Connah's Quay Low Carbon Power Station

Environmental Permit Application, Volume 3 Appendix C3: Assessment of Best Available Techniques for Energy Efficiency

Natural Resource Wales Reference: WPCC15718
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Glossary

Abbreviation	Term
ADMS	Atmospheric Dispersion Modelling System
AEELs	Associated Energy Efficiency Levels
AELs	Associated Emission Levels
AEP	Annual Exceedance Probability
AGI	Above-Ground Installation
AMP	Accident Management Plan
AN	Absolute Non-hazardous
AoD	Above Ordnance Datum
AQAL	Air Quality Assessment Levels
ASME PTC	American Society of Mechanical Engineers Performance Test Codes
BAT	Best Available Techniques
BAT AEL	Best Available Technique-Associated Emission Level
BAT-AEEL	Best Available Technique Associated Energy Efficiency Level
BATc	Best Available Technique Conclusions
bgl	Below Ground Level
BGS	British Geological Survey
BRef	Best Available Techniques Reference Document
BS ISO	British Standards (BS) Versions of International Organization for Standardization (ISO) Standards
BS EN	British Standard (BS) Implementations of European Standards (EN)
CBM	Condition-Based Maintenance
CCGT	Combined Cycle Gas Turbine
CCP	Carbon Capture Plant
CCS	Carbon Capture Storage
CEMP	Construction Environmental Management Plan
CEMs	Continuous Emissions Monitors
CHP	Combined Heat and Power
C&IEA	Construction and Indicative Enhancement Area
CM	Corrective Maintenance
COO	Chief Operating Officer
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CoPC	Contaminants of Potential Concern
CQPS	Connah's Quay Power Station
CSM	Conceptual Site Model
DAHS	Data Acquisition and Handling System
DCC	Direct Contact Cooling
DCO	Development Consent Order

Abbreviation	Term
DCS	Distributed Control System
DLN	Dry Low-Nox
DPA	Dispatchable Power Agreement
ECP	Environmentally Critical Plant
ELV	Emission Limit Value
EMS	Environmental Management System
ENI	Operator of the CO_2 transport and storage network.
EPR	Environmental Permitting Regulations
EQS	Environmental Quality Standards
ES	Environmental Statement
ESOS	Energy Savings Opportunity Scheme
FCC	Flintshire County Council
FEED	Front-End Engineering Design
FEH	Flood Estimation Hnadbook
g	Gram
GC	Gas Chromatograph
GIS	Geographic Information System
GMIs	Generation Management Instructions
GT	Gas Turbine
GTP	Gas Treatment Plant
GW	Gigawatt
ha	hectare
HP	High Pressure
HRSGs	Heat Recovery Steam Generators
HSSE	Health, Safety, Security, Environment
HVO	Hydrotreated Vegetable Oil
IED	Industrial Emissions Directive
IP	Intermediate Pressure
ISO	International Organization for Standardization
Keq	Kiliequivalent
kg	Kilogram
km	Kilometre
kV	Kilovolt
kW	Kilowatt
LCP	Large Combustion Plant
LEL	Lower Explosive Limits
LHV	Lower Heating Value
LNB	Low NOx Burners
LoW	List of Waste
LP	Low Pressure
LWS	Local Wildlife Sites

Abbreviation	Term
m	Meters
m^3	Cubic Meter
MCERTs	Monitoring Certification Scheme
MCP	Medium Combustion Plant
MH	Mirror Hazardous
MSDS	Material Safety Data Sheet
MSUL	Minimum Start-Up Load
MW	Megawatt
MWe	Megawatt Electrical
MWth	Megawatt Thermal
N_2	Nitrogen
NGET	National Grid Electricity Transmission Plc
NH_3	Ammonia
Nm^3	Normal Cubic Meter
NOx	Oxides of Nitrogen
NRW	Natural Resources Wales
NTS	National Transmission System
NVZ	Nitrate Vulnerability Zones
O_2	Oxygen
OEM	Original Equipment Manufacturer
OTNOC	Other Than Normal Operating Conditions
PAH	Polycyclic Aromatic Hydrocarbons
PC	Process Contributions
PCB	Polychlorinated Biphenyls
PCC	Post-combustion Carbon Capture
PdM	Predictive Maintenance
PFA	Paraformaldehyde
PEIR	Preliminary Environmental Information Report
PM	Preventive Maintenance
RAMS	Risk Assessment and Method Statement
SAC	Special Area of Conservation
SAP	Systems, Applications, Products
SCR	Selective Catalytic Reduction
SECR	Streamlined Energy and Carbon Reporting
SOx	Sulphur Oxides
SPA	Special Protection Area
SPZ	Source Protection Zone
SSSI	Site of Special Scientific Interest
ST	Steam turbine
SuDS	Sustainable Drainage Systems
SVOC	Semi-Volatile Organic Compounds

Abbreviation	Term
TBC	To Be Confirmed
Te/Yr	Temperature Element per Year
T&S	Transport and Storage
TPH	Total Petroleum Hydrocarbons
UK	United Kingdom
VOC	Volatile Organic Compounds
WEEE	Waste Electrical and Electronic Equipment
WFD	Water Framework Directive
WWTP	Waste Water Treatment Plant

1. Energy Efficiency BAT

1.1 Introduction

This report has been prepared by AECOM Limited ('AECOM') on behalf of Uniper UK Limited referred to as "the Operator", in support of a new bespoke Environmental Permit application for the proposed Connah's Quay Combined Cycle Gas Turbine (CCGT) with Carbon Capture Plant (CCP) project ("Proposed Installation").

The purpose of this report is to demonstrate that the Proposed Installation will be designed and operated in accordance with indicative best available techniques (BAT) for energy efficiency.

1.2 Proposed Installation

The design of the Proposed Installation is subject to ongoing technical studies, to provide flexibility and to align with the current grid connection, but it is expected to comprise the development of up to two CCGT units achieving a net electrical output capacity of up to 1,380 megawatts (MW; referred to as MWe for electrical output) (with CCP operational) onto the national electricity transmission network.

The Proposed Installation will generate electricity from combustion of natural gas within a CCGT. Hot exhaust gas from the combustion process will be used to drive the gas turbine (GT), and steam which will be generated from the heat of the exhaust gas, in the heat recovery steam generator (HRSG), will be used to drive the steam turbine (ST). The exhaust gas will then pass through pre-treatment stages, including selective catalytic reduction (SCR) using ammonia (NH_3) to reduce oxides of nitrogen (NOx) in the gas and subsequently cooled via a direct contact cooler (DCC), in the CCP. The CCP will use an amine-based solvent to absorb carbon dioxide (CO_2) from the exhaust gas within a packed column (absorber), via a weak acid-base reaction. The CO_2-depleted exhaust gas then passes through water and acid wash sections and is released to atmosphere via an absorber stack. Continuous Emissions Monitoring System (CEMs) equipment will be located within the stack to monitor pollutants to air.

The CO_2-rich solvent exits the absorber, and passes through a lean/rich heat exchanger, and then into the desorber. The CO_2 is liberated from the solvent by heat, supplied by low pressure steam from the HRSG in normal operation. This steam is supplied to the desorber reboiler. The now lean/rich solvent will be recirculated within the plant. The CO_2 rich vapour exits the top of the Desorber, and passes through a reflux stage to maximise solvent-CO_2 separation. The CO_2 vapour is conditioned to reduce water and oxygen to the transport and storage network's specifications after entering a low pressure compressor to compress the gas to the export pipeline pressure (8-43 Bara). The CO_2 is then metered and exported to the transport and storage network's CO_2 pipeline which is operated by ENI. The solvent will accumulate impurities over time, and these will be removed via a solvent reclaiming process which will be a thermal process, either continuously via a slipstream or as a batch process.

The CCP emissions will be residual pollutants from the combustion and treatment processes, including NOx, ammonia (NH_3) and carbon monoxide (CO). The CCP will be designed to capture a minimum of 95% of the CO_2 emissions from the CCP as an annual average of all normal operating conditions. There may also be trace pollutants within the flue gas, including trace levels of solvent and solvent break-down products from within the process. Emissions will be minimised using the water and acid wash steps on the absorber and monitored at the emission point within the abated flue gas stack prior to release. In addition to the CCP emission point, there will be an intermittent-use emission point from the stack, serving the HRSG exhaust. Emissions from the CCP emissions stack, and HRSG stack will meet the emission limits for LCP under the Industrial Emissions Directive (IED).

Other supporting infrastructure and plant to the Proposed Installation will include the storage of solvent, caustic soda, sulphuric acid and water-treatment chemicals, demineralisation water treatment plant to produce high-purity water for use in boilers, blending, closed loop cooling and other processes. It will include an electric auxiliary boiler for start-up and dispatchability support, emergency diesel generators for safe-shutdown during a power failure scenario, closed surface water drainage and appropriate treatment facilities, and infrastructure for natural gas import and conditioning and CO_2 conditioning and export. The number and thermal rating of the emergency generator (s) will be determined during detailed design and will be classed as medium combustion plant (MCP).

The Proposed Installation will also be supported by natural gas supply, existing potable water supply, existing water abstraction and discharge, electrical connections, utilities, access works and CO_2 export connection. The water abstraction for the Proposed Installation's cooling system will be in line with the extraction at the existing Connah's Quay Power Station and is not expected to exceed the current abstraction permit requirements. Process water and/or waste water from the site will also be discharged to the existing sites lagoon before being purged into the River Dee.

The Proposed Installation will make use of CO_2 transport and storage networks owned and operated by Liverpool Bay CCS Limited, currently under development as part of the HyNet Carbon Dioxide Pipeline Project (referred to as the 'HyNet CO_2 Pipeline Project'), which will transport CO_2 captured from existing and new industries in North Wales and North-West England, as well as from new hydrogen production facilities that are proposed as part of HyNet North West Project. The captured CO_2 will be stored in depleted offshore gas reservoirs in Liverpool Bay.

A high-level process flow diagram for the Proposed Installation is provided in Volume IV of the permit application.

The Proposed Installation will be designed to optimise the capture of CO_2 when operating in dispatchable mode, while minimising emissions and waste generation and maximising energy efficiency. BAT assessments have been prepared to demonstrate the Proposed Installation will be designed and operated in accordance with BAT for Large Combustion Plant (LCP), Energy Efficiency (EE), Post-Combustion Carbon Capture (PCC) plant design and Cooling.

1.3 BAT Considerations

This BAT assessment has been prepared using concept engineering information provided by the operator related to the initial design parameters of the Proposed Installation, available information about the local environment and the BAT conclusions for Energy Efficiency[1].

The main application document ('Supporting Statement') (Document reference: WPCC15718-APP-SS) provides an overall view of the permit application being made for the Proposed Installation. Separate BAT assessments have been prepared for the LCP CCGT technology and operation, Post-Combustion Carbon Capture plant, Energy Efficiency and for Cooling of the installation.

This document should be read in conjunction with the Supporting Statement (Document reference: WPCC15718-APP-SS). A detailed description of the operations at the Proposed Installation and how it will be operated is provided in Section 4 of the Supporting Statement and has not been included here to avoid repetition.

This document only covers the assessment of the energy efficiency consideration against the BAT techniques identified in the Energy Efficiency BReF document[1]. For assessment of BAT for carbon capture, LCP and cooling please refer to the separate assessments:

- BAT Assessment for Large Combustion Plant (Appendix C1; Document Reference WPCC15718-APP-BAT1-LCP).
- BAT Assessment for Post Combustion Carbon Capture (Appendix C2; Document Reference WPCC15718-APP-BAT2-CCS).
- BAT Assessment for Cooling (Appendix C4; Document Reference: WPC15718-APP-BAT4-COOL).

[1] Ref 1. European Commission, September 2009, Reference Document on Best Available Techniques for Energy Efficiency.

2. Approach to BAT Appraisal

Article 3 (10) of the Industrial Emissions Directive (IED)[2] defines BAT as "the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where not practicable, generally reduce emission and impact on the environment as a whole".

The Directive continues to provide further definition as follows:

- "available techniques" are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the cost and advantages, whether or not the techniques are used or produced inside the United Kingdom, as long as they are reasonably accessible to the Operator.
- "best techniques" are the most effective in achieving a high general level of protection of the environment as a whole.
- "techniques" are both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

BAT may be demonstrated by either:

- Compliance with the sector-level, indicative BAT performance such as Sector Guidance Notes provided by the Environment Agency or in the European Commission 'Reference Documents on BAT' (BRefs) and their associated BAT conclusions; or
- By conducting an installation-specific, options appraisal of candidate techniques.

The indicative BAT provided in the European BRef/BAT Conclusion documents is based on an analysis of the costs and typical benefits for typical, or representative, plants within that sector. When assessing the applicability of the sectoral, indicative BAT standards at the installation level, departures may be justified on the grounds of the technical characteristics of the installation concerned, its geographical location and the local environment.

2.1 Site Specific Consideration of BAT

At this early stage of development from concept to full scale operational plants, and in recognition of the novel technology associated with the CCP, there is a need to apply a 'technology-neutral' approach within the derivation of BAT. This is driven by the combined requirements:

- of the Technology Licensors requiring commercial confidentiality of their process and solvent blend to be maintained;
- to allow the Front-End Engineering Design (FEED) process to progress post consent without limiting options for later technology selections; and
- to determining indicative BAT and BAT Achievable Emission Levels (BAT-AELs) for the plant within this development stage such that they are consentable, taking into account environmental sensitivities and conditions at a particular site, with site-specific BAT assessments for choice of solvent and technology to be undertaken at the detailed design stage..

At the time of writing, there are currently two competitive FEED designs under consideration by the Applicant. Therefore, we have approached the appraisal of BAT by considering:

- the information available from each Technology Licensor with respect to its proposed capture process;
- a technology neutral approach where technology specific information is not yet developed; and

[2] European Parliament and Council of European Union, November 2010, Directive 2010/75/EU on Industrial Emissions (Integrated Pollution Prevention Control)

- assessment of a worst-case emissions profile for each Technology Licensor.

The design of the Proposed Installation will continue to be refined until the completion of the detailed design stage. A number of the design aspects and features of the Proposed Installation cannot be confirmed until the Principal Contractor(s) have been appointed. Wherever an element of flexibility is maintained, a worst-case scenario has been considered

Uniper will confirm the final technology selected as part of Permit pre-operational conditions.

The approach to BAT has been agreed with Natural Resource Wales (NRW) during the pre-application discussions.

3. Energy Efficiency Demonstration for the Installation

3.1 Design Basis for Energy Efficiency

The overall performance of the CCGT and CCP for optimised energy efficiency is dependent on the integration, as far as practicable, of electrical, steam, steam condensate and water circuits. The CCP and Low-Pressure Compression Plant have a parasitic load on the CCGT plant and therefore optimised integration of utilities for energy efficiency is paramount to maximising generational output.

The anticipated electrical efficiency of the proposed CCGT plant will be circa 52% (LHV) after carbon capture ('CO_2-Abated mode'), or 61 - 64% for the CCGT operating without carbon capture ('CO_2-Unabated mode'), which is compliant with the required BAT-Associated Energy Efficiency Level (BAT-AEEL) range of 57-60.5% for CCGTs having a thermal input of >600MWth.

Thermal modelling has been undertaken at pre-FEED stage to identify the key plant areas for energy performance management which will be developed further during FEED. The modelling considered:

- Optimum location for steam take-off for solvent regeneration;
- Optimised design of the HRSG to provide the steam input for the most efficient operation of the Proposed Installation;
- Steam supply to CCP from the ST will be optimized during detailed design phase;
- Optimised recovery or re-use of low-heat streams, including reuse of waste heat from compression and condensate. The reuse of waste heat from compression is considered to be impractical. However, condensate from the CCP is being integrated in the process.

The CCP will be a proprietary unit, and is therefore expected to be optimised by the Technology Licensor for the specific solvent characteristics.

Detailed thermal modelling including reheating of the stack gases to include adequate dispersion, and optimisation of the system for energy performance will be refined once the GT Technology and CCP Licensor selection has been made but may include consideration of:

- Insulation of capture plant regeneration loop to reduce heat loss during shutdown; and
- Heat recovery from condensate return stream.

3.2 Steam System

Based on the current concept design, the HRSG is a triple pressure, cold reheat configuration with high pressure (HP), intermediate pressure (IP) and low pressure (LP) steam conditions.

LP condensate from the ST condenser and CCP reboiler is used in a de-aerator to supply IP and LP pumps with feedwater which feed the IP and LP economiser sections. There are slight differences in approach whereby:

- Technology Licensor 1: collects the LP condensate from the ST turbine and the return condensate from the CCP in the steam condenser where deaeration takes place in the condenser by vacuum. The condensate extraction pumps feed the LP steam drum and the feedwater pumps. The feedwater pumps supply the condensate to the IP and HP steam drum.
- Technology Licensor 2; collects the LP condensate from the ST turbine in the steam condenser and deaeration takes place in a separate deaerator by vacuum. The return condensate from the CCP is mixed into the condensate pumps discharge and then fed to the LP drum. The feedwater pumps supply the condensate from the LP drum to the IP and HP steam drum.

HP steam is produced in the HP superheater section at 143 bara / 586°C and expanded in the HP section of the ST. IP steam is produced in the IP superheater section at 29.7 bar/585°C and expanded in the IP section of the ST. An Intermediate Pressure Cold Reheat steam line is extracted from the inlet to the IP section of the ST at 34.3 bar / 372.3°C and used to cool the turbine cooling air (TCA) in the

TCA Cooler. The exhaust steam after expansion shall be mixed with LP superheated steam and sent to the reboiler of the CO_2 stripper column of the CCP.

Indicative quality values for the steam raised in the HRSG of the condensing steam turbine cycle with reheat are shown in Table 1.

Table 1. Indicative Steam Cycle Pressure and Temperature Data

Steam Pressure Level	Pressure (bara)	Temperature (^{O}C)
High Pressure (HP) Steam	143	586
Intermediate Pressure (IP) Steam	30	585
Low Pressure (LP) Steam	4.5	290

It is possible that the selected HRSG vendor may propose an increasingly common arrangement of a once-through HP circuit instead of a steam drum to promote faster CCGT start-up times.

3.3 Steam Supply to Capture Plant

Steam off-take from the HRSG will provide heat to the Capture unit for:

- the regeneration of solvent (desorber-reboiler, extraction of CO_2); and
- solvent conditioning (Reclaimer, removal of heat-stable salts).

The desorber-reboiler, which represents the main steam demand for the CCP, does not require a high-pressure steam as it operates at around 125°C to avoid thermal degradation of the solvent, and therefore LP steam may be used. The enthalpy of LP steam is lower so will be used in preference for optimum energy efficiency. The LP steam is extracted from the IP/LP cross-over of the steam turbine, and is de-superheated, using boiler feed water, to saturation. At start-up, LP steam will be provided to the CCP reboiler from the auxiliary boiler until hot reheat steam, with de-superheating, from HRSG will be made available for early steam extraction to the CCP reboiler. Upon LP steam production reaching stable generation, there will be a smooth change over to LP steam exporting to CCP reboiler. This process will allow for faster warm-up and start-up of the CCP.

Reclaiming of solvent shall be carried out with a thermal reclaimer running either semi-continuously or in batch operation. A slipstream of the hot lean solvent from the desorber bottoms will be reclaimed in the thermal reclaimer. Reclaimer waste will be stored and removed in batches for processing off-site. Semi-continuous operation is defined as continuous processing of solvent with batch removal of sludge.

Of the processed slipstream, 99.7% is expected to be returned to circulation, heated with IP steam and the vapour driven by a vacuum package.

3.4 Start-up

CCGT start-up will be affected by the period of the shutdown and will be limited by the temperature of the equipment within the steam circuit, in particular the HRSG steam drums and steam turbine. This means there are three restart categories:

Table 2. Plant Start-up Definitions

Type of Start	Shutdown Duration	Typical Scenario
Hot Start	<8 Hours	Weekday start
Warm Start	8 – 72 Hours	Restart after weekend shutdown
Cold Start	>72 Hours	Start from ambient after overhaul

The Proposed Installation is expected to operate in dispatchable (flexible) mode, following commissioning, in which the typical annual operating profile is circa 6000 hours per year, and in the region of 130 starts per year

At start-up, steam supply to the CCP is expected to be available around 20 minutes after power plant start-up for hot starts and otherwise at a later time, depending on the start-up mode (cold / warm / hot). During the period when LP steam is not available for solvent regeneration, heat must be provided from elsewhere. Several options may be available to overcome this issue including:

- Bleeding HP steam from the cold reheat, with de-superheating, during start-up and switching to LP steam once in stable generation;
- Using an auxiliary boiler to provide superheated steam to the ST seals and sufficient LP steam to the CCP CO2 stripper;
- Maintaining a large solvent inventory, with storage for spent solvent to be regenerated in batch during operation (covered in the Carbon capture BAT document [Ref: WPCC15718/APP/BAT2/PCC); and
- Installing additional lagging and insulation within the steam and solvent system to retain the heat in the system for a longer period.

The current design includes an electric auxiliary boiler to provide 10 barg superheated steam to the steam turbine seals and also supplies sufficient LP steam to the CCP CO_2 Stripper to achieve plant warm-up. This is a key feature of design for dispatchable operation under the Dispatchable Power Agreement(DPA).

The potential opportunities for minimising efficiency losses during frequent start-ups, with maximum CO_2 capture, will be considered further during detailed design, and reviewed and optimised once operation is established.

3.5 CCGT Specifics

The activities required and time to start-up of the GT generator, following a plant shutdown or trip, are limited by the temperature of the equipment within the steam circuit, in particular the HRSG steam drums and ST. The restart of the GT generator has been classified into three categories depending on the period of shutdown and the temperature of the steam cycle components. A summary of the restart categories is provided below, and these will be finalised during FEED:

Table 3. Indicative CCGT Restart Categories

Start Type	Time Since Shutdown	Steam Drum/Steam Turbine Temperature (^{O}C)	Time to ST Full Load
Hot Start	< 8 hours	>450	65 minutes
Warm Start	Between 8 – 72 hours	Between 160 - 450	110 minutes
Cold Start	>72 hours	<160	200 minutes

The details provided above are indicative of H-class CCGT option and final numbers will be confirmed by each Technology Licensor during FEED. Each Technology Licensor shall specify the control system and start-up logic, such that the duration of unabated operation following start-up of the GT generator is minimised to optimise efficiency.

3.6 Carbon Capture Plant Specifics

Initial engineering studies indicate that the CCP imposes approximately 10-12% penalty on the electrical efficiency of the CCGT, against a published value of 11% net electrical efficiency penalty (NETL, 2019).

The penalty is incurred through a combination of direct electrical loads and indirect heat (as steam extracted from the steam cycle, equivalent to circa 10% of total heat).

The total internal electricity auxiliary (parasitic) load of the proposed installation is estimated to be 100 - 150 MWe per hour for two trains (excluding power loss due to CCP steam demand). The broad split of power consumption on site is:

- Power Plant is circa 10.6 – 15.84 MWe.
- CCP is circa 46 – 68.98 MWe.
- Compression Plant is circa 17.7 – 26.58 MWe.
- Cooling Plant is circa 24.3 – 36.45 MWe.
- Balance of Plant is circa 1.4 – 2.15 MWe.

It is considered that the use of electricity and steam generated by the CCGT plant to power the CCP instead of a separate power plant (such as an auxiliary boiler during normal operations) is the most energy efficient for the installation. This avoids the associated energy loss from generation of power in a separate combustion unit, whilst also making use of LP steam produced in the CCGT unit, to produce maximum output from the installation. This is therefore considered to represent BAT for the installation.

The CO_2 compressors will be specified to provide flexible operation in line with the longer-term objective of dispatchable operation of the plant, rather than the highest efficiency at baseload operation.

Carbon capture unit heat integration – All capture units under consideration include application of a high level of heat integration between process hot and cold streams. Each unit achieves this heat integration in different ways that are unique and proprietary to their technology and capture solvent. Selected technology will be expected to include heat exchangers that recover heat from the lean amine solution from the desorber and use it to pre-heat the rich amine from the absorber to minimise steam and cooling water requirements.

3.7 Maintenance Philosophy

The Operator will minimise the number of planned shutdowns as far as is practicable by harmonising and scheduling the maintenance of major equipment within the Installation, and by implementing an appropriate design, maintenance philosophy and spares strategy. Maintenance routines will follow a cycle as outages are required after a set number of GT operating hours or start-ups (whichever comes earliest).

All equipment for use in the Proposed Installation will be selected to maximise energy efficiency in the proposed duties, whilst considering the reliability, part load efficiency and other operating parameters.

Elements of the plant's design that help achieve high energy efficiency include the following:

- Modern design following current best practices in optimising efficiency;
- High GT combustion temperatures;
- The use of triple pressure HRSGs;
- The use of wet or hybrid cooling instead of air cooling or direct once through cooling;
- High efficiency motors and drives to reduce parasitic loads;
- The use of plant components sized appropriately for the design capacity of the plant, so that each element is operating optimally and efficiently;
- Where needed variable speed drives (VSDs) will be included on all sizeable motors (such as boiler feed pumps and cooling water pumps) to optimise process control;
- The effective insulation of hot surfaces; and
- The plant is designed to be CHP ready, to enable the potential for future use of heat from the plant and thus increase efficiency further.

The plant will also be subject to regular planned maintenance in order to optimise the efficiency of the equipment on site, including (but not limited to):

- Continuous and intermittent water quality maintenance activities, such as blowdown of the steam drum and injection of chemicals, to maintain the cycle water quality and optimum working medium;
- GT washing;
- HRSG chemical cleaning and passivation;
- Optimised lubrication schedules in accordance with OEM specifications;
- Performance monitoring for motors, pumps, blowers and compressors;
- GT combustion inspection;
- ST minor inspection;
- GT hot gas path inspection;
- GT major inspection/overhaul; and
- ST overhaul.

4. Energy Efficiency BAT Conclusions for the Proposed Installation

Table 4. BAT Conclusions for Achieving Energy Efficiency at an Installation Level

BAT Ref	BAT Description	Demonstration of BAT – Operator Response	Operating to BAT
BAT 1	**Energy Efficiency Management** BAT is to implement and adhere to an energy efficiency management system (ENEMS) that incorporates, as appropriate to the local circumstances, all of the following features (see Section 2.1. The letters (a), (b), etc. below, correspond those in Section 2.1):		
	a) commitment of top management (commitment of the top management is regarded as a precondition for the successful application of energy efficiency management)	Uniper UK has a well-established Environmental Management System (EMS), accredited to ISO 14001:2015. The Proposed Installation will be incorporated into the existing ISO 14001:2015 framework. Further detail of the EMS is provided in Section 3 of the Supporting Statement (Document reference: WP0015178/APP/SS). The Uniper Health, Safety, Security, Environment (HSSE) & Sustainability Policy Statement (September 2023) has been signed by the management board. Existing procedures, including Generation Management Instructions (GMIs), define embedded roles and responsibilities, which, where appropriate, include senior management, such as plant managers. Leadership teams are generally available during EMS audits and surveillance checks.	Yes
	b) definition of an energy efficiency policy for the installation by top management	Energy efficiency will be incorporated into the site environmental policy which forms part of the Proposed Installation management system.	Yes
	c) planning and establishing objectives and targets (see BAT 2, 3 and 8)	The existing Uniper UK EMS documentation includes procedure Generation Management Instruction (GMI)-MAN017 – Objectives and Targets ensure Objectives, Targets and KPIs. This ensures that SMART objectives and targets, are established, communicated, implemented, maintained and documented to demonstrate continual improvement. These objectives are systematically monitored, tracked, and reviewed using structured online systems.	Yes
	d) implementation and operation of procedures paying particular attention to: i. structure and responsibility ii. training, awareness and competence (see BAT 13) iii. communication iv. employee involvement v. documentation vi. effective control of processes (see BAT 14) vii. maintenance (see BAT 15) viii. emergency preparedness and response ix. safeguarding compliance with energy efficiency-related legislation and agreements (where such agreements exist).	• The Uniper organisational chart is maintained within the Uniper Management Framework. As a functional organisation, Uniper UK reports to its head office in Düsseldorf, Germany, with generating assets managed under Energy Assets within the COO area. • Uniper's management system is structured around a set of policies, business directives and multiple centrally managed GMIs (see response to section i), which define management instructions. Individual assets also maintain a suite of site-specific procedures or "GMI appendices" which integrate the requirements of central GMI at site level. Training awareness and competency requirements are outlined in the Uniper Competency Framework Handbook, specifying the necessary skills and the level of competence required for each role. Key areas include, but are not limited to maintenance strategy, maintenance planning and scheduling, change management, emissions monitoring, waste management, emissions trading, environmental permitting, and safety rules. Training programmes are managed locally to ensure staff training needs are met, with GMI-MAN009 detailing learning, development, and training requirements. • Central GMI procedures establish communication requirements and maintain a compliance register to track adherence to GMIs and applicable legislation. Centrally held procedures define management system activities, while site-specific procedures address location-specific aspects. Both document types specify applicable personnel along with their roles and responsibilities. • Maintenance operations are managed using SAP and controlled through a series of management procedures to ensure maintenance activities are scheduled, planned, and executed to the required standards. • Uniper GMI-MAN013 - Emergency Procedure outlines the requirements for sites to assess potential emergencies and threats and develop emergency response plans. Additionally, the Connah's Quay asset has a 24-hour emergency contract in place to provide assistance in managing environmental incidents.	Yes
	e) benchmarking: the identification and assessment of energy efficiency indicators over time (see BAT 8), and the systematic and regular comparisons with sector, national or regional benchmarks for energy efficiency, where verified data are available (see Sections 2.1(e), 2.16 and BAT 9)	The Proposed Installation will be regulated under the Environmental Permitting Regulations 2016 (as amended) ("EP Regs"), which requires the application of BAT to the operation of such a facility; this includes the requirement to undertake sectoral benchmarking as and when revised sector guidance is issued (e.g. EA BAT reference document) and to implement compliance with the sector guidance within 4 years of issue. This is implemented through the Regulation 61 notice process. The initial benchmarking will be completed during commissioning and will provide the baseline for future monitoring.	Yes
	f) checking performance and taking corrective action paying particular attention to: i. monitoring and measurement (see BAT 16) ii. corrective and preventive action iii. maintenance of records	**<u>Monitoring and measurement</u>** In alignment with existing Uniper practices, the Proposed Installation will establish a procedure for monitoring and reporting plant operations including fuel and energy consumption. Energy efficiency reviews are a core part of Uniper UK's processes and will be conducted regularly at the Proposed Installation, particularly following commissioning and outages. Operational data will be regularly reviewed and reported in accordance with current protocols.	Yes

BAT Ref	BAT Description	Demonstration of BAT – Operator Response	Operating to BAT
	• independent (where practicable) internal auditing in order to determine whether or not the energy efficiency management system conforms to planned arrangements and has been properly implemented and maintained (see BAT 4 and 5)	The installation will also adhere to permit requirements for four-yearly energy efficiency reviews and will comply with ESOS and SECR obligations. Periodic performance tests will be conducted in accordance with applicable standards to determine net electrical efficiency and other key parameters. During commissioning, a heat rate test will be performed to evaluate both gross and net electrical efficiency. **Corrective and Preventative Action** The Proposed Installation will be controlled and operated via an automated control system (such as a Distributed Control System (DCS)) to continuously monitor the operation of the plant and equipment at the site. Any non-conformance or deviation in normal operating parameters will be identified by the DCS to allow the operator to take action to avoid a breach of permitted emission levels. **Maintenance of Records** EMS documentation will establish requirements for record storage and retention periods. The current Uniper GMI MAN 005 - Management of Information sets out existing record retention requirements, which are likely to apply to the proposed installation. **Internal Audits** The EMS will be subject to periodic internal audits as part of the integrated internal audit programme. Additionally, external verifiers will conduct surveillance and certification audits to ensure compliance.	
	g) review of the ENEMS and its continuing suitability, adequacy and effectiveness by top management	It is anticipated that the review of the energy efficiency measures and their suitability, adequacy and effectiveness by top management will form part of the Proposed Installation management system. The plant operational data produced by the automated control system will support top management in reviewing and optimising plant processes and maintenance procedures.	Yes
	h) preparation and publication (and possibly external validation) of a regular energy efficiency statement describing all the significant environmental aspects of the installation, allowing for year-by-year comparison against environmental objectives and targets as well as with sector benchmarks as appropriate	The Operator will monitor and report on performance in accordance with the Environmental Permit requirements. The Operator will comply with Energy Savings Opportunity Scheme (ESOS) and Streamlined Energy and Carbon Reporting (SECR) obligations.	Yes
	i) having the management system and audit procedure examined and validated by an accredited certification body or an external ENEMS verifier	The EMS will be subject to an external ISO 14001 audit from an independent certified auditing company alongside Uniper UK's other accredited sites. The installation will also be subject to internal audits in accordance with risk and the Company Internal Audit Plan.	Yes
	j) when designing a new unit, taking into account the environmental impact from the eventual decommissioning of the unit	The Proposed Installation will be regulated under the EP Regs, which requires sites to have a decommissioning plan in place to manage such considerations. The initial outline structure of the plan is presented in Section 8 of the Supporting Statement (Document reference: WPCC15718/APP/SS) will be developed prior to commencement of operations and will be subject to regular reviews to ensure that correct site operations are reflected in the plan. The design of the Proposed Installation will consider appropriate measures to minimise the impact of future decommissioning. Where possible existing infrastructure will be used, e.g. common abstraction and discharge points with existing station.	Yes
	k) development of energy efficient technologies, and to follow developments in energy efficiency techniques	The proposed GT for each train will be a modern highly efficient GT having a combined nominal output up to 1380 MWe – abated from 2 trains. The management of energy efficiency at the installation will form part of the EMS and the risks and opportunities register will be updated periodically, to identify potential plant improvements.	Yes
BAT 2	**Planning and Establishing Objectives and Targets** **Continuous environmental Improvement** BAT is to continuously minimise the environmental impact of an installation by planning actions and investments on an integrated basis and for the short, medium and long term, considering the cost-benefits and cross-media effects.	The installation will be designed to current compliance and design standards. It will be operated in accordance with an EMS, with regular appraisal of the plant and equipment in use at the installation. The existing Uniper UK EMS documentation includes procedure GMI-MAN017 – Objectives and Targets ensure Objectives, Targets and KPIs. This ensures that SMART objectives and targets, are established, communicated, implemented, maintained and documented to demonstrate continual improvement. These objectives are systematically monitored, tracked, and reviewed using structured online systems. The plant operational data will allow the plant processes and maintenance procedures to be reviewed and optimised.	Yes

BAT Ref	BAT Description	Demonstration of BAT – Operator Response	Operating to BAT
BAT 3	**Identification of Energy Efficiency Aspects of an Installation and Opportunities for Energy Savings** BAT is to identify the aspects of an installation that influence energy efficiency by carrying out an audit. It is important that an audit is coherent with a systems approach (see BAT 7).	The installation will be designed to current compliance and design standards. It will be operated in accordance with an EMS, with regular appraisal of the plant and equipment in use at the installation. As part of the existing Uniper UK EMS documentation a site aspect and impact register is maintained. This register includes key aspects associated with energy efficiency and the associated requirements defined in relevant standards and regulations. The register will be updated periodically, to identify potential plant improvements.	Yes
BAT 4	**Identification of Energy Efficiency Aspects of an Installation and Opportunities for Energy Savings** When carrying out an audit, BAT is to ensure that the audit identifies the following aspects (see Section 2.11): a) energy use and type in the installation and its component systems and processes b) energy-using equipment, and the type and quantity of energy used in the installation c) possibilities to minimise energy use, d) possibilities to use alternative sources or use of energy that is more efficient, in particular energy surplus from other processes and/or systems, see Section 3.3 e) possibilities to apply energy surplus to other processes and/or systems, see Section 3.3 possibilities to upgrade heat quality (see Section 3.3.2)	The EMS will include procedures for regular energy efficiency auditing. Permit requirements set out 4 yearly reviews of energy efficiency and use of natural resources. The plant will be monitored on a daily/weekly/annual process and the data reviewed to identify any non-conformances with design standards and areas of improvement. ESOS/SECR regulations also require a review of energy use and audits to identify energy efficiency actions to continuously improve performance.	Yes
BAT 5	**Identification of Energy Efficiency Aspects of an Installation and Opportunities for Energy Savings** BAT is to use appropriate tools or methodologies to assist with identifying and quantifying energy optimisation, such as: • Energy models, databases and balances (see Section 2.15) • A technique such as pinch methodology (see Section 2.12) exergy or enthalpy analysis (see Section 2.13), or thermoeconomics (see Section 2.14) • Estimates and calculations (see Sections 1.5 and 2.10.2)	The preliminary design and configuration are based on calculated flow rates, cooling loads, and heat requirements, considering the combined needs of the CCGT and the CCP. Key equipment has been preliminarily selected with a focus on energy efficiency, reliability, and compliance with BAT standards. Appropriate tools (e.g., Aspen Plus, MATLAB, or CFD software) will be used at the detailed design stage to predict system performance under various operating conditions. Additionally, an Energy Management Plan (EMP) will be developed where aspects for identifying energy optimisation will be incorporated into the operations and will include aspects such as: ▪ Calculation of energy balances to monitor and evaluate energy flows across the integrated system. ▪ Integration of energy balances into the EMS, with periodic reviews to identify inefficiencies, track performance improvements, and ensure compliance with energy efficiency targets.	Yes
BAT 6	**Identification of Energy Efficiency Aspects of an Installation and Opportunities for Energy Savings** BAT is to identify opportunities to optimise energy recovery within the installation, between systems within the installation (see BAT 7) and/or with a third party (or parties), such as those described in Sections 3.2, 3.3 and 3.4.	The following opportunities for energy recovery have been considered in the design: • The HRSG will capture waste heat from the GT exhaust to generate steam for the ST. Its design will be optimised with multi-pressure steam systems (HP, IP, and LP sections) and incorporates economisers, superheaters, and reheaters to maximise heat transfer efficiency and recover as much energy as possible from the exhaust gases. • The CO_2 capture process will be optimised by using: a. Utilising LP steam extracted from the HRSG to supply the reboiler with the required thermal energy. b. Incorporating lean/rich solvent heat exchangers to recover heat from the solvent streams, reducing the overall energy demand of the reboiler. • Optimised recovery or re-use of low-heat streams, including reuse of waste heat from compression and condensate by: a. Reuse of the waste heat from the feedwater and condensate return streams will be integrated in the process. b. The required steam pressure in the CCP shall be minimised and the extraction pressure from the CCGT IP/LP crossover shall be optimised. This integration minimises the loss of power from the steam turbine, maximising power output. c. The return of the CCP reboiler steam condensate shall be used as a heat source within the CCP in order to maximise heat extraction and to avoid the need for extra cooling/condensing within the CCGT plant, returning condensate at the desired conditions for the steam cycle. • The overall system is designed to optimise integration between heating and cooling systems, including steam systems, lean/rich amine exchangers, and mechanical vapour recompression (MVR).	Yes
BAT 7	**A Systems Approach to Energy Management**	The overall system will be designed to optimise integration between heating and cooling systems, including steam systems, lean/rich amine exchangers, and MVR.	Yes

BAT Ref	BAT Description	Demonstration of BAT – Operator Response	Operating to BAT
	BAT is to optimise energy efficiency by taking a systems approach to energy management in the installation. Systems to be considered for optimising as a whole are, for example: - Process units - Heating systems – steam, hot water - Cooling and vacuum - Motor driven systems – compressed air, pumping - Lighting - Drying, separation and concentration	**<u>Heating systems</u>** See section 3 above for consideration of the CCGT, CCP and steam systems. **<u>Cooling</u>** The cooling method would be recirculating hybrid for both the CCGT and CCP. Cooling water would be abstracted from and discharged to the River Dee, in line with the current process and permitting requirements for the existing Connah's Quay Power Station. Subject to minor modification and alteration, the Proposed Installation would utilise the existing Connah's Quay Power Station cooling water abstraction and discharge infrastructure located within the River Dee, with upgrades to the existing cooling water intake equipment to meet current legislative requirements including the Eels (England and Wales) Regulations 2009 ('Eels Regulations') (Ref 4-2). **<u>Motor driven systems - Pumps</u>** Energy efficient electric motors will be used throughout the Proposed Installation and will be sized accordingly. All motors shall be IE3 or IE4 efficiency class in accordance with BS EN 60034-30-1 and Energy-Related Products and Energy Information Regulations 2021. Motors will be fitted with variable speed drives to minimise losses where practical. Pumps will be sized based on hydraulics specific to the site layout and operating parameters which ensures the pumps will not be oversized. The piping and overall layout design will be done to minimise hydraulic losses and optimal sizing of pumps. Pumps will have variable speed drives where practical to minimise losses and be optimised for energy efficiency and the pumping systems will be controlled using the Automated Control System. **<u>Lighting</u>** The lighting level will be adjustable to meet operational needs. The design of the central control room shall comply with current UK legislation, such as PUWER and DSE regulations. Utility industry recognised relevant standards and guidance shall be followed, such as from EEMUA and ISO organisations. For further details see BAT 28 response. **<u>Drying, Separation and Concentration</u>** The CO_2 will be dried prior to routing to the export pipeline and is subject to detailed design but will include automatic sequencing so that two beds are always in operation.	
BAT 8	**Establishing and Reviewing Energy Efficiency Objectives and Indicators** BAT is to establish energy efficiency indicators by carrying out all of the following: a) Identifying suitable energy efficiency indicators for the installation, and where necessary, individual processes, systems and/or units, and measure their change over time or after the implementation of energy efficiency measures (see Sections 1.3 and 1.3.4) b) Identifying and recording appropriate boundaries associated with the indicators (see Sections 1.3.5 and 1.5.1) **c)** identifying and recording factors that can cause variation in the energy efficiency of the relevant process, systems and/or units (see Sections 1.3.6 and 1.5.2).	The existing Uniper UK EMS documentation includes procedure GMI-MAN017 – Objectives and Targets ensures Objectives, Targets and KPIs. This ensures that SMART objectives and targets, are established, communicated, implemented, maintained and documented to demonstrate continual improvement. Objectives for energy efficiency will be developed by the Proposed Installation's operational team following commissioning of the plant to ensure compliance with this BAT conclusion. These objectives are systematically monitored, tracked, and reviewed using structured online systems.	Yes
BAT 9	**Benchmarking** BAT is to carry out systematic and regular comparisons with sector, national or regional benchmarks, where validated data are available.	The Proposed Installation's performance guarantees will be developed through the FEED process and benchmarked against performance information published from other developing CCS projects as well as performance data from test and commercial facilities. The Proposed Installation will be regulated under the EP Regs, which requires the application of BAT to the operation of such a facility; this includes the requirement to undertake sectoral benchmarking as and when revised sector guidance is issued (e.g. EA BAT reference document) and to implement compliance with the sector guidance within 4 years of issue. This is implemented through the Regulation 61 notice process. The initial benchmarking will be completed during commissioning and will provide the baseline for future monitoring.	Yes
BAT 10	**Energy Efficient Design (EED)** BAT is to optimise energy efficiency when planning a new installation, unit or system or a significant upgrade (see Section 2.3) by considering all of the following:	This is an integral part of design development and the BAT detailed are expected to be incorporated where appropriate as a result of Good International Industry Practice (GIIP)	Yes

BAT Ref	BAT Description	Demonstration of BAT – Operator Response	Operating to BAT
	a) The energy-efficient design (EED) should be initiated at the early stages of the conceptual design/basic design phase, even though the planned investments may not be well-defined. The EED should also be taken into account in the tendering process b) The development and/or selection of energy-efficient technologies (see Sections 2.1(k) and 2.3.1) c) Additional data collection may need to be carried out as part of the design project or separately to supplement existing data or fill gaps in knowledge d) The EED work should be carried out by an energy expert. The initial mapping of energy consumption should also address which parties in the project organisations influence the future energy consumption and should optimise the energy efficiency design of the future plant with them. For example, the staff in the (existing) installation who may be responsible for specifying design parameters.	Techniques being applied will include: • Heat recovery by maximising waste heat utilisation through a multi-pressure HRSG, economisers, and heat recovery from condensate, feedwater, and CO_2 compression. • Steam integration: by using LP steam from the HRSG for solvent regeneration and optimise ST extraction points to balance power generation and process needs. • Solvent optimisation by minimising energy demand with efficient lean/rich solvent heat exchangers and a low-regeneration-energy solvent. • Cooling efficiency by employing optimised cooling towers and closed-loop systems to reduce energy and water losses. • Process integration by integrating heat and energy flows between the CCGT and CCP, including MVR. • Using high-efficiency equipment such as advanced GTs, ST and multi-stage CO_2 compressors with intercooling to minimise energy losses. • Using an advanced control system to facilitate real-time monitoring and control systems to optimise performance and energy use dynamically. See section 3 of this document for further detail.	
BAT 11	**Increased Process Integration** BAT is to seek to optimise the use of energy between more than one process or system (see Section 2.4), within the installation or with a third party.	This is an integral part of design development and the BAT detailed are expected to be incorporated where appropriate. See section 3.1 of this document for further details.	Yes
BAT 12	**Maintaining Impetus of Energy Efficiency Initiatives** BAT is to maintain the impetus of the energy efficiency programme by using a variety of techniques, such as: a) Implementing a specific energy efficiency management system (see Section 2.1 and BAT1) b) Accounting for energy usage based on real (metered) values, which places both the obligation and credit for energy efficiency on the user/bill payer (see Sections 2.5, 2.10.3 and 2.15.2) c) The creation of financial profit centres for energy efficiency (see Section 2.5) d) Benchmarking (see Section 2.16 and BAT 9) e) A fresh look at existing management systems, such as using operational excellence (see Section 2.5) Using change management techniques (also a feature of operational excellence, see Section 2.5)	The Proposed Installation will be subject to regular preventative maintenance cycles to ensure the efficiency of plant and equipment is maintained.	Yes
BAT 13	**Maintaining Expertise** BAT is to maintain expertise in energy efficiency and energy-using systems by using techniques such as: a) Recruitment of skilled staff and/or training of staff. Training can be delivered by in-house staff, by external experts, by formal courses or by self-study/development (see Section 2.6) b) Taking staff off-line periodically to perform fixed term/specific investigations (in their original installation or in others, see Section 2.5). c) Sharing in-house resources between sites (see Section 2.5) **d)** Use of appropriately skilled consultants for fixed term investigations (e.g. see Section 2.11) Outsourcing specialist systems and/or functions (e.g. see Annex 7.12	The Proposed Installation will be operated by suitable personnel with required skills and training. Training awareness and competency requirements are outlined in the Uniper Competency Framework Handbook, specifying the necessary skills and the level of competence required for each role. Key areas include, but are not limited to maintenance strategy, maintenance planning and scheduling, change management, emissions monitoring, waste management, emissions trading, environmental permitting, and safety rules. Training programmes are managed locally to ensure staff training needs are met, with GMI-MAN009 detailing learning, development, and training requirements. The maintenance activities associated with the installation will be undertaken by appropriately licensed contractors. Contractors will be selected and managed in accordance with Uniper's Contractor Management Procedures which are embedded in the EMS.	Yes
BAT 14	**Effective Control of Processes** BAT is to ensure that the effective control of processes is implemented by techniques such as: a) Having systems in place to ensure that procedures are known, understood and complied with (see Sections 2.1(d)(vi) and 2.5) b) Ensuring that the key performance parameters are identified, optimised for energy efficiency and monitored (see Sections 2.8 and 2.10).	The Proposed Installation will be operated under an ISO14001 certified EMS, including operating procedures, to manage the various aspects of the operation of the plant. This includes but is not limited to energy efficiency, emissions monitoring, accident management, waste minimisation and management, and infrastructure maintenance. The Proposed Installation operations will be controlled via a central control room equipped with an automated control system, to continuously monitor key performance aspects.	Yes

BAT Ref	BAT Description	Demonstration of BAT – Operator Response	Operating to BAT
	Documenting or recording these parameters (see Sections 2.1(d)(vi), 2.5, 2.10 and 2.15).	The Proposed Installation's operational data will allow the plant processes and maintenance procedures to be reviewed and optimised.	
BAT 15	**Maintenance** BAT is to carry out maintenance at installations to optimise energy efficiency by applying all of the following: a) Clearly allocating responsibility for the planning and execution of maintenance b) Establishing a structured programme for maintenance based on technical descriptions of the equipment, norms, etc. as well as any equipment failures and consequences. Some maintenance activities may be best scheduled for plant shutdown periods c) Supporting the maintenance programme by appropriate record keeping systems and diagnostic testing d) Identifying from routine maintenance, breakdowns and/or abnormalities possible losses in energy efficiency, or where energy efficiency could be improved Identifying leaks, broken equipment, worn bearings, etc. that affect or control energy usage, and rectifying them at the earliest opportunity.	A structured maintenance programme will be developed by the Proposed Installation's operational team following commissioning of the Proposed Installation to ensure compliance with this BAT conclusion. The maintenance activities associated with the Proposed Installation will be undertaken by appropriately licensed contractors.	Yes
BAT 16	**Monitoring and Measurement** BAT is to establish and maintain documented procedures to monitor and measure, on a regular basis, the key characteristics of operations and activities that can have a significant impact on energy efficiency. Some suitable techniques are given in Section 2.10.	The operations at the installation will be monitored continuously to ensure optimum performance, including meeting energy efficiency objectives.	Yes
BAT 17	**Combustion** BAT is to optimise the energy efficiency of combustion by relevant techniques such as those specific to sectors given in vertical BRefs.	CCGT Technology will be selected to achieve higher levels of fuel efficiency. The choice of CCGT will be sized for the intended duty to ensure optimal loading (and hence high efficiency) of the units. Specific considerations include: • Ensuring combustion optimisation is integral to the process design. • Optimisation of the working medium conditions (i.e., pressure/temp). • Optimisation of the steam cycle. • Combustion air preheating system to be considered in the detailed design. • Natural gas preheating system to be considered in detailed design. • Using an automated control system to allow real-time monitoring and control of combustion processes. • Recovering heat from the GT flue gas for the steam turbine. • Minimising heat losses is integral to the design. See Section 5 of this document, and LCP BAT assessment for further details.	Yes
BAT 18	**Steam Systems** BAT for steam systems is to optimise the energy efficiency by using techniques such as those specific to sectors given in vertical BRefs.	The efficiency of the plant will be driven by the design of the CCGT including the HRSG. The plant will be designed to exploit optimum steam pressure and temperature settings to maximise overall efficiency. Optimisation of the steam cycle will initially take place during plant commissioning.	Yes
BAT 19	**Heat Recovery** BAT is to maintain the efficiency of heat exchangers by both: a) Monitoring the efficiency periodically Preventing or removing fouling	Opportunities for heat recovery (other than the HRSG) shall be identified and assessed during FEED as part of Value Engineering (e.g. implementation of a heat pump system in the CCP, energy savings). Plant performance will be monitored via the DCS, and data will facilitate periodic checks on efficiency. The installation will be subject to regular preventative maintenance cycles to ensure the efficiency of plant and equipment is maintained.	Yes
BAT 20	**Cogeneration** BAT is to seek possibilities for cogeneration, inside and/or outside the installation (with a third party).	The Proposed Installation has the potential to supply heat to other users although there are currently no viable export routes – this will be kept under review. Further details are in the CHP Readiness Report presented as Appendix K to the Supporting Statement.	Yes
BAT 21	**Electrical Power Supply** BAT is to increase the power factor according to the requirements of the local electricity distributor by using techniques such as those in Table 4.3, according to applicability (see Section 3.5.1):		

BAT Ref	BAT Description		Demonstration of BAT – Operator Response	Operating to BAT
	Technique	**Applicability**		
	Installing capacitors in the AC circuits to decrease the magnitude of reactive power	All cases. Low cost and long lasting, but requires skilled application	To be considered during FEED.	Yes
	Minimising the operation of idling or lightly loaded motors	All cases	Design has included energy use optimisation considerations so that idling or lighted loaded motors are minimised.	Yes
	Avoiding the operation of equipment above its rated voltage	All cases	Equipment will not be operated above its rated voltage.	Yes
	When replacing motors, using energy- efficient motors (see Section 3.6.1)	At time of replacement	N/A as this is a new plant	N/A
BAT 22	**Electrical Power Supply** BAT is to check the power supply for harmonics and apply filters if required (see Section 3.5.2).		The existing connection agreement with National Grid Company Ltd (NGC) provides an export capacity of 1380MWe and import capacity of 720MWe through a 400kV connection to a National Grid 400kV outdoor substation and a new 400kV GIS indoor substation located on the site. During FEED the network will be reviewed to identify if harmonic distortion exceeds acceptable limits and if so filters will be necessary to reduce these levels and prevent damage to equipment. If filters are required, then these will be designed to target specific harmonic orders.	Yes
BAT 23	**Electrical Power Supply** BAT is to optimise the power supply efficiency by using techniques such as those in Table 4.4, according to applicability: a) Ensure power cables have the correct dimensions for the power demand b) Keep online transformer(s) operating at a load above 40 - 50 % of the rated power c) Use high efficiency/low loss transformers d) Place equipment with a high current demand as close as possible to the power source (e.g. transformer)		Junction boxes, glands, and cabling shall comply with the requirements of the relevant British Standards and have the correct dimensions for the power demand. Equipment with a high demand will be located as close as practicable to the power source. Transformers will be operated above 40 – 50% of the operating load.	Yes
BAT 24	**Electric-motor-driven subsystems** BAT is to optimise electric motors in the following order (see Section 3.6): 1. Optimise the entire system the motor(s) is part of (e.g. cooling system, see Section 1.5.1) 2. Then optimise the motor(s) in the system according to the newly determined load requirements, by applying one or more of the techniques in Table 4.5, according to applicability.			
	Technique	**Applicability**		
	SYSTEM INSTALLATION or REFURBISHMENT			
	Using energy-efficient motors (EEM)	Lifetime cost benefit	All motors, except standard package motors (e.g., Fans, etc.) shall have IE3 efficiency level class according to BS EN 60034-30-1. All induction motors shall be IE4 efficiency class in accordance with BS EN 60034-30-1 and Energy-Related Products and Energy Information Regulations 2021. Motors will be sized according to the required duty and will be fitted with variable speed drives to minimise losses where practical.	Yes
	Proper motor sizing	Lifetime cost benefit		
	Installing variable speed drives (VSD)	Use of VSDs may be limited by security and safety requirements. According to load. Note in multi-machine systems with variable load systems (e.g. CAS) it may be optimal to use only one VSD motor	For equipment with significant load variations or requiring startup under full load conditions, motors should be equipped with VSDs. VSDs will be considered for fans, compressors, and other equipment where practical and beneficial. Use of VSD drives will be implemented where appropriate and their use will be identified at the FEED.	Yes
	Installing high-efficiency transmission/ reducers	Lifetime cost benefit	The CCGT with CCP shall comply with all mandatory requirements of the GB Grid Code as a Synchronous Generating Unit connected directly to the transmission system at 400 kV as an EU Code User.	Yes

BAT Ref	BAT Description		Demonstration of BAT – Operator Response	Operating to BAT
	Use: • direct coupling where possible • synchronous belts or cogged V-belts in place of V belts • helical gears in place of worm gears	All	Equipment will be selected with direct drives (directly coupled motors) wherever feasible to minimise energy losses associated with mechanical transmission systems. Motor speeds will be appropriately matched to the operational requirements of the equipment. The use of direct coupling, synchronous or cogged V-belts and the installation of helical gears in place of worm gears will be identified at the detailed design stage.	Yes
	Energy-efficient motor repair (EEMR) or replacement with an EEM	At time of repair	N/A New Installation	N/A
	Rewinding: avoid rewinding and replace with an EEM, or use a certified rewinding contractor (EEMR)	At time of repair	N/A New Installation	N/A
	Power quality control	Lifetime cost benefit	A power factor correction device has been incorporated in the design to allow compliance with power factor requirements from the network owner so the need for this is unlikely, but it will be reviewed and confirmed during FEED.	Yes
	SYSTEM OPERATION and MAINTENANCE			
	Lubrication, adjustments, tuning	All cases	The use of lubrication, adjustments and tuning will be incorporated into the planned preventative maintenance programme.	Yes
BAT 25	**Compressed Air** BAT is to optimise compressed air systems (CAS) using the techniques such as those in Table 4.6, according to applicability:			
	Technique			
	SYSTEM DESIGN, INSTALLATION or REPLACEMENT			
	Overall system design, including multi-pressure systems Upgrade compressor Improve cooling, drying and filtering Reduce frictional pressure losses (for example by increasing pipe diameter) Improvement of drives (high-efficiency motors) Improvement of drives (speed control) Use of sophisticated control systems Recover waste heat for use in other functions Use external cool air as intake Storage of compressed air near highly fluctuating uses		The compression technology selection will be specific to the selected Technology Licensers, but design will consider the following key parameters: • plant configuration and duties. • flexibility including the long-term impact on CAPEX and OPEX of cascade and compression strategy. • overall availability and the solutions offered by the vendor. It is expected to have a common set of air compressors from which plant air supply can be taken downstream of the first filtration step and upstream of air drying; instrument air taken downstream of air drying and conditioning to feed the instrument air distribution network and the Nitrogen generation system at the development.	Yes
	SYSTEM OPERATION and MAINTENANCE			
	Optimise certain end use devices Reduce air leaks More frequent filter replacement Optimise working pressure		The Proposed Installation will implement a planned preventative maintenance, and this will include plant optimisation, defect monitoring, reporting and investigation as appropriate.	Yes
BAT 26	**Pumping Systems** BAT is to optimise pumping systems by using the techniques in Table 4.7, according to applicability (see Section 3.8)			
	Technique			
	DESIGN			
	Avoid oversizing when selecting pumps and replace oversized pumps Match the correct choice of pump to the correct motor for the duty Design of pipework system (see Distribution system, below)		Pump selection will be optimised during FEED to ensure correct pump selection in terms of sizing, duty of motors and distribution system. The piping and overall layout design will be done to minimise hydraulic losses and optimal sizing of pumps. Pumps will have variable speed drives where practical to minimise losses and be optimised for energy efficiency.	Yes
	CONTROL and MAINTENANCE			
	Control and regulation system		Pump selection and associated control systems will be optimised during FEED including:	Yes

BAT Ref	BAT Description	Demonstration of BAT – Operator Response	Operating to BAT
	Shut down unnecessary pumps Use of variable speed drives (VSDs) Use of multiple pumps (staged cut in)	• integration of the control systems; • use of VSDs where appropriate; and • optimising planned preventative maintenance requirement	
	Regular maintenance. Where unplanned maintenance becomes excessive, check for: • cavitation • wear wrong type of pump	The Proposed Installation will implement a planned preventative maintenance, and this will include defect monitoring, reporting and investigation as appropriate	
	DISTRIBUTION SYSTEM		
	Minimise the number of valves and bends commensurate with keeping ease of operation and maintenance Avoiding using too many bends (especially tight bends) Ensuring the pipework diameter is not too small (correct pipework diameter)	Pipework routing and design will be optimised during FEED to ensure appropriate diameters are appropriate for their duty and to minimise the number of valves and bends.	Yes
BAT 27	**Heating, Ventilation and Air Conditioning (HVAC) Systems** BAT is to optimise heating, ventilation and air conditioning systems by using techniques such as: a) For ventilation, space heating and cooling, techniques in Table 4.8 according to applicability b) For heating, see Sections 3.2 and 3.3.1, and BAT 18 and 19 c) For pumping, see Section 3.8 and BAT 26 For cooling, chilling and heat exchangers, see the ICS BRef as well as Section 3.3 and BAT 19		
	Technique		
	DESIGN and CONTROL		
	Overall system design. Identify and equip areas separately for: • general ventilation • specific ventilation process ventilation Optimise the number, shape and size of intakes Use fans: • of high efficiency designed to operate at optimal rate Manage airflow, including considering dual flow ventilation Air system design: • ducts are of a sufficient size • circular ducts avoid long runs and obstacles such as bends, narrow sections Optimise electric motors, and consider installing a VSD Use automatic control systems. Integrate with centralised technical management systems Integration of air filters into air duct system and heat recovery from exhaust air (heat exchangers)	The design and control of HVAC will be identified at the detailed design stage and relevant aspects will be considered and optimised at this stage with consideration to relevant BAT requirements such as: • optimising and reducing heating and/or cooling needs across the Installation; • optimising the number, shape and size of intakes where these are needed: • optimising the overall design of any air system employed; • integration of the automated control systems; and • utilising VSD motors where appropriate.	Yes
	Reduce heating/cooling needs by: • building insulation • efficient glazing • air infiltration reduction • automatic closure of doors • destratification • lowering of temperature set point • during non-production period (programmable regulation) reduction of the set point for heating and raising it for cooling		

BAT Ref	BAT Description	Demonstration of BAT – Operator Response	Operating to BAT
	Improve the efficiency of heating systems through: • recovery or use of wasted heat (Section 3.3.1) • heat pumps radiative and local heating systems coupled with reduced temperature set points in the non-occupied areas of buildings		
	Improve the efficiency of cooling systems through the use of free cooling		
	MAINTENANCE		
	Stop or reduce ventilation where possible	A maintenance plan will be produced as a result of the detailed design stage.	Yes
	Ensure system is airtight, check joints		
	Check system is balanced		
	Manage airflow: optimise		
	Air filtering, optimise: • recycling efficiency • pressure loss • regular filter cleaning/replacement regular cleaning of system		
BAT 28	**Lighting** BAT is to optimise artificial lighting systems by using the techniques such as those in Table 4.9 according to applicability (see Section 3.10):		
	Technique		
	ANALYSIS and DESIGN OF LIGHTING REQUIREMENTS	Lighting shall be in accordance with BS EN 61347-1 "Lamp control gear – General and safety requirements", plus other parts in the standard series as required. The UK HSE has produced the guidance document "Lighting at work" HSG38, which looks at lighting design from a legal perspective in terms of suitability and adequacy to meet the requirements of workplace health and safety, and which shall be considered as a design benchmark. Lighting design will be identified at the detailed design stage.	Yes
	Identify illumination requirements in terms of both intensity and spectral content required for the intended task		
	Plan space and activities in order to optimise the use of natural light		
	Selection of fixtures and lamps according to specific requirements for the intended use		
	OPERATION, CONTROL, and MAINTENANCE		
	Use of lighting management control systems including occupancy sensors, timers, etc.	Lighting management control systems will be reviewed, and appropriate consideration given to occupancy sensors, timers and similar controls. A proportion of lighting will be specified for emergency operation with battery back-up included in line with the list of Codes and Standards	Yes
	Train building occupants to utilise lighting equipment in the most efficient manner		
BAT 29	**Drying, Separation and Concentration Processes** BAT is to optimise drying, separation and concentration processes by using techniques such as those in Table 4.10 according to applicability, and to seek opportunities to use mechanical separation in conjunction with thermal processes.	Opportunities for heat recovery (other than the HRSG) shall be identified and assessed during FEED as part of Value Engineering (e.g. implementation of a heat pump system in the CCP, energy savings).	Yes

5. Energy Efficiency BAT Conclusions for Large Combustion Plant

Table 5. BAT Conclusions for Large Combustion Plant

BAT Ref	BAT Requirement		Demonstration of BAT – Operator Response	Operating to BAT?
LCP BAT 12	In order to increase the energy efficiency of combustion, gasification and/or IGCC units operated ≥ 1,500h/yr, BAT is to use an appropriate combination of the techniques given below.			
	Technique	Description	The anticipated electrical efficiency of the CCGT plant at ISO conditions will be circa 52% LHV after CCP. Electrical efficiency will be circa 61 - 64% for CCGTs operating without CCP, which is in line with the BAT-AEEL having a thermal input of >600MWth.	
	Combustion optimisation	Optimising the combustion minimises the content of unburnt substances in the flue-gases and in solid combustion residues	Energy efficiency is a key priority for Uniper's existing assets. Combustion optimisation and advanced control systems are employed alongside online monitoring to ensure combustion processes remain efficient and fully optimised. Additionally, online monitors continuously record air emissions, ensuring compliance with permitted air emission limits. Specific control settings for the combustion units shall be pre-set in the control system to achieve efficient combustion and optimise plant efficiency.	Yes
	Optimisation of the working medium conditions	Operate at the highest possible pressure and temperature of the working medium gas or steam, within the constraints associated with, for example, the control of NOx emissions or the characteristics of energy demanded	The Proposed Installation will also adhere to permit requirements for four-yearly energy efficiency reviews and will comply with ESOS and SECR obligations. Periodic performance tests will be conducted in accordance with applicable standards to determine net electrical efficiency and other key parameters. During commissioning, a heat rate test will be performed to evaluate both gross and net electric efficiency.	Yes
	Optimisation of the steam cycle	Operate with lower turbine exhaust pressure by utilisation of the lowest possible temperature of the condenser cooling water, within the design conditions	The efficiency will be driven by the design of the CCGT including the HRSG. The Proposed Installation will be designed to exploit optimum steam pressure and temperature settings to maximise the overall efficiency. Optimisation of the steam cycle will initially take place during plant commissioning.	Yes
	Minimisation of energy consumption	Minimising the internal energy consumption (e.g. greater efficiency of the feed-water pump)	All plant and equipment will be designed or specified and maintained to ensure optimal operation.	Yes
	Preheating of combustion air	Reuse of part of the heat recovered from the combustion flue-gas to preheat the air used in combustion	The option of including a combustion air preheater for the GT shall be investigated during FEED to reduce the minimum emission-compliant load further and increase the efficiency in part-load operation and hence enhance the flexibility of the CCGT with CCP.	Yes
	Fuel preheating	Preheating of fuel using recovered heat	Preheating of fuel using recovered heat will be used at the Proposed Installation.	Yes
	Advanced control system	See description in Section 10.8.2. Computerised control of the main combustion parameters enables the combustion efficiency to be improved	The automated control system will display and record the plant operating parameters required for best practice process control and minimisation of environmental impacts. The automated control system will display data provided from the CEMs Data Acquisition and Handling System (DAHS) information. The Proposed Installation's operational data will allow the plant processes and maintenance procedures to be reviewed and optimised. The data available via the automated control system will also allow reporting of plant performance and environmental compliance.	Yes
	Feed-water preheating using recovered heat	Preheat water coming out of the steam condenser with recovered heat, before reusing it in the boiler	Feed-water / condensate pre-heating is foreseen in the final stage of the HRSG, in order to utilise the flue gas heat. Further heat utilisation on even lower temperature levels will be investigated during the FEED.	Yes
	Heat recovery by cogeneration (CHP)	Recovery of heat (mainly from the steam system) for producing hot water/steam to be used in industrial processes/activities or in a public network for district heating.	The ST will be used to recover heat from the GT flue gas. Opportunities for heat recovery (other than the HRSG) shall be identified and assessed during FEED as part of Value Engineering (e.g. implementation of a heat pump system in the CCP, energy savings).	Yes

BAT Ref	BAT Requirement		Demonstration of BAT – Operator Response	Operating to BAT?
			In terms of off-site use of heat, a preliminary CHP Readiness Assessment has been prepared and is provided as Appendix K of the Supporting Statement. The design will retain the flexibility to enable future implementation of CHP, although the viability is constrained by several factors including: • The high internal heat demand of the CCP which reduces the heat available for export; and • The expected dispatchable operating regime of the plant, which may not align with the consistent heat supply needs of potential off-site users. The CHP potential will be periodically reviewed as part of the applicant's ongoing compliance with environmental permit requirements and should future opportunities for viable CHP integration emerge the CHP assessment will be updated accordingly.	
	CHP readiness	The measures taken to allow the later export of a useful quantity of heat to an off-site heat load in a way that will achieve at least a 10% reduction in primary energy usage compared to the separate generation of the heat and power produced. This includes identifying and retaining access to specific points in the steam system from which steam can be extracted, as well as making sufficient space available to allow the later fitting of items such as pipework, heat exchangers, extra water demineralisation capacity, standby boiler plant and back-pressure turbines. Balance of Plant (BoP) systems and control/instrumentation systems are suitable for upgrade. Later connection of back-pressure turbine(s) is also possible.	The plant has the potential to supply heat to other users although there are currently no viable export routes – this will be kept under review. Further details are in the CHP Readiness Report presented as Appendix K to the Supporting Statement.	Yes
	Flue-gas condenser	A heat exchanger where water is preheated by the flue-gas before it is heated in the steam condenser. The vapour content in the flue-gas thus condenses as it is cooled by the heating water. The flue-gas condenser is used both to increase the energy efficiency of the combustion unit and to remove pollutants such as dust, SO_x, HCl, and HF from the flue-gas.	The flue gases from the Proposed Installation would be introduced to one or more Absorber column(s), which contain a liquid amine-based chemical solvent, to absorb the CO_2 and remove it from the exhaust gases. The solvent to be used is the subject of ongoing FEED but would be an aqueous solution of amines. The alkaline nature of the solvent would mean that it would selectively absorb acidic gases such as CO_2. A heat exchanger will be required, if waste heat from the steam condensate stream would be used to increase the thermal buoyancy of the treated, washed flue gas, before release from the top of the Absorber column(s) via dedicated Absorber stack(s) for dispersion to the atmosphere. This will be confirmed at FEED.	Yes
	Heat accumulation	Heat accumulation storage in CHP mode.	As an amount of usable heat remains in the GT exhaust gases, these would be passed into a HRSG to recover the useful heat in order to produce steam (at various pressures) to generate further electricity via a separate steam turbine set, and for heating of process streams within the CCP. Opportunities for heat recovery (other than the HRSG) shall be identified and assessed during FEED as part of Value Engineering (e.g. implementation of a heat pump system in the CCP, energy savings). The plant has the potential to supply heat to other users although there are currently no viable export routes – this will be kept under review. Further details are in the CHP Readiness Report presented as Appendix K to the Supporting Statement.	Yes
	Wet stack	Generally applicable to new and existing units fitted with wet FGD.	Wet FGD not used at the Proposed Installation.	N/A
	Cooling tower discharge	Only applicable to units fitted with wet FGD where reheating of the flue-gas is necessary before release, and where the unit cooling system is a cooling tower	Wet FGD not used at the Proposed Installation.	**N/A**
	Fuel pre-drying	Only applicable to solid-fuel-fired combustion units and to gasification/IGCC units	The Proposed Installation uses natural gas as a fuel, so this is not required.	N/A
	Minimisation of heat losses	Only applicable to new plants	The Proposed Installation uses natural gas as a fuel, so this is not required.	N/A

BAT Ref	BAT Requirement		Demonstration of BAT – Operator Response	Operating to BAT?
	Advanced materials	Use of advanced materials proven to be capable of withstanding high operating temperatures and pressures and thus to achieve increased steam/combustion process efficiencies	The Proposed Installation will be designed using materials capable of withstanding operating temperatures and pressures integral to the design to optimise operations.	Yes
	Steam turbine upgrades	This includes techniques such as increasing the temperature and pressure of medium-pressure steam, addition of a low-pressure turbine, and modifications to the geometry of the turbine rotor blades	The proposed ST is a three-pressure level reheat steam turbine. There will be an LP turbine, which is fed by IP turbine exhaust through crossover pipe.	Yes
	Supercritical and ultra-supercritical steam conditions	Use of a steam circuit, including steam reheating systems, in which steam can reach pressures above 220.6 bar and temperatures above 374 °C in the case of supercritical conditions, and above 250 – 300 bar and temperatures above 580 – 600 °C in the case of ultra-supercritical conditions	The steam circuit includes reheating systems as well as superheaters, evaporators, and economisers therefore supercritical steam is not applicable.	N/A

6. Conclusions

On the basis of the assessment against the required BAT Conclusions, as shown in Sections 2 and 3, it is considered that the proposed development will be designed and operated in compliance with the BAT for Energy Efficiency and Energy Efficiency BAT Conclusions for Large Combustion Plant.