (tonne/h)	3455.8	3455.8	94.7	94.7	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	3550.5	725.5	725.5	2825.0	2825.0	3550.5	3550.5	3550.5	3550.5
m	Nolar Flow (kgmole/h)	119636.8	119636.8	5115.6	5115.6	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	125084.2	25560.6	25560.6	99523.5	99523.5	125084.2	125084.2	125084.2	125084.2
Jase	Mass Density (kg/m3)	1.24	1.24	41.99	23.24	0.39	0.39	0.40	0.41	0.43	0.48	0.55	0.58	0.58	0.59	0.63	0.66	0.66	0.76	0.66	0.76	0.76	0.81	0.86	0.95
Ē	Nolecular Weight	28.89	28.89	18.50	18.50	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38	28.38
n od	Cp/Cv	1.40	1.40	1.49	1.24	1.32	1.32	1.33	1.33	1.33	1.34	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.37	1.36	1.37	1.37	1.37	1.37	1.38
\ \ \ \ \ \ \	Std Gas Flow (STD_m3/h)	2829000.0	2829000.0	121000.0	121000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	2958000.0	604400.0	604400.0	2353000.0	2353000.0	2958000.0	2958000.0	2958000.0	2958000.0
	/iscosity (cP)	0.0180	0.0180	0.0125	0.0173	0.0407	0.0403	0.0393	0.0388	0.0372	0.0341	0.0305	0.0293	0.0292	0.0291	0.0274	0.0265	0.0265	0.0241	0.0265	0.0241	0.0241	0.0230	0.0219	0.0203
	Z Factor	0.9992	0.9992	0.8730	0.9849	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	1.0000	0.9999	0.9999	0.9998	0.9996	0.9993
	Actual Volume Flow (m3/h)	0.0002	0.0002	0.0700	0.00.10	1.0000	1.0000		1.0000		1.0000	110000		1.0000		110000		110000	0.0000	110000	0.0000	0.0000	0.0000	0.0000	0.0000
	Mass Flow (tonne/h)																								
, e	Molar Flow (kgmole/h)																								
has	Mass Density (kg/m3)																								
<u> </u>	Molecular Weight																								
l pi-	Std Ideal Liq Vol Flow (m3/h)																								
-	Surface Tension (dyne/cm)																								
	/iscosity (cP)																								<del>                                     </del>
	Actual Volume Flow (m3/h)	1																							
ø	Mass Flow (tonne/h)																								<del>                                     </del>
has	Molar Flow (kgmole/h)																								1
s P	Mass Density (kg/m3)																								
noe	Molecular Weight		+					<b>-</b>					-									-			1
ηbγ	•																								1
~	Std Ideal Liq Vol Flow (m3/h) /iscosity (cP)																					<del>                                     </del>			
-	• • •	0.00030	0.00030	0.01910	0.01910	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606
	CO2) Nitrogen)	0.00030	0.00030	0.01910	0.00990	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606	0.04606
		0.77512	0.77512	0.00330	0.00330	0.74178	0.74176	0.74176	0.74178	0.74178	0.74178	0.74178	0.74178	0.74178	0.74176	0.74178	0.74176	0.74178	0.74176	0.74176	0.74176	0.74178	0.74178	0.74178	0.74178
	Oxygen)	0.20191	0.20191	0.00004	0.00004	0.11101	0.11137	0.1110/	0.11137	0.1113/	0.1113/	0.1110/	0.1113/	0.1113/	0.11101	0.1113/	0.11137	0.11107	0.11107	0.11101	0.11137	0.11101	0.11101	0.11137	0.11107
	H2S) H2O)	0.00727	0.00727	0.00004	0.00004	0.09166	0.09166	0.09166	0.00166	0.09166	0.09166	0.00166	0.09166	0.09166	0.00466	0.09166	0.09166	0.09166	0.09166	0.09166	0.09166	0.00466	0.09166	0.09166	0.09166
		0.00727	0.00727			0.09160	0.09160	0.09160.0	0.09166	0.09100	0.09160.0	0.09166	0.09100	0.09160.0	0.09166	0.09180.0	0.09100	0.09160	0.09160.0	0.09160	0.09180	0.09166	0.09160	0.09100	0.09160
Mol	Ammonia)					0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ition	SO2)	0.00024	0.00004				0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	i	0.00000	0.00000	0.00000	<b> </b>	0.00000	0.00000		0.00000	0.00000	0.00000	<b>†</b>	0.00000
siti	Argon)	0.00934	0.00934			0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893	0.00893
odu.	NO2)	-		0.07447	0.07447																				$\vdash$
Son	Methane)	-		0.87447	0.87447																				$\vdash$
	Ethane)			0.06980	0.06980																				$\vdash$
	Propane)			0.02190	0.02190																				$\vdash$
	n-Butane)			0.00410	0.00410																				$\vdash$
	n-Pentane)			0.00050	0.00050																				$\vdash$
ĺ	n-Hexane)	4 222	4.000	0.00020	0.00020	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	1.000
	otal	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000



HEAT AND MASS BALANCE **COMBINED CASE** POWER GENERATION H&MB

PROJECT No. 181869

THERMAL POWER WITH CCS PROJECT NAME UK

LOCATION

181869-0001-D-EM-HMB-AAA-00-00002-01 DOCUMENT No.

A02 REVISION

DATE NOVEMBER 2017

	Stream Description	Steam to HP Casing	Steam from HP Casing	Reheat Steam to HP Casing	MP Steam from HP Casing	MP Steam	MP Steam to CCP (Note 3)	MP Steam to IP Casing	Steam from IP Casing	Steam from LPS	Steam to IP/LP Casing	Steam from IP/LP Casing	LP Steam	LP Steam to CCP (Note 3)	LP Steam to LP Casing	Condensate from Turbine	Condensate from Condenser	Cooling Water Supply	Cooling Water Return	Condensate from Gland Steam	Condensate from Fuel Gas Heater	Condensate from E-103/104	Condensate from CCP	Condensate to Feedwater Tank	Water to LTE
	PFD Stream Number	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	Vapour Fraction	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Temperature (C)	573.89	342.37	573.89	522.71	522.71	235.00	522.71	270.72	291.90	272.66	234.41	234.41	138.70	234.41	39.16	39.15	17.50	35.50	39.67	104.44	51.47	49.50	50.58	50.58
	Pressure (bar)	165.000	34.390	30.000	21.510	21.510	21.510	21.510	3.375	3.375	3.375	2.400	2.400	2.400	2.400	0.071	0.429	2.986	2.308	4.023	33.890	4.023	4.023	4.023	4.023
	Actual Volume Flow (m3/h)	10366.3	35853.9	67016.9	89891.2	1744.0	1323.6	88147.2	385993.3	40439.5	426436.1	561423.6	244739.0	213808.1	316673.0	6706149.8	331.3	10670.8	10723.3	331.3	71.0	401.7	293.3	695.1	668.4
	Mass Flow (tonne/h)	482.2	465.5	522.9	534.5	10.4	13.4	524.1	524.1	52.8	576.9	580.5	253.1	276.5	327.4	328.7	328.7	10656.1	10656.1	328.7	67.9	396.6	289.9	686.5	660.2
	Molar Flow (kgmole/h)	26766.4	25839.4	29025.7	29669.6	575.6	745.4	29093.9	29093.9	2929.8	32023.7	32223.0	14043.3	15341.5	18170.9	18248.0	18248.0	591510.4	591510.4	18243.1	3767.5	22016.5	16086.7	38097.3	36647.0
l _	Mass Density (kg/m3)	46.52	12.98	7.80	5.95	5.95	10.15	5.95	1.36	1.31	1.35	1.03	1.03	1.29	1.03	0.05	992.32	998.62	993.74	992.30	956.20	987.26	988.20	987.70	987.70
<u>a</u>	Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02
ŏ	Mass Heat Capacity (kJ/kg-C)	2.69	2.45	2.26	2.21	2.21	2.83	2.21	2.04	2.04	2.04	2.03	2.03	2.12	2.03	1.88	4.18	4.18	4.18	4.18	4.22	4.18	4.18	4.18	4.18
			611000.0	686300.0	701500.0	13610.0		687900.0	687900.0	69270.0	757200.0		332153.1	362880.5	429744.9	431464.1	431464.1	13985929.5	13985929.5	431444.5		441.2	380424.6	901054.1	866500.0
	Std Gas Flow (STD_m3/h)	632900.0					17630.0					761900.0									89100.0				
	Std Ideal Liq Vol Flow (m3/h)	483.2	466.4	524.0	535.6	10.4	13.5	525.2	525.2	52.9	578.1	581.7	253.6	277.0	328.1	329.4	329.4	10677.6	10677.6	329.4	68.0	59994.2	290.4	687.9	661.5
	Viscosity (cP)	0.0332	0.0222	0.0317	0.0295	0.0295	0.0171	0.0295	0.0190	0.0199	0.0191	0.0175	0.0175	0.0136	0.0175	0.0096	0.6621	1.0656	0.7113	0.6555	0.2665	0.5309	0.5488	0.5389	0.5389
	Actual Volume Flow (m3/h)	10366.3	35853.9	67016.9	89891.2	1744.0	1323.6	88147.2	385993.3	40439.5	426436.1	561423.6	244739.0	213808.1	316673.0	6706149.8									
	Mass Flow (tonne/h)	482.2	465.5	522.9	534.5	10.4	13.4	524.1	524.1	52.8	576.9	580.5	253.1	276.5	327.4	328.7									
Se	Molar Flow (kgmole/h)	26766.4	25839.4	29025.7	29669.6	575.6	745.4	29093.9	29093.9	2929.8	32023.7	32223.0	14043.3	15341.5	18170.9	18248.0									
Pha	Mass Density (kg/m3)	46.52	12.98	7.80	5.95	5.95	10.15	5.95	1.36	1.31	1.35	1.03	1.03	1.29	1.03	0.05									$\vdash$
þ	Molecular Weight	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02									
<u>&amp;</u>	Cp/Cv	1.42	1.39	1.29	1.30	1.30	1.45	1.30	1.32	1.31	1.31	1.32	1.32	1.35	1.32	1.33									i l
>	Std Gas Flow (STD_m3/h)	632900.0	611000.0	686300.0	701500.0	13610.0	17630.0	687900.0	687900.0	69270.0	757200.0	761900.0	332153.1	362880.5	429744.9	431464.1									
	Viscosity (cP)	0.0332	0.0222	0.0317	0.0295	0.0295	0.0171	0.0295	0.0190	0.0199	0.0191	0.0175	0.0175	0.0136	0.0175	0.0096									
	Z Factor	0.9074	0.9324	0.9835	0.9849	0.9849	0.9040	0.9849	0.9902	0.9916	0.9904	0.9909	0.9909	0.9764	0.9909	0.9978									
	Actual Volume Flow (m3/h)																								
	Mass Flow (tonne/h)																								
eg.	Molar Flow (kgmole/h)																								
ha	Mass Density (kg/m3)																								
.□	Molecular Weight																								
] <u>ē</u>	Std Ideal Liq Vol Flow (m3/h)																								
-	Surface Tension (dyne/cm)																								
	Viscosity (cP)																								
														-	-	-	331.3	10670.8	10723.3	331.3	74.0	401.7	293.3	695.1	668.4
_	Actual Volume Flow (m3/h)																			1	71.0		<b>!</b>		
Jase	Mass Flow (tonne/h)															1	328.7	10656.1	10656.1	328.7	67.9	396.6	289.9	686.5	660.2
<u> </u>	Molar Flow (kgmole/h)																18248.0	591510.4	591510.4	18243.1	3767.5	22016.5	16086.7	38097.3	36647.0
ő	Mass Density (kg/m3)																992.3	998.6	993.7	992.3	956.2	987.3	988.2	987.7	987.7
l en	Molecular Weight																18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.02
ď	Std Ideal Liq Vol Flow (m3/h)																329.40	10677.62	10677.62	329.38	68.03	59994.16	290.44	687.91	661.50
L	Viscosity (cP)																0.662	1.066	0.711	0.656	0.267	0.531	0.549	0.539	0.539
1	(CO2)																								
1	(Nitrogen)			<u> </u>																					<u> </u>
1	(Oxygen)																								1
1	(H2S)																								
	(H2O)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
_	(Ammonia)																								
ĕ	(SO2)																								
io	(Argon)																								
osit	(NO2)																								
Ē	(Methane)																								
ပိ	(Ethane)																								<u> </u>
	(Propane)																								
			-				+ -						1							-	1		-		
	(n-Butane)			+			-																		<del></del>
	(n-Pentane)												-							-	-				
	(n-Hexane)			<u> </u>			<b>—</b> —							<u> </u>	<u> </u>		<b>.</b>				<u> </u>				
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000



HEAT AND MASS BALANCE **COMBINED CASE** POWER GENERATION H&MB

PROJECT No. 181869

THERMAL POWER WITH CCS PROJECT NAME

UK

LOCATION

181869-0001-D-EM-HMB-AAA-00-00002-01 DOCUMENT No. A02 REVISION

DATE NOVEMBER 2017

	Stream Description	Water to LPE	Water to LPB/IP/HP Pumps	Water to LPB (V-103)	Water to HP Feedwater Pump	Water to IP Feedwater Pump	Steam to LPS	Steam from LPS	Water to HPE0	Water to IPB/ Fuel Gas Heater	Water to Fuel Gas Heater	Water to IPB (V-102)	Water to IPS1	Steam from IPS1	Water to IPE2	Water to HPE2	Water to HPE3	Water to HPB1 (V-101)	Steam from HPB1 (V-101)	Steam from HPS0	Steam from HPS3	Steam to RH1	Steam to RH3	Steam from RH3	
	PFD Stream Number	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	69	70	71	72	
	Vapour Fraction	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	
	Temperature (C)	104.44	139.71	139.71	139.71	139.71	141.71	293.33	140.99	238.48	238.48	238.48	240.69	310.62	145.67	238.47	313.91	351.63	353.86	495.65	575.65	336.95	486.44	575.33	
	Pressure (bar)	3.906	3.792	3.792	3.792	3.792	3.792	3.611	34.900	33.890	33.890	33.890	33.890	33.220	178.540	176.560	174.660	173.340	173.340	168.860	164.480	33.220	31.850	31.050	
	Actual Volume Flow (m3/h)	691.5	713.0	57.0	520.8	135.3	25658.8	37872.3	135.2	153.6	83.2	70.3	70.6	4271.2	518.4	581.1	688.7	842.7	3893.6	8647.4	10433.2	41326.8	55995.4	64830.0	
	Mass Flow (tonne/h)	660.2	660.2	52.8	482.2	125.3	52.8	52.8	125.3	125.3	67.9	57.4	57.4	57.4	482.2	482.2	482.2	482.2	482.2	482.2	482.2	522.9	522.9	522.9	
	Molar Flow (kgmole/h)	36647.0	36647.0	2929.8	26764.8	6952.5	2929.8	2929.8	6952.5	6952.5	3768.5	3184.0	3184.0	3184.0	26764.8	26764.8	26764.8	26764.8	26764.8	26764.8	26764.8	29025.7	29025.7	29025.7	
	, ,		925.90		925.90	925.90		1.39	926.50					13.43	930.20	829.70	<b>.</b>		123.80	55.76	46.22	<b>!</b>	9.34	8.07	
la I	Mass Density (kg/m3)	954.70 18.02	18.02	925.90 18.02	18.02	18.02	2.06 18.02	18.02	18.02	815.70 18.02	815.70 18.02	815.70 18.02	812.40 18.02	18.02	18.02	18.02	700.10 18.02	572.20 18.02	18.02	18.02	18.02	12.65 18.02	18.02	18.02	
Š	Molecular Weight															1					-	<b>!</b>	<b>!</b>		
	Mass Heat Capacity (kJ/kg-C)	4.22	4.29	4.29	4.29	4.29	2.25	2.05	4.28	4.76	4.76	4.76	4.78	2.59	4.25	4.62	5.79	10.62	18.86	3.02	2.68	2.45	2.24	2.26	
	Std Gas Flow (STD_m3/h)	866500.0	866500.0	69270.0	632800.0	164400.0	69270.0	69270.0	164400.0	164400.0	89100.0	75280.0	75280.0	75280.0	632800.0	632800.0	632800.0	632800.0	632800.0	632800.0	632800.0	686300.0	686300.0	686300.0	
	Std Ideal Liq Vol Flow (m3/h)	661.5	661.5	52.9	483.1	125.5	52.9	52.9	125.5	125.5	68.0	57.5	57.5	57.5	483.1	483.1	483.1	483.1	483.1	483.1	483.1	524.0	524.0	524.0	
	Viscosity (cP)	0.2665	0.1954	0.1954	0.1954	0.1954	0.0136	0.0200	0.1935	0.1121	0.1121	0.1121	0.1111	0.0207	0.1869	0.1121	0.0858	0.0726	0.0467	0.0304	0.0333	0.0219	0.0282	0.0318	
	Actual Volume Flow (m3/h)						25658.8	37872.3						4271.2					3893.6	8647.4	10433.2	41326.8	55995.4	64830.0	
	Mass Flow (tonne/h)						52.8	52.8						57.4					482.2	482.2	482.2	522.9	522.9	522.9	
8	Molar Flow (kgmole/h)						2929.8	2929.8						3184.0					26764.8	26764.8	26764.8	29025.7	29025.7	29025.7	
ha	Mass Density (kg/m3)						2.06	1.39						13.43					123.80	55.76	46.22	12.65	9.34	8.07	
7	Molecular Weight						18.02	18.02						18.02					18.02	18.02	18.02	18.02	18.02	18.02	
οdε	Cp/Cv						1.37	1.31						1.41					5.07	1.54	1.42	1.39	1.32	1.29	
>	Std Gas Flow (STD_m3/h)						69270.0	69270.0						75280.0					632800.0	632800.0	632800.0	686300.0	686300.0	686300.0	
	Viscosity (cP)						0.0136	0.0200						0.0207					0.0467	0.0304	0.0333	0.0219	0.0282	0.0318	
	Z Factor						0.9628	0.9911						0.9181					0.4837	0.8535	0.9085	0.9324	0.9729	0.9831	
	Actual Volume Flow (m3/h)																								
	Mass Flow (tonne/h)																								
ø	Molar Flow (kgmole/h)																								
has	, <del>,</del> ,													1						1			+	+	
P P	Mass Density (kg/m3)																								
qui	Molecular Weight																								
=	Std Ideal Liq Vol Flow (m3/h)																								
	Surface Tension (dyne/cm)																								
	Viscosity (cP)																								
	Actual Volume Flow (m3/h)	691.5	713.0	57.0	520.8	135.3			135.2	153.6	83.2	70.3	70.6		518.4	581.1	688.7	842.7							
ase	Mass Flow (tonne/h)	660.2	660.2	52.8	482.2	125.3			125.3	125.3	67.9	57.4	57.4		482.2	482.2	482.2	482.2							
급	Molar Flow (kgmole/h)	36647.0	36647.0	2929.8	26764.8	6952.5			6952.5	6952.5	3768.5	3184.0	3184.0		26764.8	26764.8	26764.8	26764.8							
snc	Mass Density (kg/m3)	954.7	925.9	925.9	925.9	925.9			926.5	815.7	815.7	815.7	812.4		930.2	829.7	700.1	572.2							
nec	Molecular Weight	18.02	18.02	18.02	18.02	18.02			18.02	18.02	18.02	18.02	18.02		18.02	18.02	18.02	18.02							
A	Std Ideal Liq Vol Flow (m3/h)	661.50	661.50	52.89	483.10	125.50			125.50	125.50	68.03	57.48	57.48		483.10	483.10	483.10	483.10							
	Viscosity (cP)	0.267	0.195	0.195	0.195	0.195			0.194	0.112	0.112	0.112	0.111		0.187	0.112	0.086	0.073							
	(CO2)																							İ	
	(Nitrogen)																								
	(Oxygen)																								
	(H2S)																								
	(H2O)	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000		
	(Ammonia)																							+	
Μo	(SO2)																							+ +	
u o																					-			+	
ŝiti	(Argon)																							<del>                                     </del>	
l d	(NO2)																				-				
S S	(Methane)																								
١Ŭ	(Ethane)																								
1	(Propane)																								
	(n-Butane)																								
	(n-Pentane)																								
	(n-Hexane)																								
	Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000					



HEAT AND MASS BALANCE

COMBINED CASE

CARBON CAPTURE H&MB

PROJECT No. 181869

PROJECT NAME THERMAL POWER WITH CCS

LOCATION UK

DOCUMENT No. 181869-0001-D-EM-HMB-AAA-00-00002-01

NOVEMBER 2017

REVISION A02

_									 	 					1		
	Stream Description	Sour Gas Feed	Treated Gas to Stack	Treated Gas from Amine	LP Steam to Reboiler	LP Condensate from											
				Reflux Drum		Reboiler											
	PFD Stream Number	100	101	102	103	104				-							
	Vapour Fraction	1.000	1.000	1.000	1.000	0.000											
	Temperature (C)	87.80	64.60	26.30	138.70	126.14											
-	Pressure (bar)	1.010	1.009	2.000	2.400	2.400											
	Actual Volume Flow (m3/h)	3714505.5	3170265.6	65083.0	217108.4	297.0											
	Mass Flow (tonne/h)	3550.5	3215.1	230.2	278.6	278.6											
	Molar Flow (kgmole/h)	125083.1	113959.6	5286.4	15462.3	15462.3											
=	Mass Density (kg/m3)	0.956	1.014	3.537	1.283	937.811											
Šer	Molecular Weight	28.39	28.21	43.55	18.02	18.02											
l°	Mass Heat Capacity (kJ/kg-C)	1.06	1.04	0.86	1.94	4.56											
	Std Gas Flow (STD_m3/h)	2957520.0	2694511.2	124994.2	365597.5	365597.5											
	Std Ideal Liq Vol Flow (m3/h)	6292.1	5906.8	279.8	279.1	279.1											
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141	0.2165											
	Actual Volume Flow (m3/h)	3714505.5	3170265.6	65083.0	217108.4												
	Mass Flow (tonne/h)	3550.5	3215.1	230.2	278.6												
g.	Molar Flow (kgmole/h)	125083.1	113959.6	5286.4	1546.2												
has	Mass Density (kg/m3)	0.96	1.01	3.54	1.28												
1 2	Molecular Weight	28.39	28.21	43.55	18.02												
8	Cp/Cv	1.38	1.40	1.30	1.34												
>	Std Gas Flow (STD_m3/h)	2957520.0	2694511.2	124994.2	365597.5												
	Viscosity (cP)	0.0206	0.0199	0.0151	0.0141												
	Z Factor	0.9994	0.9996	0.9890	0.9841												
	Actual Volume Flow (m3/h)																
	Mass Flow (tonne/h)																
se	Molar Flow (kgmole/h)																
Pha	Mass Density (kg/m3)																
亨	Molecular Weight																
Ē	Std Ideal Liq Vol Flow (m3/h)																
	Surface Tension (dyne/cm)																
	Viscosity (cP)																
	Actual Volume Flow (m3/h)	1				297.0	1			1	İ		İ				
e e	Mass Flow (tonne/h)					278.6											
ha	Molar Flow (kgmole/h)	1				15462.3	1										
us F	Mass Density (kg/m3)	1				937.8	1										
eo	Molecular Weight					18.02											
Aqı	Std Ideal Liq Vol Flow (m3/h)					279.09	1										
	Viscosity (cP)					0.216											
	H2O	0.09166	0.04858	0.01749	1.00000	1.00000	1										
1	CO2	0.04606	0.00505	0.98090	0.00000	0.00000	1										
	H2S	0.00000	0.00000	0.00000	0.00000	0.00000	1										
(MoI)	Oxygen	0.11157	0.12246	0.00002	0.00000	0.00000	1			1	1	1					
	Nitrogen	0.74178	0.81417	0.00026	0.00000	0.00000	1										
sitic	SO2	0.00000	0.00000	0.00020	0.00000	0.00000						+					
8	Ammonia	0.00000	0.00000	0.00000	0.00000	0.00000	+					1					
Son	Argon	0.00893	0.00000	0.00127	0.00000	0.00000	+					1					
1	NO2	0.00093	0.00000	0.00000	0.00000	0.00000	+					1					
	Total	1.000	1.000	1.000	1.000	1.000	+			1	1	+					
	IUIAI	1.000	1.000	1.000	1.000	1.000								l			

Refer to Note 2.



HEAT AND MASS BALANCE

COMBINED CASE

TEESSIDE TO ENDURANCE

PROJECT No. 181869

PROJECT NAME THERMAL POWER WITH CCS

LOCATION UK

 DOCUMENT No.
 181869-0001-D-EM-HMB-AAA-00-00002-01

 REVISION
 A01

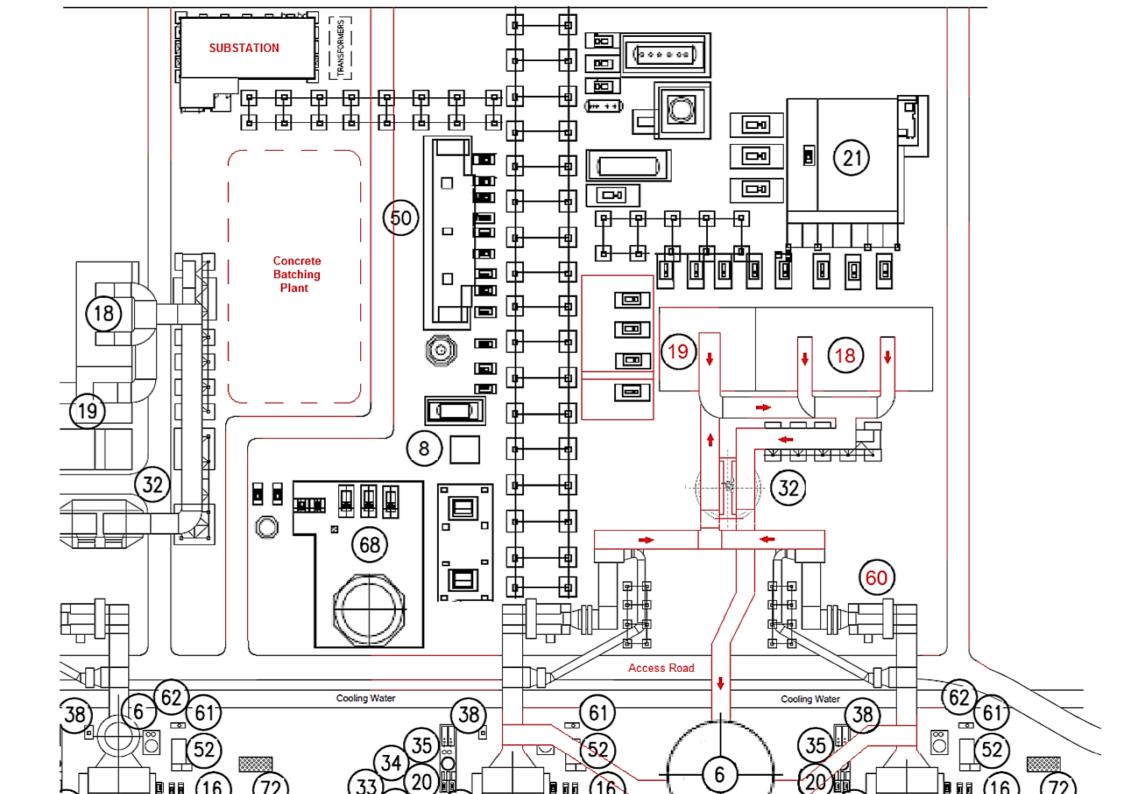
 DATE
 NOVEMBER 2017

	Stream Description	Gas to 6th Stage Cooler	Gas to 7th Stage CO <sub>2</sub> Compressor	Gas from 7th Stage CO <sub>2</sub> Compressor	Gas to 8th Stage Cooler	Gas from 7th Stage CO <sub>2</sub> Compressor	Gas to CO <sub>2</sub> Metering (Note 6)	CO <sub>2</sub> to Onshore Pipeline								
	PFD Stream Number	224	225	226	227	228	229	240								
	Vapour Fraction	1.000	1.000	1.000		0.000	0.000	0.000								
	Temperature (C)	106.3	36.0	89.1		36.0	36.0	36.0								
	Pressure (bar)	74.420	74.220	150.700		150.500	150.500	150.500								
	Actual Volume Flow (m3/h)	1776.0	850.1	619.1		292.4	1462.0	1462.0								
	Mass Flow (tonne/h)	228.6	228.6	228.5		228.5	1142.7	1142.7								
	Molar Flow (kgmole/h)	5196.6	5195.0	5194.2		5195.9	25979.7	25979.7								
=	Mass Density (kg/m3)	128.70	268.90	369.10		781.60	781.60	781.60								
Over	Molecular Weight	44.00	44.00	44.00		44.00	44.00	44.00								
0	Mass Heat Capacity (kJ/kg-C)	1.2710	2.8530	2.8750		2.4000	2.4000	2.4000								
	Std Gas Flow (STD_m3/h)															
	Std Ideal Liq Vol Flow (m3/h)															
	Viscosity (cP)	0.0223	0.0234	0.0322		0.0518	0.0518	0.0518								
	Actual Volume Flow (m3/h)	1776.0	850.1	835.5												
	Mass Flow (tonne/h)	228.6	228.6	228.5												
eg.	Molar Flow (kgmole/h)	5196.6	5195.0	5194.2												
Pha	Mass Density (kg/m3)	128.70	268.90	369.10												
Ę	Molecular Weight	44.00	44.00	44.00												
	Cp/Cv	1.6	5.9	2.7												
>	Std Gas Flow (STD_m3/h)															
	Viscosity (cP)	0.0223	0.0234	0.0322												
	Z Factor	0.8174	0.4790	0.6005												
	Actual Volume Flow (m3/h)					292.4	1462.0	1462.0								
	Mass Flow (tonne/h)					228.5	1142.7	1142.7								
co.	Molar Flow (kgmole/h)					5195.9	25979.7	25979.7								
툽	Mass Density (kg/m3)					781.60	781.60	781.60								
	Molecular Weight					44.00	44.00	44.00								
	Std Ideal Liq Vol Flow (m3/h)															
	Surface Tension (dyne/cm)					0.0037	0.0037	0.0037								
	Viscosity (cP)		ļ			0.0518	0.0518	0.0518								
	Actual Volume Flow (m3/h)															
ase	Mass Flow (tonne/h)															
4	Molar Flow (kgmole/h)															
sno	Mass Density (kg/m3)		-						1			1				
Aque	Molecular Weight		-						1			1				
Ĭ	Std Ideal Liq Vol Flow (m3/h)		-						1			1				
	Viscosity (cP)															
	(CO2)	0.998312	0.998312	0.998312		0.998312	0.998312	0.998312	1			1				
	(Nitrogen)	0.000261	0.000261	0.000261		0.000261	0.000261	0.000261	1			1				
ē	(Oxygen)	0.000020	0.000020	0.000020		0.000020	0.000020	0.000020								1
sition (Mol )	(H2S)	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000								
tion	(H2O)	0.000050	0.000050	0.000050		0.000050	0.000050	0.000050								1
	(Ammonia)	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000								
	(SO2)	0.000008	0.000008	0.000008		0.000008	0.000008	0.000008								
និ	(Argon)	0.001295	0.001295	0.001295		0.001295	0.001295	0.001295								
	(NO2)	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	1			1				1
	Total	1.000	1.000	1.000		1.000	1.000	1.000								

Refer to Note 6.

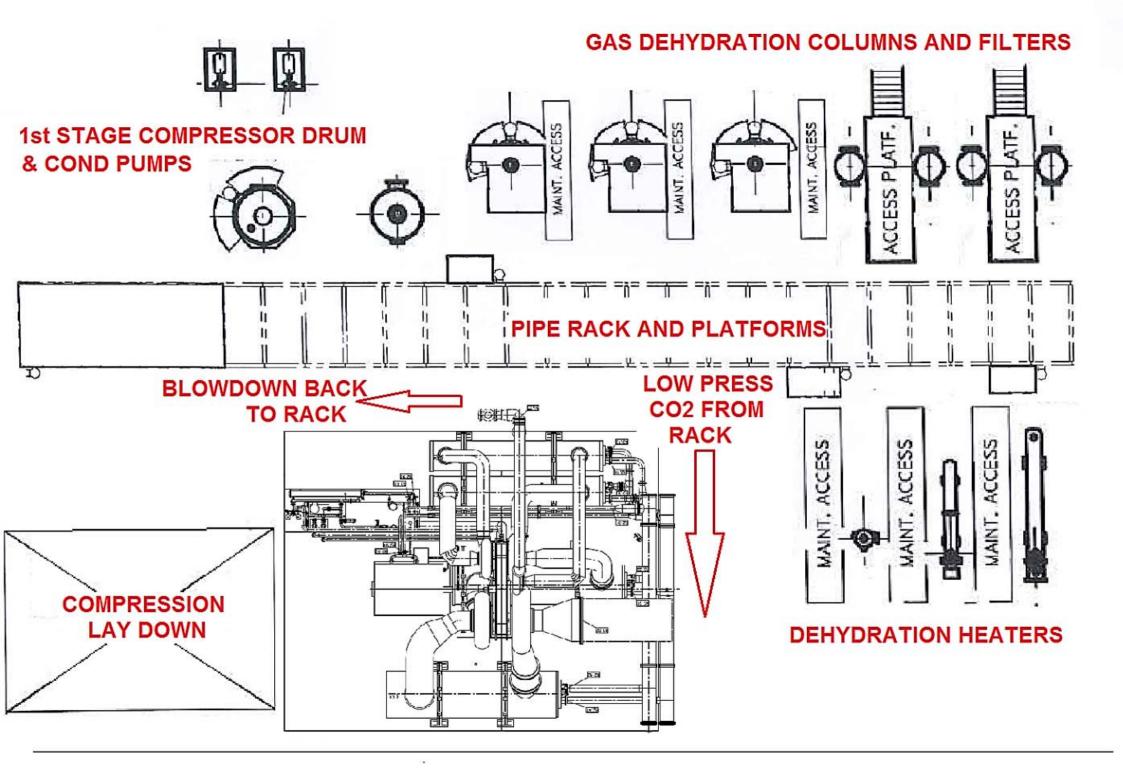


## ATTACHMENT 4 - Layout (CC area only) Attachment 4.1.1 - 2 CCGT into 1 CC Case Carbon Capture



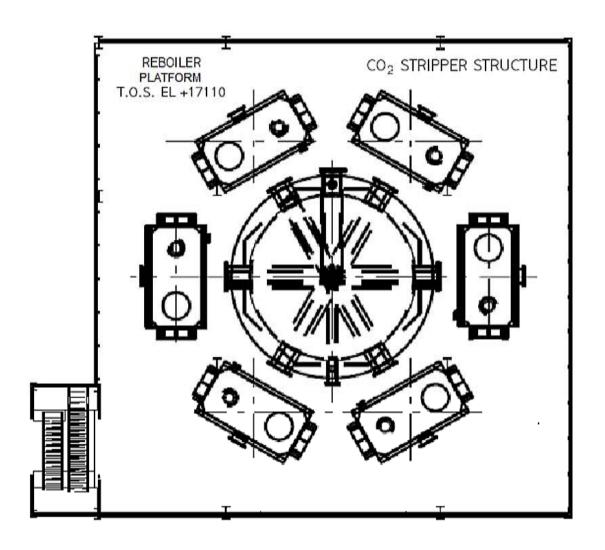


# ATTACHMENT 4 - Layout (CC area only) Attachment 4.1.2 - 2 CCGT into 1 CC Case Compression





## <u>Attachment 4.2 – Brochure Efficiency Reboiler Case</u>



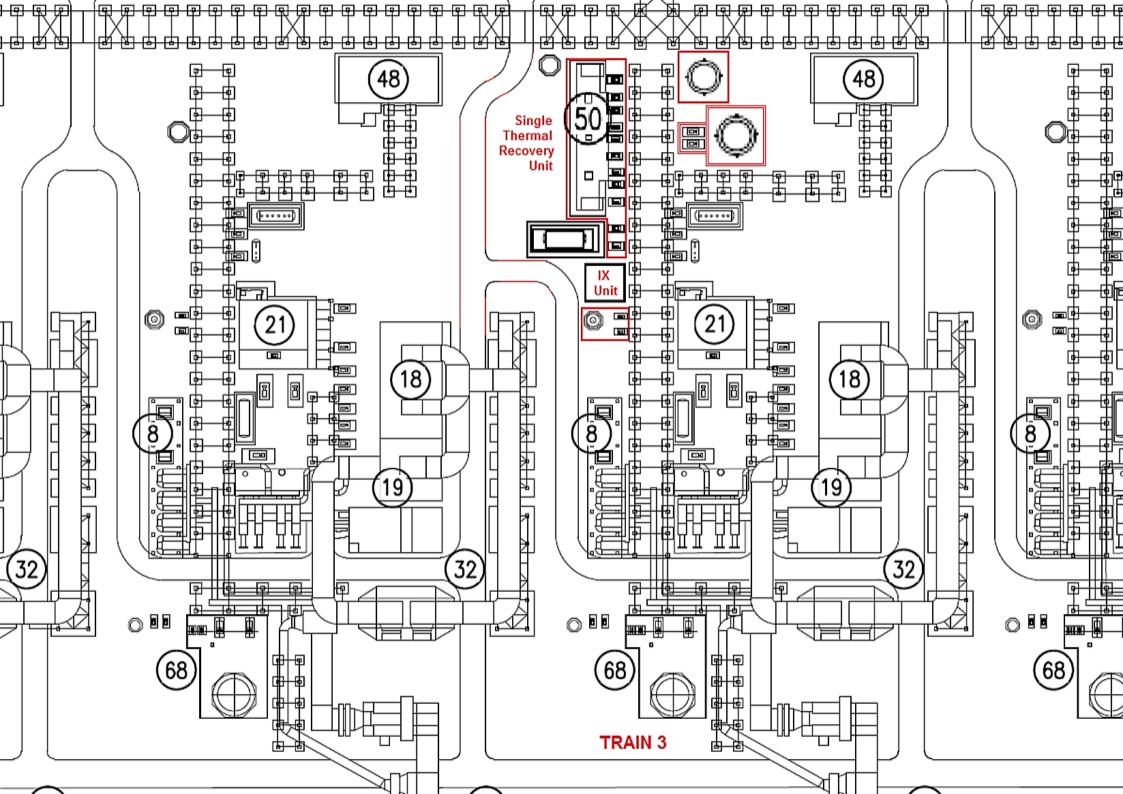


## **Attachment 4.3 - 150 barg Compressor Case**

No Layout Impact Identified

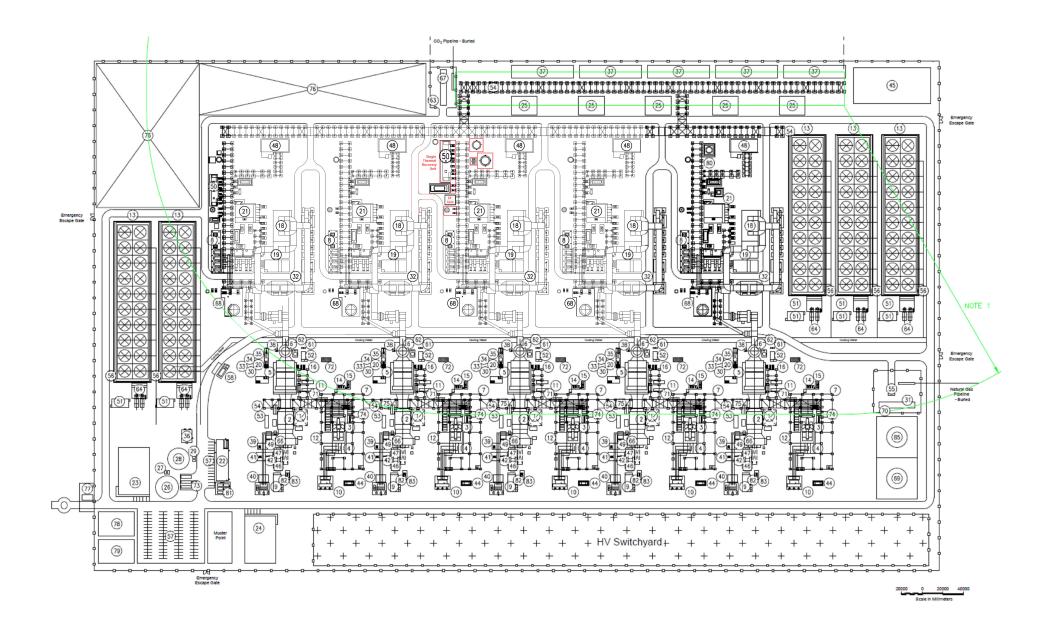


## <u>Attachment 4.4 – Single TRU Case</u>





## **Attachment 4.5 - Combined Case**





## <u>ATTACHMENT 5 - Update to Teesside CAPEX model</u> <u>Attachment 5.1 - 2 CCGT into 1 CC Case</u>

PROJECT: Thermal Power with CCS Croydon

**Project Summary** 

Teesside - 2\_1 train Optimisation

Project NO.: 181869

LOCATION:

	Thermal Power with CCS	2 + 1 Trains	Base Case 2 trains	
1.0	Power Generation (CCGT)	1,025,296,852	1,012,492,216	- 12,804,636
2.0	Carbon Capture	1,077,277,661	1,042,862,652	- 34,415,009
3.0	CO2 Transportation	233,640,883	233,640,883	-
4.0	Offshore Storage	222,799,376	222,799,376	-
	Total	2,559,014,772	2,511,795,127	- 47,219,645

ICSS and vent stack

-0.033

-0.0188

Risk and Contingency	2 + 1 Trains	2 Trains		
P50	2,830,270,338	2,778,045,411	-	52,224,927
P90	3,006,842,357	2,951,359,275	-	55,483,083

62,209,034
66,090,068

Savings with original ducting costs

12,330,059

68,576,926

56,246,866

Increase in ducting costs of from 25m to 87m for 2 train negate cost savings (impacts formulas for contractors/owners/commissioning costs as well)

CLIENT: ETI USD/GBP 1.29

PROJECT: Thermal Power with CCS Carbon Capture and Compression Teesside - 2\_1 train Ceur/GBP EUR/GBP 1.13

LOCATION:CroydonSubcontract Uplift1.02Modularisation FactorProject NO.:181869Labour Rate1.02Modularisation Factor

	Thermal Power with CCS	Equipment (GBP)	Materials	Labour	Subcontract	Item Total	Subtotal	One Train	2 Trains	3 Trains	4 Trains	5 Trains	Estimate Quality	Source
4.1	Detailed Design Engineering			25,766,253		25,766,253	25,766,253	32,207,816					2	Comparison of 3 similar projects
4.2	Mechanical													
4.2.1	Carbon Capture Equipment					_	191,709,190	184,040,823						updated for modularisation savings
4.2.1.1	CO2 Stripper - Column and Internals	9,471,373		_	866,663	10,338,036	, ,	,					1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.2	CO2 Absorber - Column and Internals	55,309,435		-	5,351,469	60,660,904							1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.3	Direct Contact Cooler - Column and Internals	6,064,623		389,299	237,605	6,691,527							1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.4	Thermal Recovery Unit	28,376,938		-	121,704	28,498,642							2	2 scaled vendor quote + scaled labour
4.2.1.5	Thermal Reclaimer Vacuum Package	5,750,581		211,379	_	5,961,960							2	2 scaled vendor quote + scaled labour
4.2.1.6	Ion Exchange Package	962,799		125,702		1,088,501							2	2 scaled vendor quote + scaled labour
4.2.1.7	Booster Fans	10,138,608		512,947		10,651,554							2	2 scaled vendor quote + scaled labour
4.2.1.8	Gas-Gas Heat Exchanger	7,507,837		251,023		7,758,859							1	vendor quote + labour
4.2.1.9	Lean/Rich Amine Exchanger	30,965,250		2,282,160		33,247,410							1	vendor quote + labour
4.2.1.10	CO2 Stripper Reboilers	6,264,723		703,152		6,967,875							2	2 scaled vendor quote + scaled labour
4.2.1.11	Heat Exchangers	1,974,409		591,653		2,566,061							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.12	Pumps	6,683,356		706,570		7,389,926							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.13	Vessels	1,552,198		354,586	-	1,906,784							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.14	Tanks	3,523,630		71,392		3,595,022							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour fro EPC project
4.2.1.15	Other Equipment	4,343,305		42,190	633	4,386,128							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour fro EPC project
		, ,				, ,								
4.2.2	Compression Equipment						51,380,521	49,325,300	98,650,600	147,975,901	197,301,201	246,626,501		updated for modularisation savings
4.2.2.1	Compression Package	30,157,318		1,177,587		31,334,906							2	Scaled quote + scaled labour
4.2.2.2	Dehydration Package	449,395		283,917		733,312							2	2 scaled quote + scaled labour
4.2.2.3	Tracer Dosing Package	16,742		3,906		20,648							3	S scaled quote + scaled labour  Vendor quotes, scaled vendor quotes, scaled labour fro
4.2.2.4	Pumps	49,876		18,838		68,714							1 and 2	EPC project  Vendor quotes, scaled vendor quotes, scaled labour fro
4.2.2.5	Vessels	4,467,796		643,856		5,111,652							1 and 2	EPC project  Vendor quotes, scaled vendor quotes, scaled labour fro
4.2.2.6	Heat Exchangers	493,565		56,776		550,342							1 and 2	EPC project
4.2.2.7	Electrical Equipment	3,261,426		-		3,261,426							2	2 scaled vendor quote + scaled labour
4.2.2.8	Other equipment	10,051,085		248,436		10,299,521							2	2 scaled vendor quote + scaled labour
4.3	Bulk Material Subcontracts						356,495,460	356,495,460	712,990,920	1,069,486,380	1,425,981,840	1,782,477,300		factored from MTO based vendor quotes from selected
4.3.1	Concrete				54,413,006	54,413,006							2	similar projects factored from MTO based vendor quotes from selected
4.3.2	Steelwork				12,202,476	12,202,476							2	similar projects  factored from MTO based vendor quotes from selected
4.3.3	Site transport & Rigging				3,549,835	3,549,835							2	similar projects factored from MTO based vendor quotes from selected
4.3.4	Piping				90,223,346	90,223,346							2	2 similar projects
4.3.5	Electrical and Instrumentation, Telecoms				71,822,208	71,822,208							2	factored from MTO based vendor quotes from selected similar projects
4.3.6	Ducting				87,979,619	87,979,619							2	factored from MTO based vendor quotes from selected similar projects factored from MTO based vendor quotes from selected
4.3.7	Scaffolding				24,203,314	24,203,314							2	similar projects
4.3.8	Painting & Insulation				12,101,656	12,101,656							2	factored from MTO based vendor quotes from selected similar projects
4.4	Pre-Commissioning and Commissioning					10,839,425	31,087,824	31,087,824	34,962,658	52,443,986	69,925,315	87,406,644	2 and 4	compared to prior project for fills and subcontracts, factor used for labour
4.4.1	Start-up					2,167,885	,,+	,,+	,,	, 1,110	-,,	. , , , , , , , , , , ,		
		1				_, ,							1	

CLIENT: PROJECT: LOCATION: Project NO.:	Thermal Power with CCS Croydon	Carbon Ca	pture and	Compression	on	Teesside -	2_1 train (	USD/GBP EUR/GBP Subcontract Uplif Labour Rate	t			USD/GBP EUR/GBP Subcontract Uplif Labour Rate	1.29 1.13 1.02 33.41	2 Modularisation Factor
4.5	Owner's Commissioning Costs					9,380,271	11,256,326	11,256,326	14,609,547	21,914,321	29,219,095	36,523,868		(e) Contractor and Owner Costs
4.5.1	Owner's start-up Costs					1,876,054	,	,		, ,	,	,		
4.6	Contractor's Soft Costs					195,590,013	195,590,013	195,590,013	252,250,794	378,376,192	504,501,589	630,626,986		(e) Contractor and Owner Costs
4.7	Owner's Soft Costs					62,095,688	62,095,688	62,095,688	80,092,876	120,139,315	160,185,753	200,232,191		(e) Contractor and Owner Costs
	Subtotal Carbon Capture and Compression	73,404,506	-	34,441,623	363,073,534	925,381,275	925,381,275	922,099,250	1,193,557,396	1,790,336,095	2,387,114,793	2,983,893,491		
	Thermal Power with CCS	Equipment (GBP)	Materials	Labour	Subcontract	Item Total	Subtotal	2 Trains	2 Trains				Estimate Quality	Source
					-	-	-							
	Proportion of Site Acquisition					-	3,807,800	6,458,800	6,458,800					(a) Site Acquisition
	Proportion of Site Enabling Works				37,502,588	37,502,588	37,502,588	37,502,588	37,502,588					(c) Site Enabling Works
	Proportion of Front End Engineering				29,993,550	29,993,550	29,993,550	29,993,550	29,993,550					(b) Front End Engineering
	Proportion of Facilities and Utilities				62,783,819	62,783,819	62,783,819	62,783,819	68,544,522					(d) Facilities and Utilities
	Proportion of Other Connections				8,984,790	8,984,790	8,984,790	9,999,866	9,999,866					(f) Other Connections
	Spares				8,439,788	8,439,788	8,439,788	8,439,788	8,439,788				4	estimating norms
4.0	Total Carbon Capture and Compression				510,778,069	510,778,069	1,073,085,810	1,077,277,661	1,354,496,511					



## **Attachment 5.2 - Brochure Efficiency Reboiler Case**

**PROJECT:** Thermal Power with CCS

#### **Project Summary**

LOCATION: Croydon

Teesside - Optimisation for Reboiler Efficiency 2.7 GJ/Tonne

**Project NO.:** 181869

							Origi	nal	Savi	ngs
	Thermal Power with CCS	One Train	2 Trains	3 Trains	4 Trains	5 Trains	One Train	5 Trains	One Train	5 Trains
1.0	Power Generation (CCGT)	576,963,960	1,012,492,216	1,438,301,613	1,857,181,526	2,269,390,994	576,963,960	2,269,390,994	-	-
2.0	Carbon Capture	582,183,819	1,036,228,586	1,492,361,554	1,948,381,497	2,405,051,161	585,218,624	2,420,225,190	3,034,806	15,174,029
3.0	CO2 Transportation	224,488,663	233,640,883	254,674,734	303,388,525	303,389,214	224,488,663	303,389,214	-	-
4.0	Offshore Storage	206,185,776	222,799,376	239,412,976	427,734,607	444,348,207	206,185,776	444,348,207		-
	Total	1,589,822,218	2,505,161,062	3,424,750,877	4,536,686,155	5,422,179,576	1,592,857,024	5,437,353,605	3,034,806	15,174,029
	Risk and Contingency	One Train	2 Trains	3 Trains	4 Trains	5 Trains	One Train	5 Trains		
	P50	1,758,343,373	2,770,708,134	3,787,774,470	5,017,574,888	5,996,930,611	1,761,699,868	6,013,713,087	3,356,495	16,782,476
	P90	1,868,041,106	2,943,564,247	4,024,082,280	5,330,606,232	6,371,061,001	1,871,607,003	6,388,890,485	3,565,897	17,829,484

**PROJECT:** Thermal Power with CCS

Carbon Capture and Compression

Teesside - Optimisation for Reboiler Efficiency 2.7 GJ/Tonne

USD/GBP 1.29

EUR/GBP 1.13

Subcontract Uplift 1.02

33.41

Labour Rate

Modularisation Factor 0.96

LOCATION: Croydon Project NO.: 181869

1 2 3 4 5

	Thermal Power with CCS	Equipment (USD)	Equipment (GBP)	Equipment (EUR)	Materials	Labour	Subcontract	Item Total	Subtotal	One Train	2 Trains	3 Trains	4 Trains	5 Trains	Estimate Quality	Source
		(03D)	(GBF)	(EUN)											Quality	
4.1	Detailed Design Engineering					25,766,253		25,766,253	25,766,253	25,766,253	38,649,380	51,532,506	64,415,633	77,298,759	2	Comparison of 3 similar projects
4.2	Mechanical															
4.2.1	Carbon Capture Equipment							-	112,176,424	107,689,367	215,378,735	323,068,102	430,757,469	538,446,837		updated for modularisation savings
4.2.1.1	CO2 Stripper - Column and Internals		4,890,892			-	480,000	5,370,892							1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.2	CO2 Absorber - Column and Internals		27,613,666			-	2,937,000	30,550,666							1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.3	Direct Contact Cooler - Column and Internals		2,383,115			308,600	203,000	2,894,715							1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.4	Thermal Recovery Unit		16,177,490			-	121,704	16,299,194							2	scaled vendor quote + scaled labour
4.2.1.5	Thermal Reclaimer Vacuum Package		8,615,237			175,821	-	8,791,060							2	scaled vendor quote + scaled labour
4.2.1.6	Ion Exchange Package		620,239			80,978		701,218							2	scaled vendor quote + scaled labour
4.2.1.7	Booster Fans		9,225,570			468,254		9,693,824							2	scaled vendor quote + scaled labour
4.2.1.8	Gas-Gas Heat Exchanger		3,495,903			195,587		3,691,490							1	vendor quote + labour
4.2.1.9	Lean/Rich Amine Exchanger		15,482,625			1,141,615		16,624,240							1	vendor quote + labour
4.2.1.10	CO2 Stripper Reboilers		2,689,878	-		353,714		3,043,592							2	scaled vendor quote + scaled labour
4.2.1.11	Heat Exchangers		1,784,286			578,212		2,362,506							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.12	Pumps		4,123,738			517,919		4,641,658							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.13	Vessels		599,992	-		275,499	-	875,491							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.14	Tanks	-	3,669,489	-		71,392		3,740,880							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.15	Other Equipment		2,857,317	-		37,049	633	2,894,999							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2	Compression Equipment							-	28,609,878	27,465,483	54,930,967	82,396,450	109,861,933	137,327,417		updated for modularisation savings
4.2.2.1	Compression Package		19,770,285	-		832,680		20,602,965							2	scaled quote + scaled labour
4.2.2.2	Dehydration Package		208,580	-		370,080		578,660							2	scaled quote + scaled labour
4.2.2.3	Tracer Dosing Package		16,742			3,906		20,648							3	scaled quote + scaled labour
4.2.2.4	Pumps		18,126	-		9,586		27,712							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.5	Vessels		3,467,977	•		420,760		3,888,738							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.6	Heat Exchangers		203,523	-		23,632		227,155							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.7	Electrical Equipment		2,452,200	-		-		2,452,200							2	scaled vendor quote + scaled labour
4.2.2.8	Other equipment		706,431	-		105,370		811,801							2	scaled vendor quote + scaled labour
4.3	Bulk Material Subcontracts								144,327,235	144,327,235	288,654,471	432,981,706	577,308,942	721,636,177		
4.3.1	Concrete						27,206,503	27,206,503	,==.,===	,		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	,,		2	factored from MTO based vendor quotes from selected similar projects
4.3.2	Steelwork						6,101,238	6,101,238								factored from MTO based vendor quotes from selected similar projects
4.3.3	Site transport & Rigging						1,419,934	1,419,934							2	factored from MTO based vendor quotes from selected similar projects
4.3.4	Piping						44,484,673	44,484,673							2	factored from MTO based vendor quotes from selected similar projects
4.3.5	Electrical and Instrumentation, Telecoms						35,911,104	35,911,104							2	factored from MTO based vendor quotes from selected similar projects
4.3.6	Ducting						11,051,298	11,051,298							2	factored from MTO based vendor quotes from selected similar projects
4.3.7	Scaffolding						12,101,657	12,101,657							2	factored from MTO based vendor quotes from selected similar projects
4.3.8	Painting & Insulation						6,050,828	6,050,828							2	factored from MTO based vendor quotes from selected similar projects
									45 574 767	45 574 767	00.007.464	AF 004 701	04 000 070	70.400.050	0 1	compared to prior project for fills and subcontracts, factor
4.4	Pre-Commissioning and Commissioning						5,442,925	5,442,925	15,571,767	15,571,767	30,637,124	45,821,701	61,006,279	76,190,856	∠ and 4	used for labour
4.4.1	Start-up						1,088,585	1,088,585								
4.4.2	First Fills						9,040,257	9,040,257								

CLIENT: PROJECT: LOCATION: Project NO.:	ETI Thermal Power with CCS Croydon 181869		Carbon Ca	apture and (	Compression	on		Teesside -	Optimisati	on for Reb	oiler Efficie	ency 2.7 G	J/Tonne	USD/GBP EUR/GBP Subcontract Uplif Labour Rate	1.29 1.13 1.02 33.41	Modularisation Factor 0.96
4.5	Owner's Commissioning Costs							4,710,224	5,652,269	5,652,269	10,866,297	16,183,497	21,500,698	26,817,898		(e) Contractor and Owner Costs
4.5.1	Owner's start-up Costs							942,045								
4.6	Contractor's Soft Costs							95,508,733	95,508,733	95,508,733	183,612,338	273,459,283	363,306,228	453,153,173		(e) Contractor and Owner Costs
4.7	Owner's Soft Costs							29,810,818	29,810,818	29,810,818	58,320,865	86,858,988	115,397,111	143,935,234		(e) Contractor and Owner Costs
	Subtotal Carbon Capture and Compression	68,877,547	55,239,975	25,244,430	-	5,970,655	163,641,340	431,657,125	457,423,378	451,791,926	881,050,175	1,312,302,233	1,743,554,292	2,174,806,350		
	Thermal Power with CCS	Equipment (USD)	Equipment (GBP)	Equipment (EUR)	Materials	Labour	Subcontract	Item Total	Subtotal	One Train	2 Trains	3 Trains	4 Trains	5 Trains	Estimate Quality	Source
							-	-	-							
	Proportion of Site Acquisition							-	3,807,800	3,807,800	6,458,800	9,158,000	11,784,900	14,460,000		(a) Site Acquisition
	Proportion of Site Enabling Works						34,152,291	34,152,291	34,152,291	34,152,291	37,502,588	40,855,604	44,208,540	47,564,206		(c) Site Enabling Works
	Proportion of Front End Engineering						29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550		(b) Front End Engineering
	Proportion of Facilities and Utilities						45,013,673	45,013,673	45,013,673	45,013,673	62,783,819	80,553,965	98,324,111	116,679,107		(d) Facilities and Utilities
	Proportion of Other Connections						8,984,790	8,984,790	8,984,790	8,984,790	9,999,866	11,058,413	12,076,315	13,108,159		(f) Other Connections
	Spares						8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	4	estimating norms
		1						-						l		

**PROJECT:** Thermal Power with CCS

Project Summary
Teesside - Optimisation for Reboiler Efficiency 2.4 GJ/Tonne

LOCATION: Croydon **Project NO.:** 181869

> Original Savings

							Orig.			iligo
	Thermal Power with CCS	One Train	2 Trains	3 Trains	4 Trains	5 Trains	One Train	5 Trains	One Train	5 Trains
1.0	Power Generation (CCGT)	576,963,960	1,012,492,216	1,438,301,613	1,857,181,526	2,269,390,994	576,963,960	2,269,390,994	-	-
2.0	Carbon Capture	581,548,651	1,034,958,250	1,490,456,049	1,945,840,825	2,401,875,320	585,218,624	2,420,225,190	3,669,974	18,349,870
3.0	CO2 Transportation	224,488,663	233,640,883	254,674,734	303,388,525	303,389,214	224,488,663	303,389,214	-	-
4.0	Offshore Storage	206,185,776	222,799,376	239,412,976	427,734,607	444,348,207	206,185,776	444,348,207	-	ı
	Total	1,589,187,050	2,503,890,725	3,422,845,372	4,534,145,482	5,419,003,735	1,592,857,024	5,437,353,605	3,669,974	18,349,870

Risk and Contingency	One Train	2 Trains	3 Trains	4 Trains	5 Trains	One Train	5 Trains		
P50	1,757,640,877	2,769,303,142	3,785,666,982	5,014,764,904	5,993,418,131	1,761,699,868	6,013,713,087	4,058,991	20,294,956
P90	1,867,294,784	2,942,071,602	4,021,843,312	5,327,620,942	6,367,329,388	1,871,607,003	6,388,890,485	4,312,219	21,561,097

4.2.1.1

4.2.1.2

4.2.1.3

4.2.1.4

4.2.1.5

4.2.1.6

4.2.1.7

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4.2.1.9

4.2.1.10

4.2.1.11

4.2.1.12

4.2.1.13

4.2.1.14

4.2.1.15

4.2.2

4.2.2.1

4.2.2.2

4.2.2.3

4.2.2.4

4.2.2.5

4.2.2.6

4.2.2.7

4.2.2.8

4.3.1

4.3.2

434

4.3.5

4.3.6

437

4.4

4.4.1

442

Carbon Capture Equipment

Thermal Recovery Unit

Ion Exchange Package

Gas-Gas Heat Exchanger

CO2 Stripper Reboilers

Heat Exchangers

Other Equipment

Compression Equipment

Compression Package

Dehydration Package

Tracer Dosing Package

Vessels

Tanks

Pumps

Vessels

Heat Exchangers

Other equipment

Concrete

Steelwork

Piping

Scaffolding

Start-up

First Fills

Painting & Insulation

Electrical Equipment

**Bulk Material Subcontracts** 

Site transport & Rigging

Electrical and Instrumentation, Telecoms

Pre-Commissioning and Commissioning

Lean/Rich Amine Exchanger

Booster Fans

CO2 Stripper - Column and Internals

CO2 Absorber - Column and Internals

Thermal Reclaimer Vacuum Package

Direct Contact Cooler - Column and Internals

4,890,892

27,613,666

2,383,115

1,619,097

8,615,237

620,239

9,225,570

3,495,903

15,482,625

2,218,902

1,593,558

4,123,817

3,669,489

2,857,317

19,770,285

208 580

16,742

18,126

3,467,977

203,523

706.431

2,452,200

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535,270,996

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137,327,417

721,636,177

76,190,856

and 4

pdated for modularisation savings

and 2 unit rates, scaled vendor quote, scaled up labour

2 scaled vendor quote + scaled labour

scaled vendor quote + scaled labour

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updated for modularisation savings

2 scaled quote + scaled labour

2 scaled quote + scaled labour

EPC project

similar projects

similar projects

similar projects

similar projects

2 similar projects

similar projects

similar projects

similar projects

Vendor quotes, scaled vendor quotes, scaled labour from EPC project

Vendor quotes, scaled vendor quotes, scaled labour from

Vendor quotes, scaled vendor quotes, scaled labour from EPC project

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Vendor quotes, scaled vendor quotes, scaled labour from EPC project

Vendor quotes, scaled vendor quotes, scaled labour from EPC project

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factored from MTO based vendor quotes from selected

compared to prior project for fills and subcontracts, factor

Vendor quotes, scaled vendor quotes, scaled labour from EPC project

scaled vendor quote + scaled labour

caled vendor quote + scaled labou

Vendor quotes, scaled vendor quotes, scaled labour from

1 vendor quote + labour

vendor quote + labour

EPC project

unit rates, scaled vendor quote, scaled up labour

unit rates, scaled vendor quote, scaled up labour

**Carbon Capture and Compression** Teesside - Optimisation for Reboiler Efficiency 2.4 GJ/Tonne **PROJECT:** Thermal Power with CCS EUR/GBP LOCATION: Croydon Modularisation Factor Subcontract Uplift Project NO.: 181869 Labour Rate 33 41 0.96 **Estimate** Thermal Power with CCS Materials Labour Subcontract Item Total Subtotal One Train 2 Trains 3 Trains 4 Trains 5 Trains Source Quality **Detailed Design Engineering** 25,766,253 25,766,253 25,766,253 25,766,253 38,649,380 51,532,506 64,415,633 77,298,759 Mechanical 4.2

5,370,892

30,550,666

2,894,715

16,299,194

8,791,060

701,218

9,693,824

3,691,490

16,624,240

2,572,616

2,171,770

4,641,736

875,491

3,740,880

2,894,999

20,602,965

578,660

20,648

27,712

3,888,738

227,155

2,452,200

811.801

27,206,503

6,101,238

1,419,934

44,484,673

35,911,104

11,051,298

12,101,657

6,050,828

5,442,925

1,088,585

9.040.257

15,571,767

15,571,767

480,000

2,937,000

203,000

121,704

308,600

175,821

80,978

468,254

195,587

1,141,615

353,714

578,212

517,919

275,499

71,392

37,049

832,680

370,080

3,906

9,586

420,760

23,632

105.370

27,206,503

6,101,238

44,484,673

35,911,104

11,051,298

12,101,657

6,050,828

5,442,925

1,088,585

9,040,257

111,514,791

28,609,878

107,054,199

27,465,483

54,930,967

288,654,471

30,637,124

214,108,398

321,162,598

82,396,450

432,981,706

45,821,701

61,006,279

428,216,797

109,861,933

CLIENT: PROJECT: LOCATION: Project NO.:	Thermal Power with CCS Croydon 181869  Carbon Capture and Compression Teesside - Optimisation for Reboiler Efficiency 2.4 GJ/Tor										J/Tonne	USD/GBP EUR/GBP Subcontract Uplif Labour Rate	1.29 1.13 1 1.02 33.41	Modularisation Factor 0.96
4.5	Owner's Commissioning Costs					4,710,224	5,652,269	5,652,269	10,866,297	16,183,497	21,500,698	26,817,898		(e) Contractor and Owner Costs
4.5.1	Owner's start-up Costs					942,045								
4.6	Contractor's Soft Costs					95,508,733	95,508,733	95,508,733	183,612,338	273,459,283	363,306,228	453,153,173		(e) Contractor and Owner Costs
4.7	Owner's Soft Costs					29,810,818	29,810,818	29,810,818	58,320,865	86,858,988	115,397,111	143,935,234		(e) Contractor and Owner Costs
	Subtotal Carbon Capture and Compression	54,583,462	-	5,970,655	163,641,340	430,995,492	456,761,745	451,156,758	879,779,839	1,310,396,729	1,741,013,619	2,171,630,510		
	Thermal Power with CCS	Equipment (GBP)	Materials	Labour	Subcontract	Item Total	Subtotal	One Train	2 Trains	3 Trains	4 Trains	5 Trains	Estimate Quality	Source
					-	-	-							
	Proportion of Site Acquisition					-	3,807,800	3,807,800	6,458,800	9,158,000	11,784,900	14,460,000		(a) Site Acquisition
	Proportion of Site Enabling Works				34,152,291	34,152,291	34,152,291	34,152,291	37,502,588	40,855,604	44,208,540	47,564,206		(c) Site Enabling Works
	Proportion of Front End Engineering				29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550		(b) Front End Engineering
	Proportion of Facilities and Utilities				45,013,673	45,013,673	45,013,673	45,013,673	62,783,819	80,553,965	98,324,111	116,679,107		(d) Facilities and Utilities
	Proportion of Other Connections				8,984,790	8,984,790	8,984,790	8,984,790	9,999,866	11,058,413	12,076,315	13,108,159		(f) Other Connections
	Spares				8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	4	estimating norms
						-								
4.0	Total Carbon Capture and Compression				290,225,432	290,225,432	557,579,584	581,548,651	1,034,958,250	1,490,456,049	1,945,840,825	2,401,875,320		



## <u>Attachment 5.3 – 150 barg Compressor Case</u>

**PROJECT:** Thermal Power with CCS

**Project Summary** Teesside - Case 3 Compressor

LOCATION: Croydon **Project NO.:** 181869

1	Thermal Power with CCS	One Train	2 Trains	3 Trains	4 Trains	5 Trains	One Train	5 Trains	One Train	5 Trains
1.0	Power Generation (CCGT)	576,963,960	1,012,492,216	1,438,301,613	1,857,181,526	2,269,390,994	576,963,960	2,269,390,994	-	-
2.0	Carbon Capture	584,269,832	1,040,400,613	1,498,619,594	1,956,725,551	2,415,481,228	585,218,624	2,420,225,190	948,792	4,743,962
3.0	CO2 Transportation	224,488,663	233,640,883	254,674,734	303,388,525	303,389,214	224,488,663	303,389,214	-	-
4.0	Offshore Storage	206,185,776	222,799,376	239,412,976	427,734,607	444,348,207	206,185,776	444,348,207	-	-
	Total	1,591,908,231	2,509,333,088	3,431,008,917	4,545,030,209	5,432,609,643	1,592,857,024	5,437,353,605	948,792	4,743,962

Risk and Contingency	One Train	2 Trains	3 Trains	4 Trains	5 Trains	One Train	5 Trains	One Train	5 Trains
P50	1,760,650,504	2,775,322,396	3,794,695,862	5,026,803,411	6,008,466,265	1,761,699,868	6,013,713,087	1,049,364	5,246,822
P90	1,870,492,172	2,948,466,379	4,031,435,477	5,340,410,495	6,383,316,330	1,871,607,003	6,388,890,485	1,114,831	5,574,155

**PROJECT:** Thermal Power with CCS

Pre-Commissioning and Commissioning

4.4.1

4.4.2

Start-up

First Fills

**Carbon Capture and Compression** 

**Teesside - Case 3 Compressor** 

15,571,767

5,442,925

1,088,585

9,040,257

15,571,767

30,637,124

45,821,701

61,006,279

76,190,856

EUR/GBP 1.13
Subcontract Uplift 1.02 Modularisation Factor
Labour Rate 33.41 0.96

compared to prior project for fills and subcontracts, factor used for labour

USD/GBP

LOCATION: Croydon Project NO.: 181869

	Thermal Power with CCS	Equipment (USD)	Equipment (GBP)	Equipment (EUR)	Materials	Labour	Subcontract	Item Total	Subtotal	One Train	2 Trains	3 Trains	4 Trains	5 Trains	Estimate Quality	Source
		( )	(- )													
4.1	Detailed Design Engineering					25,766,253		25,766,253	25,766,253	25,766,253	38,649,380	51,532,506	64,415,633	77,298,759	2	2 Comparison of 3 similar projects
4.2	Mechanical															
4.2.1	Carbon Capture Equipment							-	114,877,317	110,282,224	220,564,448	330,846,672	441,128,896	551,411,120		updated for modularisation savings
4.2.1.1	CO2 Stripper - Column and Internals		4,890,892			-	480,000	5,370,892							1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.2	CO2 Absorber - Column and Internals		27,613,666			-	2,937,000	30,550,666							1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.3	Direct Contact Cooler - Column and Internals		2,383,115			308,600	203,000	2,894,715							1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.4	Thermal Recovery Unit		16,177,490			-	121,704	16,299,194							2	2 scaled vendor quote + scaled labour
4.2.1.5	Thermal Reclaimer Vacuum Package		9,807,293			175,821	-	8,791,060							2	2 scaled vendor quote + scaled labour
4.2.1.6	lon Exchange Package		620,239			80,978		701,218							2	2 scaled vendor quote + scaled labour
4.2.1.7	Booster Fans		9,225,570			468,254		9,693,824							2	2 scaled vendor quote + scaled labour
4.2.1.8	Gas-Gas Heat Exchanger		3,495,903			195,587		3,691,490							1	1 vendor quote + labour
4.2.1.9	Lean/Rich Amine Exchanger		15,482,625			1,141,615		16,624,240							1	1 vendor quote + labour
4.2.1.10	CO2 Stripper Reboilers		3,541,980			353,714		3,895,695							2	2 scaled vendor quote + scaled labour
4.2.1.11	Heat Exchangers		3,028,394			578,212		3,606,606							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.12	Pumps		4,728,428			517,919		5,246,348							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.13	Vessels		599,992			275,499	-	875,491							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.14	Tanks		3,669,489			71,392		3,740,880							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.15	Other Equipment		2,857,317			37,049	633	2,894,999							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2	Compression Equipment							_	27,428,792	26,331,640	52,663,280	78,994,920	105,326,560	131,658,200		updated for modularisation savings
4.2.2.1	Compression Package		18,590,575			832,680		19,423,254							2	2 scaled quote + scaled labour
4.2.2.2	Dehydration Package		208,580			370,080		578,660							2	2 scaled quote + scaled labour
4.2.2.3	Tracer Dosing Package		16,742			3,906		20,648							3	3 scaled quote + scaled labour
4.2.2.4	Pumps		18,126			9,586		27,712							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.5	Vessels		3,466,601			420,760		3,887,362							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.6	Heat Exchangers		203,523			23,632		227,155							1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.7	Electrical Equipment		2,452,200			-		2,452,200							2	2 scaled vendor quote + scaled labour
4.2.2.8	Other equipment		706,431			105,370		811,801								2 scaled vendor quote + scaled labour
4.3	Bulk Material Subcontracts								144.954.235	144.954.235	289,908,471	434,862,706	579,816,942	724,771,177		
4.3.1	Concrete						27,206,503	27,206,503	144,004,200	144,004,200	200,000,471	101,002,700	070,010,042	123,111,111		factored from MTO based vendor quotes from selected 2 similar projects
4.3.2	Steelwork						6,101,238	6,101,238								factored from MTO based vendor quotes from selected 2 similar projects
4.3.3	Site transport & Rigging						1,419,934	1,419,934								factored from MTO based vendor quotes from selected 2 similar projects
4.3.4	Piping						45,111,673	45,111,673								factored from MTO based vendor quotes from selected 2 similar projects
4.3.5	Electrical and Instrumentation, Telecoms						35,911,104	35,911,104								factored from MTO based vendor quotes from selected 2 similar projects
4.3.6	Ducting						11,051,298	11,051,298								factored from MTO based vendor quotes from selected 2 similar projects
4.3.5	Scaffolding						12,101,657	12,101,657								z similar projects factored from MTO based vendor quotes from selected similar projects
																factored from MTO based vendor quotes from selected
4.3.8	Painting & Insulation						6,050,828	6,050,828							- 2	2 similar projects

5,442,925

1,088,585

9,040,257

CLIENT:	ETI													USD/GBP	1.29	
PROJECT:	Thermal Power with CCS		Carbon Ca	apture and	Compressi	on		Teesside -	Case 3 Co	mpressor				EUR/GBP	1.13	
LOCATION:														Subcontract Uplif	1.02	Modularisation Factor
Project NO.:	181869													Labour Rate	33.41	0.96
	1									[						
4.5	Owner's Commissioning Costs							4,710,224	5,652,269	5,652,269	10,866,297	16,183,497	21,500,698	26,817,898		(e) Contractor and Owner Costs
4.5.1	Owner's start-up Costs							942,045								
4.6	Contractor's Soft Costs							95,508,733	95,508,733	95,508,733	183,612,338	273,459,283	363,306,228	453,153,173		(e) Contractor and Owner Costs
4.7	Owner's Soft Costs							29,810,818	29,810,818	29,810,818	58,320,865	86,858,988	115,397,111	143,935,234		(e) Contractor and Owner Costs
	_															
	Subtotal Carbon Capture and Compression	43,176,015	57,340,001	47,165,901	-	5,970,655	164,268,340	433,803,931	459,570,184	453,877,940	885,222,202	1,318,560,274	1,751,898,345	2,185,236,417		
	Thermal Power with CCS	Equipment (USD)	Equipment (GBP)	Equipment (EUR)	Materials	Labour	Subcontract	Item Total	Subtotal	One Train	2 Trains	3 Trains	4 Trains	5 Trains	Estimate Quality	Source
							_	_	_							
	Proportion of Site Acquisition							-	3,807,800	3,807,800	6,458,800	9,158,000	11,784,900	14,460,000		(a) Site Acquisition
	Proportion of Site Enabling Works						34,152,291	34,152,291	34,152,291	34,152,291	37,502,588	40,855,604	44,208,540	47,564,206		(c) Site Enabling Works
	Proportion of Front End Engineering						29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550	29,993,550		(b) Front End Engineering
	Proportion of Facilities and Utilities						45,013,673	45,013,673	45,013,673	45,013,673	62,783,819	80,553,965	98,324,111	116,679,107		(d) Facilities and Utilities
	Proportion of Other Connections						8,984,790	8,984,790	8,984,790	8,984,790	9,999,866	11,058,413	12,076,315	13,108,159		(f) Other Connections
	Spares						8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	8,439,788	4	estimating norms
4.0	Total Carbon Capture and Compression						290.852.432	290,852,432	560,388,023	504.000.000	1,040,400,613	4 400 040 504	4 050 705 554	0 445 404 000		



## <u>Attachment 5.4 – Single TRU Case</u>

PROJECT: Thermal Power with CCS

**Project Summary**Teesside - Optimisation for TRU

Croydon Project NO.: 181869

LOCATION:

							Original	Savings
	Thermal Power with CCS	One Train	2 Trains	3 Trains	4 Trains	5 Trains	5 Trains	5 Trains
1.0	Power Generation (CCGT)					2,268,085,133	2,269,390,994	1,305,861
2.0	Carbon Capture					2,259,690,146	2,420,225,190	160,535,044
3.0	CO2 Transportation					303,389,214	303,389,214	-
4.0	Offshore Storage					444,348,207	444,348,207	-
	Total					5,275,512,700	5,437,353,605	161,840,905

Risk and Contingency	One Train	2 Trains	3 Trains	4 Trains	5 Trains	5 Trains	
P50	1,726,936,566	2,694,932,986	3,695,508,015	4,894,909,619	5,834,717,046	6,013,713,087	178,996,041
P90	1,834,674,923	2,863,061,717	3,926,059,600	5,200,288,248	6,198,727,422	6,388,890,485	190,163,063

CLIENT: ETI

PROJECT: Thermal Power with CCS
Carbon Capture and Compression
Teesside - Optimisat EUR/GBP
1.29

LOCATION: Croydon
Project NO: 181869

USD/GBP
1.29

Labour Rate
1.13

Subcontract Uplit 1.02
Modularisation Factor
Labour Rate 33.41
0.96

		Equipment	Equipment	Equipment						5	Estimate	_
	Thermal Power with CCS	(USD)	(GBP)	(EUR)	Materials	Labour	Subcontract	Item Total	Subtotal	5 Trains	Quality	Source
4.1	Detailed Design Engineering					25,766,253		25,766,253	24,422,147	74,610,547	2	Comparison of 3 similar projects
4.2	Mechanical											
4.2.1	Carbon Capture Equipment							-	88,174,950	423,239,761		updated for modularisation savings
4.2.1.1	CO2 Stripper - Column and Internals	-	4,890,892			-	480,000	5,370,892			1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.2	CO2 Absorber - Column and Internals	-	27,613,666			-	2,937,000	30,550,666			1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.3	Direct Contact Cooler - Column and Internals		2,383,115			308,600	203,000	2,894,715			1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.4	Thermal Recovery Unit		31,139,295	-		-	121,704			31,260,999	2	scaled vendor quote + scaled labour
4.2.1.5	Thermal Reclaimer Vacuum Package	-	3,924,042			175,821	-			4,099,863	2	scaled vendor quote + scaled labour
4.2.1.6	Ion Exchange Package		6,178,481	-		-				6,178,481	2	scaled vendor quote + scaled labour
4.2.1.7	Booster Fans	-	9,225,570	-		468,254		9,693,824			2	scaled vendor quote + scaled labour
4.2.1.8	Gas-Gas Heat Exchanger		3,495,903	-		195,587		3,691,490			1	vendor quote + labour
4.2.1.9	Lean/Rich Amine Exchanger	-	15,482,625	-		1,141,615		16,624,240			1	vendor quote + labour
4.2.1.10	CO2 Stripper Reboilers	-	3,541,980	-		353,714		3,895,695			2	scaled vendor quote + scaled labour
4.2.1.11	Heat Exchangers		2,991,153			538,613		3,529,767			1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.11.1	Heat Exchangers for TRU	-	118,694			39,599				158,293		
4.2.1.12	Pumps		4,371,214			480,089		4,851,303			1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.12.1	Pumps - TRU		1,493,815			37,830		1,001,000		1,531,645	T GIIG 2	
4.2.1.13	Vessels		498,156	_		159,247	_	657,403		1,001,040	1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.13.1	Vessels - TRU					116,251		007,400		279,830	1 dilu 2	Ero piojeci
			163,579	-				0.407.070		279,030	4 10	Vendor quotes, scaled vendor quotes, scaled labour from
4.2.1.14	Tanks	-	3,443,363	-		54,609		3,497,972			1 and 2	EPC project
4.2.4.14.1	Tanks - TRU	-	445,479	-		33,554				479,033		Vendor quotes, scaled vendor quotes, scaled labour from
4.2.1.15	Other Equipment		2,882,426	-		33,924	633	2,916,983			1 and 2	EPC project
4.2.1.15.1	Other Equipment - TRU	-	41,849	-		3,125				44,974		
4.2.2	Compression Equipment							-	28,411,918	136,377,208		updated for modularisation savings
4.2.2.1	Compression Package		19,801,360	-		832,680		20,602,965			2	scaled quote + scaled labour
4.2.2.2	Dehydration Package	-	208,580	-		370,080		578,660			2	scaled quote + scaled labour
4.2.2.3	Tracer Dosing Package	-	16,742	-		3,906		20,648			3	scaled quote + scaled labour
4.2.2.4	Pumps	-	18,126	-		9,586		27,712			1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.5	Vessels		3,270,017	-		420,760		3,690,778			1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.6	Heat Exchangers		203,523	-		23,632		227,155			1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.2.7	Electrical Equipment		2,452,200	-		-		2,452,200			2	scaled vendor quote + scaled labour
4.2.2.8	Other equipment		706,431	-		105,370		811,801			2	scaled vendor quote + scaled labour
4.3	Bulk Material Subcontracts								147,972,235	666,265,267		updated for savings on TRU -18,500,422 for concrete and - 30,675,937 for piping and -24,419,551 for electrical
4.3.1							27,206,503	27 206 502	147,372,233	000,200,201	2	factored from MTO based vendor quotes from selected
4.3.1	Concrete							27,206,503				similar projects factored from MTO based vendor quotes from selected
	Steelwork						6,101,238	6,101,238				similar projects factored from MTO based vendor quotes from selected
4.3.3	Site transport & Rigging						1,419,934	1,419,934				similar projects factored from MTO based vendor quotes from selected
4.3.4	Piping						45,111,673	45,111,673			2	similar projects
4.3.4.1	Supplementary Piping for TRU						3,018,000	3,018,000				factored from MTO based vendor quotes from selected
4.3.5	Electrical and Instrumentation, Telecoms						35,911,104	35,911,104				similar projects factored from MTO based vendor quotes from selected
4.3.6	Ducting						11,051,298	11,051,298			2	similar projects factored from MTO based vendor quotes from selected
4.3.7	Scaffolding						12,101,657	12,101,657			2	similar projects factored from MTO based vendor quotes from selected
4.3.8	Painting & Insulation						6,050,828	6,050,828			2	similar projects
4.4	Pre-Commissioning and Commissioning						5,009,008	5,009,008	15,051,067	74,698,219	2 and 4	compared to prior project for fills and subcontracts, factor used for labour
4.4.1	Start-up						1,001,802	1,001,802				
4.4.2	First Fills						9,040,257	9,040,257				
7.7.6							0,040,207	0,040,207				

CLIENT: PROJECT: LOCATION:	Thermal Power with CCS Croydon		Carbon Ca	apture and	Compressi	ion		Teesside	- Optimisat	USD/GBP EUR/GBP Subcontract Uplit	1.29 1.13 1 1.02	Modularisation Factor
Project NO.:	181869									Labour Rate	33.41	0.96
4.5	Owner's Commissioning Costs							4,334,719	5,201,663	25,526,193		(e) Contractor and Owner Costs
4.5.1	Owner's start-up Costs							866,944				
4.6	Contractor's Soft Costs							90,588,253	90,588,253	444,794,685		(e) Contractor and Owner Costs
4.7	Owner's Soft Costs							28,758,760	28,758,760	141,206,199		(e) Contractor and Owner Costs
	Subtotal Carbon Capture and Compression	84,827,012	57,429,728	31,257,417	-	5,906,449	166,765,639	404,158,847	428,580,994	2,030,751,197		updated for reduction in bulk materials for 5 trains
	Thermal Power with CCS	Equipment (USD)	Equipment (GBP)	Equipment (EUR)	Materials	Labour	Subcontract	Item Total	Subtotal	5 Trains	Estimate Quality	Source
							-	-	-			
	Proportion of Site Acquisition							-	3,807,800	14,460,000		(a) Site Acquisition
	Proportion of Site Enabling Works						34,152,291	34,152,291	34,152,291	47,564,206		(c) Site Enabling Works
	Proportion of Front End Engineering						29,993,550	29,993,550	29,993,550	29,993,550		(b) Front End Engineering
	Proportion of Facilities and Utilities						44,752,501	44,752,501	44,752,501	115,373,246		(d) Facilities and Utilities
	Proportion of Other Connections						8,984,790	8,984,790	8,984,790	13,108,159		(f) Other Connections
	Spares						8,439,788	8,439,788	8,439,788	8,439,788	4	estimating norms
4.0	Total Carbon Capture and Compression						293,088,560	293,088,560	530,481,767	2,259,690,146		



## **Attachment 5.5 - Combined Case**

**PROJECT:** Thermal Power with CCS

P50

P90

**Project Summary**Teesside - Optimisation for TRU, Reboiler, Compressor LOCATION: Croydon

181869 Project NO.:

					Original	Savings
	Thermal Power with CCS			5 Trains	5 Trains	5 Trains
1.0	Power Generation (CCGT)			2,268,085,133	2,269,390,994	1,305,861
2.0	Carbon Capture			2,240,007,598	2,420,225,190	180,217,592
3.0	CO2 Transportation			303,389,214	303,389,214	-
4.0	Offshore Storage			444,348,207	444,348,207	-
	Total			5,255,830,152	5,437,353,605	181,523,453
	Risk and Contingency			5 Trains	5 Trains	

5,812,948,148

6,175,600,428

6,013,713,087

6,388,890,485

200,764,939

213,290,057

CLIENT: ETI

PROJECT: Thermal Power with CCS
Carbon Capture and Compression
Teesside - Optimisat
EUR/GBP
1.29

LOCATION: Croydon
Project NO: 181869

USD/GBP 1.29

Labour Rate 33.41

Modularisation Factor
Labour Rate 33.41

O 96

5												
	Thermal Power with CCS	Equipment (USD)	Equipment (GBP)	Equipment (EUR)		Labour	Subcontract	Item Total	Subtotal	5 Trains	Estimate Quality	Source
4.1	Detailed Design Engineering					25,766,253		25,766,253	25,766,253	77,298,759		Comparison of 3 similar projects
						23,700,233		23,700,233	25,700,255	11,290,139		companson of 3 similar projects
4.2	Mechanical								05 440 004	440.450.504		
4.2.1.1	Carbon Capture Equipment		4,890,892				480,000		85,448,034	410,150,564	4 4 0	updated for modularisation savings
4.2.1.1	CO2 Stripper - Column and Internals  CO2 Absorber - Column and Internals		4,890,892 27,613,666			-	2,937,000	5,370,892 30,550,666			1 and 2 1 and 2	unit rates, scaled vendor quote, scaled up labour unit rates, scaled vendor quote, scaled up labour
4.2.1.3	Direct Contact Cooler - Column and Internals		2,383,115			308,600	203,000	2,894,715			1 and 2	unit rates, scaled vendor quote, scaled up labour
4.2.1.4	Thermal Recovery Unit		31,139,295			300,000	121,704	2,034,713		31,260,999		Scaled vendor quote + scaled labour
4.2.1.5	Thermal Reclaimer Vacuum Package		3,924,042			175,821	121,704			4,099,863		Scaled vendor quote + scaled labour
4.2.1.6	Ion Exchange Package		6,178,481			-				6,178,481		scaled vendor quote + scaled labour
4.2.1.7	Booster Fans	_	9,225,570	_		468,254		9,693,824		0,170,101		scaled vendor quote + scaled labour
4.2.1.8	Gas-Gas Heat Exchanger		3,495,903	_		195,587		3,691,490				vendor quote + labour
4.2.1.9	Lean/Rich Amine Exchanger	_	15,482,625	_		1,141,615		16,624,240			1	vendor quote + labour
4.2.1.10	CO2 Stripper Reboilers	_	2,689,878	_		353,714		3,043,592			2	scaled vendor quote + scaled labour
4.2.1.11	Heat Exchangers		1,720,952			538,613		2,259,565			1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.11.1	Heat Exchangers for TRU		118,694			39,599		2,200,000		158,293	r unu z	E. O projekt
4.2.1.12	Pumps		3,766,577			480,089		4,246,692		130,233	1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.12.1	Pumps - TRU		1,493,815			37,830		4,240,032		1,531,645	T dild 2	E. O projekt
4.2.1.13	Vessels		498,156	_		159,247	_	657,403		1,551,045	1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.13.1	Vessels - TRU		163,579			116,251		037,403		279,830	1 and 2	Ero project
4.2.1.14	Tanks	_	3,443,363			54,609		3,497,972		213,030	1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.4.14.1	Tanks - TRU	_	445,479			33,554		3,431,312		479,033	1 and 2	El Optoject
4.2.1.15	Other Equipment	_	2,882,426			33,924	633	2,916,983		473,033	1 and 2	Vendor quotes, scaled vendor quotes, scaled labour from EPC project
4.2.1.15.1	Other Equipment - TRU	_	41,849	_		3,125	033	2,910,900		44,974	1 and 2	Ero project
			41,040	-		3,123						
4.2.2	Compression Equipment							-	27,232,208	130,714,597		updated for modularisation savings
4.2.2.1	Compression Package	-	18,590,575			832,680		19,423,254			2	scaled quote + scaled labour
4.2.2.2	Dehydration Package	-	208,580	-		370,080		578,660			2	scaled quote + scaled labour
4.2.2.3	Tracer Dosing Package	-	16,742	-		3,906		20,648			3	S scaled quote + scaled labour  Vendor quotes, scaled vendor quotes, scaled labour from
4.2.2.4	Pumps	-	18,126	-		9,586		27,712			1 and 2	EPC project  Vendor quotes, scaled vendor quotes, scaled labour from
4.2.2.5	Vessels		3,270,017	-		420,760		3,690,778			1 and 2	EPC project  Vendor quotes, scaled vendor quotes, scaled labour from
4.2.2.6	Heat Exchangers		203,523	-		23,632		227,155			1 and 2	EPC project
4.2.2.7	Electrical Equipment	-	2,452,200	-		-		2,452,200			2	scaled vendor quote + scaled labour
4.2.2.8	Other equipment		706,431	-		105,370		811,801			2	scaled vendor quote + scaled labour  updated for savings on TRU -18,500,422 for concrete and
4.3	Bulk Material Subcontracts								147,972,235	666,265,267		30,675,937 for piping and -24,419,551 for electrical factored from MTO based vendor quotes from selected
4.3.1	Concrete						27,206,503	27,206,503			2	similar projects
4.3.2	Steelwork						6,101,238	6,101,238			2	factored from MTO based vendor quotes from selected similar projects factored from MTO based vendor quotes from selected
4.3.3	Site transport & Rigging						1,419,934	1,419,934			2	similar projects
4.3.4	Piping						45,111,673	45,111,673		2,391,000	2	factored from MTO based vendor quotes from selected similar projects
4.3.4.1	Supplementary Piping for TRU						3,018,000	3,018,000				factored from MTO based used as suches from astronomy
4.3.5	Electrical and Instrumentation, Telecoms						35,911,104	35,911,104			2	factored from MTO based vendor quotes from selected similar projects factored from MTO based vendor quotes from selected
4.3.6	Ducting						11,051,298	11,051,298			2	lactored from MTO based vendor quotes from selected similar projects factored from MTO based vendor quotes from selected
4.3.7	Scaffolding						12,101,657	12,101,657			2	similar projects
4.3.8	Painting & Insulation						6,050,828	6,050,828			2	factored from MTO based vendor quotes from selected similar projects
4.4	Pre-Commissioning and Commissioning						4,964,591	4,964,591	14,997,767	74,413,829	2 and 4	compared to prior project for fills and subcontracts, factor used for labour
4.4.1	Start-up						992,918	992,918				
	·						9,040,257	9,040,257			İ	

CLIENT:	ETI									USD/GBP	1.29	
PROJECT:	Thermal Power with CCS		Carbon Ca	apture and	Compressi	on		Teesside -	<ul> <li>Optimisat</li> </ul>	EUR/GBP	1.13	
LOCATION:	Croydon									Subcontract Uplit		
Project NO.:	181869									Labour Rate	33.41	0.96
4.5	Owner's Commissioning Costs							4,296,281	5,155,537	25,280,086		(e) Contractor and Owner Costs
4.5.1	Owner's start-up Costs							859,256	5,100,001			<u></u>
4.6	Contractor's Soft Costs							89,808,854	89,808,854	440,636,117		(e) Contractor and Owner Costs
4.7	Owner's Soft Costs							28,511,199	28,511,199	139,885,311		(e) Contractor and Owner Costs
	Subtotal Carbon Capture and Compression	59,630,837	55,328,326	51,349,758	-	5,906,449	166,712,339	399,125,834	424,892,087	2,011,068,649		
	Thermal Power with CCS	Equipment (USD)	Equipment (GBP)	Equipment (EUR)	Materials	Labour	Subcontract	Item Total	Subtotal	5 Trains	Estimate Quality	Source
							-	-				
	Proportion of Site Acquisition							-	3,807,800	14,460,000		(a) Site Acquisition
	Proportion of Site Enabling Works						34,152,291	34,152,291	34,152,291	47,564,206		(c) Site Enabling Works
	Proportion of Front End Engineering						29,993,550	29,993,550	29,993,550	29,993,550		(b) Front End Engineering
	Proportion of Facilities and Utilities						44,752,501	44,752,501	44,752,501	115,373,246		(d) Facilities and Utilities
	Proportion of Other Connections						8,984,790	8,984,790	8,984,790	13,108,159		(f) Other Connections
	Spares						8,439,788	8,439,788	8,439,788	8,439,788	4	estimating norms
								-				
4.0	Total Carbon Capture and Compression						293,035,259	293,035,259	525,448,754	2,240,007,598		



## ATTACHMENT 6 – Supplemental Information Attachment 6.1.1 – Brochure Efficiency Reboiler Case 2.7 GJ/tonne CO<sub>2</sub> case

181869-0001-T-EM-TNT-AAA-00-01008 Design Optimisations.docx

#### LP Steam

Unit	User (LP Steam)	Pressure	Temp In	Temp Out	Normal	Intermittent	
	Per Train	bara	٥C	۰C	kg/hr	kg/hr	
Power	Steam Turbine	2.4	130		-	2,000	Note 1
Carbon Capture	Utility Station	2.4	130		-	332	1
Carbon Capture	CO <sub>2</sub> Stripper Reboilers - Steam Heating	2.4	138.7	126.1	278,611	-	
Carbon Capture	Steam Sparger Condensate Pot - Steam Heating	2.4	130		33	-	
Carbon Capture	LP Steam (From MP Condensate =15.66 %)	2.4	138.7	126.1	- 2,103	-	Note 2
	Total						]

#### NOTES:

- 1. Steam supply for start-up, shutdown, and standby.
- 2. Steam flashed from MP Condensate in piping special flash pot within Carbon Capture Unit Flash fed to LP Steam Header for cunsumption in Carbon Capture Unit Flash steam deducted from LP Steam demand from Power Generation Plant

#### Condensate

Unit	User (Condensate Balance)	Q (norm)	Pressure	Temp In	Temp Out	Normal	
	Per Train	kW	bara	٥C	٥C	kg/hr	
Produced							
Carbon Capture	LP Condensate		2.4	138.7	126.1	276,541	
Carbon Capture	MP Condensate		21.06	235 / 215	215	13,429	
LP Condensate							
Users							
Carbon Capture	LP Steam (From MP Condensate =15.66 %)		2.4	215	138.9	2,103	Note
Carbon Capture	Thermal Reclaimer No.1 Pre-Heater	226	6	130.2	49.8	3,534	
Carbon Capture	IX Demin Water Heater	52	6	130.2	49.8	430	
Carbon Capture	Condensate Cooler	26714	8.5	130.2	49.8	283,903	

26620.36

#### NOTES:

<sup>1.</sup> Steam flashed from MP Condensate in piping special flash pot within Carbon Capture Unit Flash fed to LP Steam Header for cunsumption in Carbon Capture Unit



## Attachment 6.1.2 – Brochure Efficiency Reboiler Case 2.4 GJ/tonne CO<sub>2</sub> case

#### LP Steam

Unit	User (LP Steam)	Pressure	Temp In	Temp Out	Normal	Intermittent	
	Per Train	bara	۰C	۰C	kg/hr	kg/hr	1
Power	Steam Turbine	2.4	130		-	2,000	Note 1
Carbon Capture	Utility Station	2.4	130		-	332	
Carbon Capture	CO <sub>2</sub> Stripper Reboilers - Steam Heating	2.4	138.7	126.1	247,607	-	
Carbon Capture	Steam Sparger Condensate Pot - Steam Heating	2.4	130		33	-	
Carbon Capture	LP Steam (From MP Condensate =15.66 %)	2.4	138.7	126.1	- 2,103	-	Note 2
				Total	245,537	2,332	]

#### NOTES:

- 1. Steam supply for start-up, shutdown, and standby.
- 2. Steam flashed from MP Condensate in piping special flash pot within Carbon Capture Unit Flash fed to LP Steam Header for cunsumption in Carbon Capture Unit Flash steam deducted from LP Steam demand from Power Generation Plant

#### Condensate

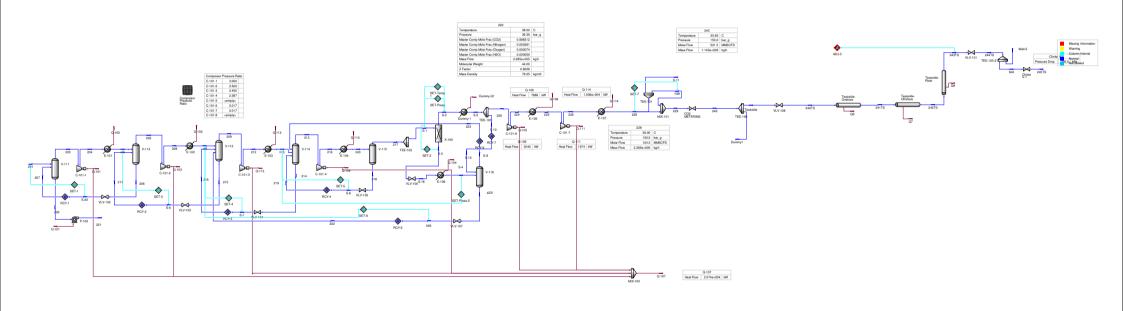
Unit	User (Condensate Balance)	Q (norm)	Pressure	Temp In	Temp Out	Normal	
	Per Train	kW	bara	٥C	٥C	kg/hr	
Produced							
Carbon Capture	LP Condensate		2.4	138.7	126.1	245,537	
Carbon Capture	MP Condensate		21.06	235 / 215	215	13,429	
LP Condensate							
Users							
Carbon Capture	LP Steam (From MP Condensate =15.66 %)		2.4	215	138.9	2,103	Note '
Carbon Capture	Thermal Reclaimer No.1 Pre-Heater	226	6	130.7	50.4	3,534	
Carbon Capture	IX Demin Water Heater	52	6	130.7	50.4	430	
Carbon Capture	Condensate Cooler	23797	8.5	130.7	50.4	252,899	

#### NOTES:

<sup>1.</sup> Steam flashed from MP Condensate in piping special flash pot within Carbon Capture Unit Flash fed to LP Steam Header for cunsumption in Carbon Capture Unit



## Attachment 6.2 - HYSYS Model for CO<sub>2</sub> Compression





## <u>Attachment 6.3 – Letter Providing Permission to</u> <u>Share with ETI Legacy Vehicles</u>



#### **SNC-LAVALIN UK LIMITED**

Knollys House, 17 Addiscombe Road Croydon, Surrey CR0 6SR 

181869-0001-SLI-C-LET-ETI-0015

10<sup>th</sup> November 2017

Energy Technologies Institute LLP Holywell Building Holywell Way Loughborough Leicester LE11 3UZ

Attn: Mr A Green, Programme Manager CCS

Dear Andrew

SNC-Lavalin grant permission to The ETI to share the Technical Note - Design Optimisations to the GBC, document reference 181869-0001-T-EM-TNT-AAA-00-01008, as Confidential Information (under terms of confidentiality no less onerous than the current Clause 10 of the Agreement for the Thermal Power with CCS Project - Generic Business Case) with the following organisations:

- Energy Systems Catapult.
- OGCI Climate Investments LLP, with whom the ETI currently has an agreement to transfer the Clean Gas Project.

Yours sincerely,

Matt Wills BEng (Hons), CEng, MIMechE **Head of Mechanical Engineering** 

**SNC-Lavalin UK Limited**