EP SHB

South Humber Bank Energy Centre

South Marsh Road, Stallingborough, DN41 8BZ

Environmental Permit Application - Indicative BAT Assessment

Environmental Permit (England and Wales) Regulations 2016 (as amended)

Applicant: EP SHB Limited
Date: December 2018

DOCUMENT HISTORY

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GLOSSARY OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	**Description**
BAT	Best Available Techniques
BREF	Best Available Techniques Reference document
CCGT	Combined cycle gas turbine
CHP	Combined heat and power
DH	District Heating scheme.
EA	Environment Agency
EPUKI	EP UK Investments Limited
EU	European Union
FB	Fluidised Bed
Fichtner	Fichtner Consulting Engineers Limited
FGT	Flue Gas Treatment
GWP	Global Warming Potential
IED	Industrial Emissions Directive
RDF	Refuse Derived Fuel
SAC	Special Area of Conservation
SCR	Selective Catalytic Reduction
SHBPS	South Humber Bank Power Station
SHBEC	South Humber Bank Energy Centre
SNCI	Site of Nature Conservation Importance
SNCR	Selective Non-Catalytic Reduction
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WFD	Waste Framework Directive

CONTENTS

TABLES

1.0 INTRODUCTION

1.1.1 This document supports the application submitted by EP SHB Limited (“EP SHB”) under the Environmental Permitting (England and Wales) Regulations 2016 (“the EPR Regulations”) (as amended) to vary the environmental permit for the South Humber Bank Power Station (“SHBPS”) (permit reference: EPR/MP3235LY), to include the installation of an energy from waste (EfW) facility – South Humber Bank Energy Centre (“SHBEC”); located at South Marsh Road, Stallingborough, North East Lincolnshire, DN41 8BZ (the ‘Site’).

1.1.2 The EfW facility will generate up to 49.9MW$_e$ gross electrical output, operating for an expected 7,850 hours per annum. The facility will also have the capability to recover heat in the form of steam, exporting up to 84MW$_{th}$ to the CCGT power station.

1.1.3 The EfW facility is being designed to allow input of refuse derived fuel (RDF) and similar fuels having a range of Net Calorific Values (NCVs) between 9MJ/kg and 14MJ/kg, to manage any potential variation in the waste composition. The facility therefore has the potential based upon the expected running regime to combust a maximum of 753,500 tonnes per annum (tpa) of fuel having NCV of 9MJ/kg from various sources of processed commercial and industrial (C&I) waste, based on a nominal lifetime availability to combust fuel of 89.6%. The availability could be higher in the early years and also years with no outage requirements.

1.1.4 The environmental permit application and all associated impact assessments have been prepared on the basis of the lifetime average plant availability of 89.6% (7,850 hours per annum) and a maximum throughput of 753,500tpa of fuel having a NCV of 9MJ/kg.

1.1.5 Due to the nature and specification of the waste that will be utilised as a fuel within the combustion plant it is necessary consider the installation as a waste incineration plant. This report contains BAT assessments for combustion technologies, acid gas abatement and nitrogen oxides abatement to identify the selected ‘Best Available Techniques’ (BAT) for SHBEC. Each assessment follows the structure of Technical Guidance Note EPR-H1 and includes comments on all of the relevant environmental parameters mentioned in EPR-H1.

1.1.6 This document presents a review of the proposed SHBEC against the requirements to use ‘Best Available Techniques’ (BAT).

1.1.7 AECOM has prepared this assessment using concept engineering information provided by Fichtner Consulting Engineers Limited (“Fichtner”) related to the initial design parameters of the EfW facility, available information about the local environment and the existing standards and guidelines presented in published guidance, including:

- EU Reference Document on the application of Best Available Techniques for Waste Incineration (August 2006);
- EU Best Available Techniques (BAT) Reference Document on Waste Incineration (Draft 1) (May 2017);
- EU Reference Document on the application of Best Available Techniques to Industrial Cooling Systems (December 2001);
- Waste Framework Directive; and
- Environment Agency (EA) Sector Guidance Note for Combustion Activities EPR 1.01 (March 2009).

1.1.8 This document is divided into the following Sections:

- Section 2 - Assessment of the overall EfW facility against the BAT Conclusions as published in the EU Best Available Techniques (BAT) Reference Document on Waste Incineration (Draft 1) (May 2017); - See Section 2;
- Section 3 – Assessment of BAT for combustion techniques;
- Section 4 – Assessment of BAT for flue gas treatment options;
- Section 5 – Identification of Indicative BAT.

1.1.9 The review of BAT for cooling systems at SHBEC is presented as a separate document.

2.0 ASSESSMENT AGAINST BAT CONCLUSIONS

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
1.	**Environmental Management Systems** BAT 1. In order to improve the overall environmental performance, BAT is to implement and adhere to an environmental management system (EMS) that incorporates all of the following features: i. commitment of the management, including senior management; ii. definition, by the management, of an environmental policy that includes the continuous improvement of the environmental performance of the installation; iii. planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment; iv. implementation of procedures paying particular attention to: a) structure and responsibility; b) recruitment, training, awareness and competence; c) communication; d) employee involvement; e) documentation; f) effective process control; g) planned regular maintenance programmes; h) emergency preparedness and response; i) safeguarding compliance with environmental legislation; v. checking performance and taking corrective action, paying particular attention to: a) monitoring and measurement (see also the JRC Reference Report on Monitoring of emissions to air and water from IED-installations – ROM); b) corrective and preventive action; c) maintenance of records; d) independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;	Yes	An EMS certified to ISO14001 is in place for the operation of the CCGT power station installation, which will be extended to include the operation of the EfW facility. The EMS comprises an environmental policy and other management documents, including site specific management procedures. The procedures provide the contact details for applicable responsible personnel on the Site, and their roles and responsibilities. All emissions to air from the EfW facility will be included in the varied Environmental Permit for the South Humber Bank Power Station and be monitored as required by the permit. The emissions monitoring procedures shall also cover the actions for monitoring emissions to air during periods of abnormal operation (such as start-up and shut-down). All plant and equipment at the Site will be regularly maintained, via qualified technicians, in line with a maintenance schedule for the installation extended to include the EfW facility. The EfW facility will be covered by a Distributed Control System (DCS) to continuously monitor the operation of the plant and equipment at the EfW facility. Any non-conformance or deviation in normal operating parameters will be identified by the DCS and CEMS to allow operators to take action to avoid a breach of permitted emission levels. The EMS requires to record data on plant performance, incidents, and potential incidents and to record subsequent incident investigation, and implementation of actions arising from the investigations. The EMS defines the requirements for maintaining and storing records. The EMS is subject to periodic reviews and updates by senior management and will be subject to internal as well as external audits. The decommissioning and closure plan for the CCGT power station installation will be extended to include additional decommissioning and closure procedures for the EfW facility. Any alterations or new plant additions to the EfW facility will be subject to the Site change management controls which include the consideration of decommissioning aspects. The installation has waste management procedures in place detailing the waste

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	vi. review, by senior management, of the EMS and its continuing suitability, adequacy and effectiveness; vii. following the development of cleaner technologies; viii. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life including: a) avoiding unnecessary underground structures; b) incorporating features that facilitate dismantling; c) choosing surface finishes that are easily decontaminated; d) using an equipment configuration that minimises trapped chemicals and facilitates drainage or cleaning; e) designing flexible, self-contained equipment that enables phased closure; f) using biodegradable and recyclable materials where possible; ix. application of sectoral benchmarking on a regular basis. Specifically for incineration plants and, where relevant, bottom ash treatment plants, BAT is to also incorporate the following features in the EMS: x. waste stream management plan (see BAT 10 and BAT 11); xi. residues management plan including measures aiming to: a) minimise the generation of residues; b) optimise the reuse, regeneration, recycling and/or energy recovery of the residues; c) ensure the proper disposal of residues; xii. Other than Normal Operating Conditions (OTNOC) management plan (see BAT 19); xiii. accident management plan (see BAT 2); xiv. odour management plan where odour nuisance at sensitive receptors is expected and/or has been substantiated, including: a) a protocol for conducting odour monitoring in accordance with EN standards (e.g. EN 13725); it may be complemented by measurement/estimation of odour exposure (e.g. according to EN 16841-1 or EN 16841-2) or estimation of odour impact;		storage and handling procedures on Site; these procedures will be revised to include the additional waste generated from the EfW facility. The waste management procedures outline the identification of waste streams and how they must be handled, including appropriate segregation and storage within designated waste storage areas on site. According to existing procedures waste generated on Site is quantified, and records of waste generated and disposal routes applied will be retained on Site. The potential for fugitive emissions shall be regularly reviewed as part of the EMS environmental aspect and impact identification procedure and on a daily basis through on-going site observations. The EMS comprises procedures for management of accidental releases from the Site. Site procedures will be extended to the EfW facility operations to minimise the risk of contamination to include management of surface water run-off from the roadways, and installation of oil/water interceptors in drains in any areas where vehicles will be present. Existing procedures for management of dust, noise and odours will be extended to include the operation of the EfW facility. A noise assessment has been undertaken for the facility (see Chapter 8 of the Environmental Statement (ES) Volume I presented in Appendix 6 of the Permit Variation application documents) and concluded that the overall impact on identified noise sensitive receptors (both residential and ecological) from the EfW facility was not expected to be significant. A detailed noise management plan for the facility is therefore not considered to be required. Dust and odours from the facility will be managed by implementation of appropriate management procedures. All fuel delivered to the facility will be in covered vehicles, with all fuel tipping and storage procedures to be carried out indoors. The tipping hall will be installed with automatic doors, which will remain closed except to allow fuel delivery, to prevent any odorous emissions from escaping. Appropriate complaint procedures are available at the Site to log any complaints received. The EMS includes assignment of responsibilities for closing out issues identified by the complaints. The EfW facility will therefore comply with the BAT conclusions (BATc).

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	b) a protocol for response to identified odour incidents, e.g. complaints; c) an odour prevention and reduction programme designed to identify the source(s); to measure/estimate odour exposure; to characterise the contributions of the sources; and to implement prevention and/or reduction measures; xv. noise management plan (see also BAT 36) where noise nuisance at sensitive receptors is expected and/or has been substantiated, including; a) a protocol for conducting noise monitoring; b) a protocol for response to identified noise and vibration incidents; c) a noise and vibration reduction programme designed to identify the source(s), to measure/estimate noise and vibration exposure, to characterise the contributions of the sources and to implement prevention and/or reduction measures.		
2.	**Environmental Management Systems** BAT 2. In order to prevent the occurrence of accidents and to reduce the environmental consequences when accidents occur, BAT is to set up and implement an accident management plan (see BAT 1).	Yes	The existing Accident Management Plan (AMP) for the installation will be amended by the operator to reflect the new operations, and implemented once the facility is operational. The AMP will identify all potential accident scenarios from the proposed EfW facility operations. An assessment of potential accident risks from the EfW facility and measures in place to manage these risks has been undertaken, and is provided in Appendix 7 of the permit supporting document. The EfW facility will therefore comply with the BAT conclusions (BATc).
3.	**Monitoring** BAT 3. BAT is to determine the gross electrical efficiency and/or the gross total heat efficiency of the incineration plant by carrying out a performance test at full load (1), according to EN standards, after the commissioning of the plant and after each modification that could significantly affect the gross electrical efficiency and/or the gross total heat efficiency of the plant. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality. (1) In the case of cogeneration plants, if all of the steam produced at full load is converted to electricity, the gross electrical efficiency is determined. If, for technical reasons, not all of the steam produced at full load can be converted to electricity, the gross total heat efficiency is determined instead.	Yes	The total fuel used in the EfW facility, comprising both the primary fuel (RDF and similar fuels), and auxiliary fuel (diesel), will be recorded and reported routinely, in line with existing procedures for the installation. Regular performance tests will be undertaken for EfW facility, and shall be undertaken in accordance with applicable BS EN standards. The EfW facility will generate electricity from combustion of fuel and export steam to the adjacent CCGT power station allowing it to utilise more of its existing capacity and potentially reduce the required natural gas consumption in the CCGT units, and is therefore considered to be a cogeneration plant with equal electrical and thermal output. The electrical and steam outputs from the EfW facility will be monitored continuously so as to ensure that the R1 waste recovery status of the EfW is

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td></td><td></td><td></td><td>maintained.
The EfW facility will therefore comply with the BAT conclusions (BATc).</td></tr>
<tr><td>4.</td><td>Monitoring
BAT 4. BAT is to monitor key process parameters relevant for emissions to air and water including those given below.
<table>
<tr><th>Stream</th><th>Parameter</th><th>Monitoring</th></tr>
<tr><td>Flue-gas from incineration</td><td>Flow, oxygen content, temperature, pressure, vapour content</td><td rowspan="3">Continuous measurement</td></tr>
<tr><td>Waste water from flue-gas treatment</td><td>Flow, pH, temperature</td></tr>
<tr><td>Waste water from bottom ash treatment</td><td>Flow, pH, conductivity</td></tr>
<tr><td colspan="3">Note: (1) The continuous measurement of the water vapour content of the flue-gas is not necessary if the sampled flue- gas is dried before analysis.</td></tr>
</table>
</td><td>Yes</td><td>Monitoring of point source emissions will be undertaken through the use of certified continuous emissions monitoring systems (CEMS), in accordance with the waste incineration articles of the Industrial Emissions Directive (2010/75/EU) and revised waste incineration BRef (WI BRef).
CEMS will also allow continuous measurement of flow, oxygen content, temperature, pressure, vapour content of the flue gas emissions from the facility.
During normal operation, all waste water generated at the facility will be transferred to the process water tank, which will allow reuse of the water for site operations. In the event of an abnormal operating conditions, waste water will be discharged to the foul sewer in compliance with a Trade Effluent Discharge Consent; any discharge of process/trade effluent will be monitored prior to discharge.
The EfW facility will therefore comply with the BAT conclusions (BATc).</td></tr>
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<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr>
<td>5.</td>
<td>
<p>Monitoring</p>
<p>BAT 5. BAT is to monitor emissions to air with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.</p>
<table>
<tr><th>Substance/ Parameter</th><th>Process</th><th>Standard(s) (1)</th><th>Minimum monitoring frequency</th><th>Monitoring associated with</th></tr>
<tr><td>NOX</td><td>Incineration</td><td>Generic EN</td><td>Continuous</td><td>BAT 29</td></tr>
<tr><td>NH3</td><td>When SNCR and/or SCR is used</td><td>Generic EN standards</td><td>Continuous</td><td>BAT 29</td></tr>
<tr><td>N2O</td><td>Incineration in fluidised bed furnaces
When SNCR is operated with urea</td><td>EN 21258</td><td>Once every year</td><td>BAT 29</td></tr>
<tr><td>CO</td><td>Incineration</td><td>Generic EN standards</td><td>Continuous</td><td>BAT 28</td></tr>
<tr><td>SO2</td><td>Incineration</td><td>Generic EN standards</td><td>Continuous</td><td>BAT 28</td></tr>
<tr><td>HCl</td><td>Incineration</td><td>Generic EN standards</td><td>Continuous</td><td>BAT 28</td></tr>
<tr><td>HF</td><td>Incineration</td><td>Generic EN standards</td><td>Continuous</td><td>BAT 28</td></tr>
<tr><td>Dust</td><td>Bottom ash treatment</td><td>EN 13284-1</td><td>Once every year</td><td>BAT 27</td></tr>
</table>
</td>
<td>Yes</td>
<td>
<p>The only point source emissions from the EfW facility will comprise emissions to air. All gases produced from combustion process will be treated using various systems in a flue gas treatment (FGT) system. The FGT will comprise a SNCR system for mitigating emissions of NOx, acid scrubber using hydrated lime injection for management of SO_2 and other acid gas (HCl, HF) emissions, activated carbon injection to manage emissions of heavy metals, dioxins and furans, with a bag filter system to remove the particulate emissions comprising combustion residue and resides from previous FGT processes.</p>
<p>Monitoring of point source emissions will be undertaken through the use of certified continuous emissions monitoring systems (CEMS) which will be installed at each stack emission point (one for each boiler), in accordance with the waste incineration articles of the Industrial Emissions Directive (2010/75/EU) and the revised WI BRef.</p>
<p>Periodic stack monitoring will also be undertaken on specific determinands, through a sampling location designed to meet the requirements of the Environment Agency's M1 Monitoring Guidance Note.</p>
<p>The monitoring of emissions will ensure that they are in compliance with the Environmental Permit, and applicable BAT-AELs.</p>
<p>The potential for dust emissions from the facility is considered to be negligible since all fuel receipt and storage will be undertaken in an enclosed area, whilst all bottom ash generated on site will be quenched and therefore will contain some moisture when it is removed from Site; thereby minimising dust emissions. However, the facility operations will be monitored continuously to ensure that dust emissions are kept to a minimum and are managed appropriately.</p>
<p>The EfW facility will therefore comply with the BAT conclusions (BATc).</p>
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</table>

BAT No.	BATc Requirements					Operating to BAT	Demonstration of BAT
		Incineration	Generic EN standards and EN 13284-2	Continuous	BAT 26		
	Metals and metalloids except mercury (As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Tl, V)	Incineration	EN 14385	Once every six month	BAT 26		
	Hg	Incineration	Generic EN standards and EN 14884	Continuous (3)	BAT 31		
	TVOC	Incineration	Generic EN standards	Continuous (3)	BAT 30		
	PCDD/F	Incineration	No EN standard available for long-term sampling, EN 1948-2, EN 1948-3	Once every month (4)	BAT 30		
	Dioxin-like PCBs	Incineration	No EN standard available for long-term sampling, EN 1948-2, EN 1948-4	Once every month (5)(6)	BAT 30		

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	Benzo[a]pyrene | Incineration | No EN standard available | Once every year | BAT 30 (1) Generic EN standards for continuous measurements are EN 15267-1, EN 15267-2, EN 15267-3, and EN 14181. EN standards for periodic measurements are given in the table or in the footnotes. (2) The continuous measurement of HF may be replaced by periodic measurements with a minimum frequency of once every six months if the HCl emission levels are proven to be sufficiently stable. No EN standard is available for the periodic measurement of HF. (3) For incineration plants with a capacity of < 100 000 tonnes/year incinerating exclusively non-hazardous waste, and for plants incinerating wastes with intrinsically low and constant mercury content (e.g. sewage sludge, mono- streams of waste of controlled composition), the continuous monitoring of emissions can be replaced by long-term sampling or periodic monitoring with a minimum frequency of once every six months. In the latter case the relevant standard is EN 13211. (4) The monitoring frequency of once every month refers to monitoring carried out by long-term sampling. For incineration plants incinerating exclusively non-hazardous waste and for incineration plants where PCCD/F emission levels are proven to be sufficiently stable, the monthly long-term sampling of PCDD/F emissions can be replaced by periodic measurements with a minimum monitoring frequency of once every six months. In this case the relevant standard for sampling is EN 1948-1. (5) The monitoring frequency of once every month refers to monitoring carried out by long-term sampling. For incineration plants burning exclusively non-hazardous waste and for incineration plants where PCB emission levels are proven to be sufficiently stable, the monthly long-term sampling of PCB emissions can be replaced by periodic measurements with a minimum monitoring frequency of once every six months. In this case the relevant standard for sampling is EN 1948-1. (6) Where emissions of dioxin-like PCBs are demonstrated to represent less than 20 % of the toxic equivalent of PCDD/F expressed as WHO-TEQ, the		

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	monitoring of PCBs does not apply.		
6.	**Monitoring** BAT 6. BAT is to appropriately monitor emissions from the incineration plant during OTNOC.	Yes	Monitoring of point source emissions will be undertaken through the use of an MCERTS certified continuous emissions monitoring systems (CEMS).The CEMS will allow identification of OTNOCs, and monitoring of emissions during OTNOCs; all emissions data logged continuously via the DCS system. The EfW facility will therefore comply with the BAT conclusions (BATc).
7.	**Monitoring** BAT 7. BAT is to monitor emissions to water from FGC and/or bottom ash treatment with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.	N/A	The facility will not discharge any process waste water to controlled waters under normal operating conditions. In normal operation, all process waste water generated by the site will be reused on site for processes like bottom ash quenching. During abnormal operating conditions, the facility would discharge waste water to the foul sewer in compliance with a Trade Effluent Discharge Consent, following appropriate testing to ensure compliance. The EfW facility will therefore comply with the BAT conclusions (BATc).

Substance/ Parameter	Process	Standard(s)	Minimum monitoring frequency	Monitoring associated with
Total organic carbon (TOC)	FGC Bottom ash treatment	EN 1484	Once every month	BAT 34
Total suspended solids (TSS)	FGC Bottom ash treatment	EN 872		
As	FGC	Various EN standards available (e.g. EN ISO 11885 or EN ISO		
Cd	FGC			
Cr	FGC			

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th></th><th></th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td></td><td>Cu</td><td>FGC</td><td>17294-2)</td><td></td><td></td></tr>
<tr><td></td><td>Mo</td><td>FGC</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Ni</td><td>FGC</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Pb</td><td>FGC
Bottom ash treatment</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Sb</td><td>FGC</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Tl</td><td>FGC</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Zn</td><td>FGC</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Hg</td><td>FGC</td><td>Various EN standards available (e.g. EN ISO 12846 or EN ISO 17852)</td><td></td><td></td></tr>
<tr><td></td><td>NH4-N</td><td>Bottom ash treatment</td><td>Various EN standards (i.e. EN ISO 10304-1, EN ISO 15682)</td><td></td><td></td></tr>
<tr><td></td><td>SO42-</td><td>Bottom ash treatment</td><td>EN ISO 10304-1</td><td></td><td></td></tr>
<tr><td></td><td>PCDD/F</td><td>FGC
Bottom ash treatment</td><td>No EN standard available</td><td></td><td></td></tr>
</table>

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>8.</td><td>Monitoring
BAT 8. BAT is to monitor the total organic carbon content of bottom ashes/slags and/or their loss on ignition in accordance with EN 13137 and/or EN 15169. The minimum monitoring frequency is once every three months.</td><td>Yes</td><td>Appropriate procedures will be developed by the operator to analyse the quality of incinerator bottom ash generated at the installation prior to it being taken off-site.
The facility will implement procedures as part of the EMS to monitor the total organic carbon content or loss on ignition of the bottom ash generated by the process, every three months as a minimum.
The EfW facility will therefore comply with the BAT conclusions (BATc).</td></tr>
<tr><td>9.</td><td>Monitoring
BAT 9. For the incineration of hazardous waste containing POPs, BAT is to monitor the POP destruction efficiency at least once every year in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.</td><td>N/A</td><td>The EfW facility will not be designed to combust hazardous substances; and specification of acceptable fuel, defining the relevant acceptance criteria, will be agreed with each supplier prior to commencement of operations. This BATc is therefore not considered to be applicable to the installation.
The EfW facility will therefore comply with the BAT conclusions (BATc).</td></tr>
<tr><td>10.</td><td>General environmental and combustion performance
BAT 10. In order to improve the overall environmental performance of the incineration plant, as part of the waste stream management plan (see BAT 1), BAT is to use all of the techniques (a) to (d) given below, and, where relevant, also techniques (e) and (f).
<table>
<tr><th></th><th>Technique</th><th>Description</th></tr>
<tr><td>a)</td><td>Determination of the types of waste that can be incinerated</td><td>Based on the characteristics of the incineration plant, identification of the types of waste which can be incinerated in terms of, for example, the physical state and the acceptable ranges of calorific value, humidity, ash content, size.</td></tr>
<tr><td>b)</td><td>Set-up and implementation of</td><td>These procedures aim to ensure the technical (and legal) suitability of waste</td></tr>
</table></td><td>Yes</td><td>The facility will only operate using RDF and similar fuels; although diesel will be available for the operation of auxiliary burners for starting and shutting down the process and for combustion stabilisation..
The facility will only operate using fuels with specific characteristics, with design fuel, and acceptable deviations outlined in the permit supporting document. The facility will be designed to be able to operate with a range of net calorific values (NCVs) to reflect the variability of RDF (and similar fuels) from commercial and industrial (C&I) sources. An indicative list of acceptable wastes, including applicable European Waste Catalogue (EWC) codes is shown in Appendix 3 of the permit support document.
It is expected that the site will receive largely homogenous waste for combustion; therefore the likelihood of cross-contamination and risk from blending is not considered to be a significant risk at the installation.
All fuel received and accepted for combustion at the site will be received in the enclosed tipping hall and stored in the dedicated fuel bunker. The level of fuel in the bunker will be monitored to ensure that there is sufficient storage capacity.
The operator will produce and implement pre-acceptance, acceptance and quarantine procedures at the facility. Outline procedures for waste pre-acceptance,</td></tr>
</table>

BAT No.	BATc Requirements			Operating to BAT	Demonstration of BAT
		waste characterisation and pre-acceptance procedures	treatment operations for a particular waste prior to the arrival of the waste at the plant. They include procedures to collect information about the waste input and may include waste sampling and characterisation to achieve sufficient knowledge of the waste composition. Waste pre-acceptance procedures are risk-based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety and environmental impact, as well as the information provided by the previous waste holder(s).		acceptance and rejection are included in the permit supporting document. The waste acceptance procedure will include, as a minimum, recording of each waste load accepted, and providing a description of the waste. Procedures will also include implementation of appropriate waste documentation. The process control system will allow tracking of all wastes accepted; although the mixing of fuel for ensuring homogeneity might make it difficult to track specific waste streams. A waste tracking system and inventory will track the quantity of waste stored in the fuel bunker. The site recording system will hold all the information generated during waste pre-acceptance procedures (e.g. date of arrival at the plant and unique reference number of the waste, information on the previous waste holder(s), pre-acceptance and acceptance analysis results, nature and quantity of waste held on site including all identified hazards), acceptance, storage, treatment and/or transfer off-site. The EfW facility will therefore comply with the BAT conclusion (BATc).
	c)	Set-up and implementation of waste acceptance procedures	Acceptance procedures aim to confirm the characteristics of the waste, as identified in the pre-acceptance stage. These procedures define the elements to be verified upon the delivery of the waste at the plant as well as the waste acceptance and rejection criteria. They may include waste sampling, inspection and analysis. Waste acceptance procedures are risk- based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety and environmental impact, as well as the information provided by the previous waste holder(s). The elements to be monitored for each type of waste are detailed in BAT 12.		
	d)	Set-up and	A waste tracking system and inventory		

BAT No.	BATc Requirements			Operating to BAT	Demonstration of BAT
		implementation a waste tracking system and inventory	aim to track the location and quantity of waste in the plant. It holds all the information generated during waste pre-acceptance procedures (e.g. date of arrival at the plant and unique reference number of the waste, information on the previous waste holder(s), pre-acceptance and acceptance analysis results, nature and quantity of waste held on site including all identified hazards), acceptance, storage, treatment and/or transfer off site. The waste tracking system is risk-based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety and environmental impact, as well as the information provided by the previous waste holder(s). The waste tracking system includes clear labelling of wastes that are stored in places other than the waste bunker or sludge storage tank (e.g. in containers, drums, bales or other forms of packaging) such that they can be identified at all times.		
	e)	Waste segregation	Wastes are kept separated depending on their properties in order to enable easier and environmentally safer storage and incineration. Waste segregation relies on the physical separation of different wastes and on procedures that identify when and where wastes are stored.		

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	f) Verification of waste compatibility prior to mixing or blending of waste — Compatibility is ensured by a set of verification measures and tests in order to detect any unwanted and/or potentially dangerous chemical reactions between wastes (e.g. polymerisation, gas evolution, exothermal reaction, decomposition) upon mixing or blending. The compatibility tests are risk-based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety and environmental impact, as well as the information provided by the previous waste holder(s).		
11.	**General environmental and combustion performance** BAT 11. In order to improve the overall environmental performance of the bottom ash treatment plant, as part of the waste stream management plan (see BAT 1), BAT is to set up and implement an output quality management system.	Yes	Appropriate procedures will be developed by the operator to analyse the quality of incinerator bottom ash generated at the installation prior to it being taken off-site. The EfW facility will therefore comply with the BAT conclusion (BATc).
12.	**General environmental and combustion performance** BAT 12. In order to improve the overall environmental performance, BAT is to monitor the waste deliveries as part of the waste acceptance procedures (see BAT 10) including the elements given below. **Waste type** / **Monitoring** Municipal solid waste and other non-hazardous waste: • Radioactivity detection • Weighing of the waste deliveries • Visual inspection • Periodic sampling of individual deliveries and analysis of key properties/substances (e.g. calorific value, content of halogens and metals/metalloids). For municipal solid waste, this involves separate unloading	Yes	**Waste type** / **Monitoring** Municipal solid waste and other non-hazardous waste: The facility will only combust RDF and similar wastes as fuel, covered under the definition of municipal solid waste and other non-hazardous waste, from commercial and industrial (C&I) sources. The facility will be compliant with the monitoring requirements outlined in BAT 12. All waste delivery vehicles will be weighed using incoming and outgoing weighbridges to provide and record the weight of the waste accepted at the facility. Vehicle loads will regularly be inspected visually at the weighbridge, with periodic detailed assessment, to confirm the nature of incoming fuel, and only authorised fuel will proceed to the fuel reception area. Radioactivity detection will also be installed to monitor incoming fuel.

BAT No.	BATc Requirements		Operating to BAT	Demonstration of BAT	
	Sewage sludge	• Weighing of the waste deliveries • Visual inspection • Periodic sampling and analysis of key properties/substances (e.g. calorific value, water and ash content)		Sewage sludge	Not applicable
	Hazardous waste	• Radioactivity detection • Weighing of the waste deliveries • Visual inspection • Unpacking and visual inspection of baled waste deliveries • Control and comparison of individual waste deliveries with the declaration of the waste producer • Sampling of the content of: – all bulk tankers – randomly selected drums/bales in drummed and other packaged waste deliveries and analysis of: – combustion parameters (including calorific value and flashpoint) – waste compatibility, to detect possible hazardous reactions upon blending or mixing wastes, prior to storage – key substances including PCBs, halogens and sulphur, metals/metalloids		Hazardous waste	Not applicable
	Clinical waste	• Radioactivity detection • Weighing of the waste deliveries		Clinical waste	Not applicable
				The EfW facility will therefore comply with the BAT conclusion (BATc).	

BAT No.	BATc Requirements		Operating to BAT	Demonstration of BAT	
13.	**General environmental and combustion performance** BAT 13. In order to reduce the environmental risks associated with the reception, handling and storage of waste, BAT is to use both of the techniques given below.		Yes		
	Technique	**Description**		**Technique**	**Compliance Measure**
	a) Impermeable surfaces and segregated drainage	Depending on the risks posed by the waste in terms of soil or water contamination, the surface of the waste reception, handling and storage areas is concrete-based or made impermeable to the liquids concerned, and fitted with segregated drainage		a) Impermeable surfaces and segregated drainage	The EfW facility will have separate drainage systems for process water and surface water from the CCGT power station. In normal operation, all process effluent will drain to the process water system via a separate drainage system, and will be reused within the facility, predominantly as ash quench. Uncontaminated surface water run-off will be directed to a surface water attenuation pond located at the eastern edge of the EfW facility from where it will discharge into one of the existing land drainage ditches located along the boundary of the Site, at greenfield discharge rates.
	b) Adequate storage capacity	Measures are taken to avoid accumulation of waste, such as: • the maximum waste storage capacity is clearly established and not exceeded, taking into account the characteristics of the wastes (e.g. regarding the risk of fire) and the treatment capacity; • the quantity of waste stored is regularly monitored against the maximum allowed storage capacity; • the maximum residence time of waste is clearly established		b) Adequate storage capacity	The fuel bunker has been designed to accommodate up to 4 days of fuel deliveries. The crane control system will display fuel heights within the bunker and will be monitored by the operator, who will ensure that storage is appropriately managed. As such, the bunker will be visible from the control room, allowing the operator to determine whether the bunker is approaching capacity. The facility will have appropriate procedures in place to divert incoming waste loads to other suitable facilities in case there is no spare storage capacity at the facility. The DCS system will allow the operators to continuously monitor the combustion process and ensure that the required residence time is achieved. The facility will

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
			also have auxiliary burner system to ensure that the required residence time at the minimum temperature of 850°C is achieved. The EfW facility will therefore comply with the BAT conclusion (BATc).
14.	**General environmental and combustion performance** BAT 14. In order to reduce the environmental risk associated with the storage and handling of clinical waste, BAT is to use technique (a) and either technique (b) or (c) given below.	N/A	The EfW facility will not accept clinical waste; this BATc is therefore not considered to be applicable to the installation.

	Technique	Description
a)	Automated waste handling	The use of non-manual waste handling and loading systems
b)	Use of sealed, puncture-resistant containers	Clinical waste is delivered in sealed and robust, puncture-resistant combustible containers that are never opened throughout storage and handling operations
c)	Cleaning and disinfection of containers	Waste containers that are to be reused are cleaned in a designated cleaning area and disinfected in a facility specifically designed for disinfection. Any solid residues from the cleaning operations are incinerated

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
15.	**General environmental and combustion performance** BAT 15. In order to improve the overall environmental performance, to reduce the content of unburnt substances in slags and bottom ashes, and to reduce emissions to air from the incineration of waste, BAT is to use an appropriate combination of the techniques given below.	Yes	

Technique	Description	Applicability

	Technique	Compliance Measure
a)	Waste blending and mixing	The facility will receive non-hazardous RDF and similar fuels. The fuel will be mixed using the fuel cranes prior to combustion to improve homogeneity. It is expected that the facility will receive largely homogenous wastes, mixing of

BAT No.	BATc Requirements				Operating to BAT	Demonstration of BAT		
	a)	Waste blending and mixing	See Section 5.2.1	Not applicable to infectious clinical waste. Blending and mixing is not applicable where undesired reactions may occur between different types of waste.				which will not lead to unpredicted and dangerous reactions.
	b)	Advanced control system	See Section 5.2.1	Generally applicable		b)	Advanced control system	The only emissions from the installation will comprise emissions to air via a flue stack, monitored continuously by a CEMS system. The process control at the facility will be via a DCS system, which is a computer-based automatic system to control the combustion process efficiently and support the prevention and/or reduction of emissions. The CEMS will feed into the DCS system, providing the operator information regarding the emissions profile. The DCS will monitor a number of combustion performance parameters to ensure optimum operation.
	c)	Optimisation of the incineration process	See Section 5.2.1	Optimisation of the design of the incineration chamber is not applicable to existing furnaces		c)	Optimisation of the incineration process	The automated control of the entire operation via DCS, including that of the combustion chamber, will allow optimisation of the process. The DCS will continuously monitor the temperature, flow rates and points of injection of the primary and secondary combustion air to effectively oxidise the organic compounds while reducing the generation of NOx. Optimisation of the design and operation of the combustion chamber will be undertaken during the detailed design stage to allow monitoring of flue-gas

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
			temperature, flue-gas and residence time, oxygen level, and waste agitation within the combustion chamber by the DCS. During operation, the temperature in the combustion chamber will be continuously monitored and recorded to demonstrate compliance with the requirements of the IED; auxiliary burners will be in place to ensure that combustion temperature and residence times required by IED are achieved. The EfW facility will therefore comply with the BAT conclusion (BATc).
16.	**BAT-associated environmental performance levels** BAT 16. In order to improve the overall environmental performance of the incineration plant and to reduce emissions to air, BAT is to set up and implement procedures for the adjustment of the plant's settings, e.g. though the advanced control system (see description in Section 5.2.1), as and when needed and practicable, based on the characterisation and control of the input waste (see BAT 12).	Yes	The EfW facility will be controlled via a DCS system, which is a computer-based automatic system to control the combustion efficiency and support the prevention and/or reduction of emissions. The only emissions from the facility will comprise emissions to air via a flue stack, monitored continuously by a CEMS system. The CEMS will feed into the DCS system, providing the operator information regarding the emissions profile. The DCS will monitor a number of combustion performance parameters to ensure optimum operation. The EfW facility will therefore comply with the BAT conclusion (BATc).
17.	**BAT-associated environmental performance levels** BAT 17. In order to improve the overall environmental performance of the incineration plant, BAT is to set up and implement operational procedures (e.g. organisation of the supply chain, continuous rather than batch operation, preventive maintenance) to limit as far as practicable shutdown and start-up operations.	Yes	The facility will implement appropriate procedures to ensure optimised operation of the installation. The entire operation will be controlled via automated distributed control system (DCS) and will have procedures to manage the combustion chamber so as to comply with the Industrial Emissions Directive (IED) requirements for combustion as well as minimise emissions and unburnt fuel. The installation will have periodic scheduled shutdowns for undertaking preventative maintenance. The installation will have procedures for managing fuel deliveries during planned shutdown periods, and in case of unplanned outages. The EfW facility will therefore comply with the BAT conclusion (BATc).
18.	**BAT-associated environmental performance levels**	Yes	The facility will undergo regular scheduled maintenance cycles, which will include

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	BAT 18. In order to reduce emissions to air and water, BAT is to ensure, by appropriate design, operation and maintenance, that the flue-gas cleaning system and the waste water treatment plant are used at optimal capacity and availability.		shutdown and maintenance of all aspects of the process including the combustion chamber and the flue gas treatment system to ensure that all systems are optimised. As such, the entire operation will be covered by a DCS system to monitor and identify any issues with any of the equipment. At this stage of design, it is expected that the facility will not require a waste water treatment facility. However, if during detailed design phase, the requirement for an on-site waste water treatment plant is identified, then it will be designed and managed in accordance with applicable site procedures and regulatory requirements. All infrastructure including site drains will be subject to regular inspections to identify blockages etc. which could affect the operation. The EfW facility will therefore comply with the BAT conclusion (BATc).
19.	**BAT-associated environmental performance levels** BAT 19. In order to reduce the frequency of the occurrence of OTNOC and to reduce emissions to air and/or to water from the incineration plant during OTNOC, BAT is to set up and implement a risk-based OTNOC management plan as part of the environmental management system (see BAT 1) that includes all of the following elements: • identification of potential OTNOC, of their root causes (e.g. failure of emission abatement systems, including identification of equipment critical to the protection of the environment ('critical equipment')) and of their potential consequences, and regular review and update of the list of identified OTNOC following the periodic assessment below; • appropriate design of critical equipment (e.g. compartmentalisation of the bag filter, supplementary burners to heat up the flue-gas and obviate the need to bypass the bag filter on start-up, etc.); • set-up and implementation of a preventive maintenance plan for critical equipment; • monitoring and recording of emissions during OTNOC and associated circumstances (see BAT 6); • periodic assessment of the emissions occurring during OTNOC (e.g. frequency of events, duration, amount of pollutants emitted) and implementation of corrective actions if necessary.	Yes	The installation will monitor all aspects of the process via the DCS system, so as to be able to quickly identify any abnormal operating state. The installation will develop and implement appropriate procedures for managing any system failures identified by the DCS. The CEMS feeds information about the emissions from the installation, which also enables monitoring of the flue gas treatment system. The installation will be subject to scheduled maintenance program, as well as a regular visual inspection schedule to identify any issues, and procedures for managing any issues identified during the inspections. The installation will have standby equipment including auxiliary burners for ensuring the required temperature is achieved for the required time in the combustion chamber. There will also be an auxiliary generator on site to manage any unplanned outages, so that the plant can be shut down safely. There will be a standby CEMS in place so that emissions monitoring continues even if the main CEMS is down. The EfW facility will therefore comply with the BAT conclusion (BATc).

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<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td>20.</td><td>Energy efficiency
BAT 20. In order to increase resource efficiency and enable the recovery of energy from the incineration of waste, BAT is to use a heat recovery boiler.</td><td>Yes</td><td>The facility will operate as a cogeneration plant, supplying steam to the CCGT power station, and will be designed to be CHP ready. A CHP Readiness (CHP-R) assessment has been undertaken for the installation and is included in Appendix 8 of the permit supporting application.
The facility is designed with a steam turbine to generate electricity and steam for export to the CCGT power station from the combustion of RDF (and similar fuels); export of steam to the CCGT power station will allow it to utilise more of its existing capacity and potentially reduce the required natural gas consumption in the CCGT units. The operator is also reviewing options to export steam to third party operations in the vicinity of the installation.
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
<tr><td>21.</td><td>Energy efficiency
BAT 21. In order to increase the energy efficiency of the incineration plant, BAT is to use a combination of the techniques given below.
<table>
<tr><th></th><th>Technique</th><th>Description</th><th>Applicability</th></tr>
<tr><td>a)</td><td>Thermal drying of sewage sludge</td><td>After mechanical dewatering, sewage sludge is further dried using low-grade heat prior to incineration</td><td>Applicable within the constraints associated with the availability of low-grade heat</td></tr>
<tr><td>b)</td><td>Reduction of the flue-gas flow</td><td>The flue-gas flow is reduced through, e.g.:
• Improving the primary and secondary air distribution;
• recirculation of raw flue-gas (extracted before the FGC); see Section 5.2.2;
• Oxygen-enriched</td><td>Generally applicable</td></tr>
</table></td><td>Yes</td><td>
<table>
<tr><th></th><th>Technique</th><th>Description</th></tr>
<tr><td>a)</td><td>Thermal drying of sewage sludge</td><td>The facility will not accept sewage sludge for combustion. This is therefore not applicable to the facility.</td></tr>
<tr><td>b)</td><td>Reduction of the flue-gas flow</td><td>The combustion control system will be an automated system, including: monitoring of the steam flow, oxygen content, temperature conditions of the grate; modification of the fuel feed rates; and the control of primary and secondary air.
Flue gas recirculation may be incorporated; this will be confirmed at detailed design stage.</td></tr>
<tr><td>c)</td><td>Minimisation of heat losses</td><td>The facility will operate as a cogeneration plant, with a steam turbine in place to produce electricity, and export the excess heat as steam to the CCGT power station.
The plant will be designed with due consideration of minimisation of thermal losses e.g. via thermal insulation.</td></tr>
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<tr><td></td><td></td><td>combustion air.
• A smaller flue-gas volume reduces the energy demand of the plant (e.g. for induced draft fans).</td><td></td></tr>
<tr><td>c)</td><td>Minimisation of heat losses</td><td>Heat losses are minimised through:
• thermal insulation of furnaces and boilers;
• recovery of heat from the cooling of slags and bottom ashes</td><td>Generally applicable</td></tr>
<tr><td>d)</td><td>Optimisation of the boiler design</td><td>The heat transfer in the boiler is improved by optimising, for example, the:
• flue-gas velocity and distribution;
• water/steam circulation;
• convection bundles;
• cleaning devices for the convection bundles.</td><td>Applicable to new plants and to major retrofits of existing plants</td></tr>
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<tr><td>d)</td><td>Optimisation of the boiler design</td><td>The boiler will be designed based on the fuel characteristics, to achieve maximum efficiency whilst combusting the fuel with the proposed NCVs. Computational Fluid dynamics modelling will be undertaken to optimise the furnace and boiler design.
The combustion process will be optimised via automatic control by use of DCS.
In-line cleaning systems will be installed within the boilers that are able to operate with the facility in operation, to prevent fouling and the associated impact on heat transfer from the boiler to the water-steam cycle.</td></tr>
<tr><td>e)</td><td>Low flue-gas temperature at boiler exit</td><td>The flue gas exit temperature will primarily be controlled by appropriate sizing of the boiler. It is possible to control this temperature through cleaning.</td></tr>
<tr><td>f)</td><td>High steam conditions</td><td>It is currently proposed to export high pressure steam to the CCGT power station installation allowing it to utilise more of its existing capacity and potentially reduce the required natural gas consumption in the CCGT units. To export steam to the CCGT power station, the facility will be designed to provide live steam at a pressure to match that of the CCGT power station’s high pressure steam, since if the pressure is not matched then the steam cannot be fed into the high pressure header at the CCGT.
Based on the current concept design the final steam temperature is limited to approximately 430°C. The temperature is</td></tr>
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<tr><td>e)</td><td>Low flue-gas temperature at boiler exit</td><td>Special corrosion-resistant heat exchangers are used to recover additional energy from the flue-gas, reducing its temperature at the boiler exit</td><td>Applicable within the constraints of the operating temperature of the downstream FGC system</td></tr>
<tr><td>f)</td><td>High steam conditions</td><td>The higher the steam conditions (temperature and pressure), the higher the electricity conversion efficiency allowed by the steam cycle.
Working at increased steam conditions (e.g. above 45 bar, 400 °C) requires the use of special steel alloy or refractory cladding to protect the boiler sections that are exposed to the highest temperatures.</td><td>Applicable to new plants and to major retrofits of existing plants, where the plant is mainly oriented towards the generation of electricity.
The applicability may be limited by:
• the stickiness of the fly ashes;
• the corrosiveness of the flue-gas.</td></tr>
<tr><td>g)</td><td>Cogeneration</td><td>Cogeneration of heat and electricity where the heat (mainly from the steam system) is used for producing</td><td>Applicable within the constraints associated with the local heat and power demand</td></tr>
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<tr><td></td><td></td><td>limited to avoid excessive corrosion associated with exposure to the Hydrogen Chloride in the flue gas. This temperature is significantly higher than that referenced as “increased steam conditions” within BAT 21.</td></tr>
<tr><td>g)</td><td>Cogeneration</td><td>The facility will operate as a cogeneration plant, generating both electricity and designed to export heat (in the form of steam) to the CCGT power station.</td></tr>
<tr><td>h)</td><td>Flue-gas condenser</td><td>Installation of a flue gas cooler is not considered appropriate for the EfW facility since it would reduce the temperature of the flue gas (expected to be around 120°C), reducing the dispersion of emissions from the stack and increasing the likelihood of acid gas dew-point corrosion.</td></tr>
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The EfW facility will therefore comply with the BAT conclusion (BATc).
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<tr><td></td><td></td><td>hot water/steam to be used in industrial processes/activities or in a public network for district heating/cooling</td><td></td></tr>
<tr><td>h)</td><td>Flue-gas condenser</td><td>A heat exchanger where the water vapour contained in the flue-gas condenses, transferring the latent heat to water at a sufficiently low temperature (e.g. return flow of a district heating network).
The flue-gas condenser also provides co-benefits by reducing emissions to air (e.g. of dust and acid gases).
The use of heat pumps can increase the amount of energy recovered from flue-gas condensation</td><td>Applicability may be limited by the demand for low- temperature heat, e.g. by the availability of a district heating network with a sufficiently low return temperature</td></tr>
</table></td><td></td><td></td></tr>
<tr><td></td><td>Table 5.1: BAT-associated energy efficiency levels (BAT-AEELs) for incineration<table>
<tr><th rowspan="2">Type of waste incinerated</th><th colspan="2">BAT-AEELs [New plant]</th></tr>
<tr><th>Gross electrical efficiency (%) (1) (2)</th><th>Gross heat efficiency (%) (3)</th></tr>
</table></td><td>Yes</td><td>The estimated energy efficiency of the EfW facility, in line with the methodology for estimation of energy efficiency of cogeneration plants outlined in the current drafting of the WI-BRef Annex demonstrates that the facility is expected to operate above the minimum required BAT-AEELs. Therefore, the proposed EfW facility is considered to be compliant with the required BAT-AEEL.</td></tr>
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<tr><th></th><th>New plant</th><th>New or existing plant</th></tr>
<tr><td>Municipal solid waste and other non-hazardous waste</td><td>25–35</td><td>72–91(4)</td></tr>
<tr><td>Sewage sludge</td><td>15– > 21(5)</td><td>60–70 (5)</td></tr>
<tr><td>Hazardous waste (6)</td><td>16–32</td><td>65–89</td></tr>
</table>
(1) The BAT-AEELs for gross electrical efficiency apply to plants producing only electricity and to cogeneration plants mainly oriented towards the production of electricity.
(2) The higher end of the BAT-AEEL range can be achieved with high steam conditions (pressure, temperature).
(3) The BAT-AEELs for gross heat efficiency apply to plants producing only heat (steam and/or hot water) and to cogeneration plants mainly oriented towards the production of heat.
(4) A gross heat efficiency exceeding the higher end of the BAT-AEEL range (even above 100 %) can be achieved where a flue-gas condenser is used.
(5) For the incineration of sewage sludge, the gross electrical efficiency is highly dependent on the water content.
(6) The BAT-AEELs do not apply if a heat recovery boiler is not applicable.</td><td></td><td>The facility will only combust RDF and similar non-hazardous fuel. At the design point, based on a thermal input to the boilers of 240MW, the expected proportion of steam going to steam turbine (based on mass flow rate), the gross electrical output of 49.9MW and steam export of 84MW$_{th}$, the gross electrical efficiency is expected to be around 30%, which is compliant with the BAT-AEEL for cogeneration plants mainly oriented towards the production of electricity.
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
<tr><td>22.</td><td>**Emissions to air - Diffuse emissions**
BAT 22. In order to prevent or reduce diffuse emissions, including odour emissions, from bulk waste storage areas including tanks and bunkers and from waste pre-treatment areas, BAT is to enclose those areas, keep them under negative pressure, and use the extracted air as combustion air for incineration. When the incinerator is not available (e.g. during maintenance), BAT is to minimise the amount of waste in storage and/or to use an alternative abatement technique (e.g. a wet scrubber).</td><td>Yes</td><td>Primary air for the boiler will be extracted from the tipping hall and above the fuel bunker to minimise diffuse emissions and odour. Moreover, the doors to the tipping hall will be kept closed at all times, except when fuel is being delivered.
During shutdown periods the amount of fuel in storage will be minimised, by interrupting or reducing deliveries, as part of the waste stream management plan.
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
<tr><td>23.</td><td>**Emissions to air - Diffuse emissions**
BAT 23. In order to prevent diffuse emissions of volatile compounds from the handling of gaseous and liquid wastes, BAT is to feed them into the furnace by direct injection.</td><td>N/A</td><td>The facility will only accept and combust solid fuels; and no gaseous or liquid wastes will be accepted at the facility. This BATc is therefore not applicable to the facility.</td></tr>
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<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td>24.</td><td>Emissions to air - Channelled emissions
BAT 24. In order to improve the environmental performance of the incineration plant and to reduce emissions to air, BAT is to optimise the combustion performance, the flue- gas flow through the FGC system, and the injection of reagents by using flow modelling.</td><td>Yes</td><td>Combustion will be optimised in the installation by continuous monitoring of the fuel feed rates, flue gas flow through the FGT system, and the injection of reagents. It is proposed that Computational Fluid Dynamics (CFD) modelling be undertaken following development of detailed design of the plant to ensure optimised installation performance.
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
<tr><td>25.</td><td>Emissions to air - Channelled emissions
BAT 25. In order to reduce peak emissions to air from the incineration of waste while limiting the consumption of reagents and the amount of residues generated from dry sorbent injection and semi-wet absorbers, BAT is to use technique (a) and also, where appropriate, technique (b) given below.
<table>
<tr><th></th><th>Technique</th><th>Description</th><th>Applicability</th></tr>
<tr><td>a)</td><td>Optimised and automated reagent dosage</td><td>The use of continuous HCl and/or SO2 monitoring (or of other parameters that may prove useful for this purpose) upstream and/or downstream of the FGC system for the optimisation of the automated reagent dosage</td><td>Generally applicable</td></tr>
<tr><td>b)</td><td>Recirculation of reagents</td><td>The recirculation of a proportion of the collected FGC solids to reduce the amount of unreacted reagent(s) in the residues.
The technique is relevant in particular in the case of FGC techniques with a high stoichiometric ratio</td><td>Generally applicable to new plants.
Applicable to existing plants within the constraints of the size of the bag filter</td></tr>
</table></td><td>Yes</td><td>
<table>
<tr><th></th><th>Technique</th><th>Compliance Measure</th></tr>
<tr><td>a)</td><td>Optimised and automated reagent dosage</td><td>Reagent feed rates will be monitored continuously to ensure that the reagent injection rate is optimised for emissions control.</td></tr>
<tr><td>b)</td><td>Recirculation of reagents</td><td>Some of the residual material from scrubber (containing injected reagents) may be recirculated to improve the gas clean up and reduce the amount of reagent consumed by the FGT system. Use of flue gas recirculation will be confirmed during the detailed design stage.</td></tr>
</table>
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
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<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
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<td>26.</td>
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Emissions to air - Emissions of dust, metals and metalloids
BAT 26. In order to reduce emissions to air of dust, metals and metalloids from the incineration of waste, BAT is to use one or a combination of the techniques given below.
<table>
<tr><th>Technique</th><th>Description</th><th>Applicability</th></tr>
<tr><td>a) Bag filter</td><td>See Section 5.2.2</td><td>Applicable within the constraints associated with the overall pressure drop and the operating temperature profile of the FGC system configuration</td></tr>
<tr><td>b) Electrostatic precipitator</td><td>See Section 5.2.2</td><td>Generally applicable</td></tr>
<tr><td>c) Dry sorbent injection</td><td>See Section 5.2.2.
Not relevant for the reduction of dust emissions.
Adsorption of metals by injection of activated carbon or other reagents</td><td>Generally applicable</td></tr>
<tr><td>d) Wet scrubber</td><td>See Section 5.2.2.
Wet scrubbers are not used to remove the main dust load but, installed after other abatement techniques, to further reduce the concentrations of dust, metals and metalloids in the flue-gas</td><td>There may be economic restrictions to retrofitting existing plants burning non-hazardous waste with a capacity of < 250 000 tonnes/year</td></tr>
</table>
</td>
<td></td>
<td>
<table>
<tr><th>Technique</th><th>Compliance Measure</th></tr>
<tr><td>a) Bag filter</td><td>The facility will implement compartmentalised bag filter system within the FGT system to remove particulates, including dust, metals and metalloids and residue from previous FGT processes.</td></tr>
<tr><td>b) Electrostatic precipitator</td><td>The facility will install bag filters to control dust; installation of electrostatic precipitators is therefore not required.</td></tr>
<tr><td>c) Dry sorbent injection</td><td>A scrubbing system will be installed at the installation, using hydrated lime or sodium bicarbonate as a reagent. The residual material will be recovered at the outlet of the flue gas scrubbing system.
Activated carbon will also be injected into the flue gas duct to minimise the emissions of dioxins, mercury, and other heavy metals.</td></tr>
<tr><td>d) Wet scrubber</td><td>As dry scrubbing will be implemented to the facility, additional wet scrubbing is not considered to be required.</td></tr>
</table>
The EfW facility will therefore comply with the BAT conclusion (BATc).
</td>
</tr>
</table>

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	Table 5.2: BAT-associated emission levels (BAT-AELs) for emissions to air of dust, metals and metalloids from incineration <table><tr><th>Parameter</th><th>BAT-AEL (mg/Nm3)</th><th>Averaging period</th></tr><tr><td>Dust</td><td>2–5 (1)</td><td>Daily average</td></tr><tr><td>Cd + Tl</td><td>0.01–0.02</td><td>Average over the sampling period</td></tr><tr><td>Sb + As + Pb + Cr + Co + Cu+ Mn + Ni + V</td><td>0.05–0.3</td><td>Average over the sampling period</td></tr><tr><td colspan="3">(1) The higher end of the BAT-AEL range is 7 mg/Nm3 for existing plants where a bag filter is not applicable.</td></tr></table>	Yes	It is expected that following application of FGT, the emissions will be compliant with the required BAT-AELs. The EfW facility will therefore comply with the BAT conclusion (BATc).
27.	**Emissions to air - Emissions of dust, metals and metalloids** BAT 27. In order to reduce dust emissions to air from the treatment of slags and bottom ashes, BAT is to carry out these activities in enclosed equipment under	N/A	All bottom ash generated will be quenched within the process and therefore be stored and removed from Site as a wet waste rather than dry, hence minimising the potential for dust generation. As such, these activities will be undertaken in an

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td></td><td>negative pressure and to treat the extracted air with a bag filter (see Section 5.2.2).
Table 5.3: BAT-associated emission levels (BAT-AELs) for dust emissions to air from the treatment of slags and bottom ashes
<table><tr><th>Parameter</th><th>BAT-AEL (mg/Nm3)</th><th>Averaging period</th></tr><tr><td>Dust</td><td>2–5</td><td>Average over the sampling period</td></tr></table></td><td></td><td>enclosed area.
There are not anticipated to be any emission of dust from bottom ash handling at the site.
Hence this BATc is therefore not considered to be applicable to the installation.</td></tr>
<tr><td>28.</td><td>**Emissions to air - Emissions of HCl, HF and SO_2**
BAT 28. In order to reduce emissions of HCl, HF and SO_2 to air from the incineration of waste, BAT is to use one or a combination of the techniques given below.
<table><tr><th>Technique</th><th>Applicability</th></tr><tr><td>a) Wet scrubber</td><td>There may be economic restrictions to retrofitting existing plants burning non-hazardous waste with a capacity of <250,000 tonnes/year</td></tr><tr><td>b) Semi-wet absorber</td><td>Generally applicable</td></tr><tr><td>c) Dry sorbent injection</td><td>Generally applicable</td></tr><tr><td>d) Direct desulphurisation</td><td>Only applicable to fluidised bed furnaces</td></tr><tr><td>e) Boiler sorbent injection</td><td>Generally applicable</td></tr></table>
Table 5.4: BAT-associated emission levels (BAT-AELs) for emissions to air of HCl, HF</td><td>Yes</td><td>The facility FGT system will comprise a dry or semi-wet acid scrubbing system using hydrated lime or sodium bicarbonate. Activated carbon will also be injected in to the flue gas to manage emissions of dioxins, mercury, and other heavy metals.
The emissions from the installation following FGT will be compliant with the required BAT-AELs.
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
</table>

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td></td><td>and SO2 from incineration
<table>
<tr><th>Parameter</th><th>BAT-AEL (mg/Nm3) [for new plants]</th><th>Averaging period</th></tr>
<tr><td>HCl</td><td>2 – 6 (1)</td><td>Daily average</td></tr>
<tr><td>HF</td><td><1</td><td>Daily average or average over the sampling period</td></tr>
<tr><td>SO2</td><td>10 – 30</td><td>Daily average</td></tr>
</table>
(1) The lower end of the BAT-AEL range can be achieved when using a wet scrubber; the higher end of the range may be associated with the use of dry sorbent injection.</td><td></td><td></td></tr>
<tr><td>29.</td><td>**Emissions to air - Emissions of NOX, N2O, CO and NH3**
BAT 29. In order to reduce NOX emissions to air while limiting the emissions of CO and N2O from the incineration of waste and the emissions of NH3 from the use of SNCR and/or SCR, BAT is to use a combination of the techniques given below.
<table>
<tr><th>Technique</th><th>Applicability</th></tr>
<tr><td>a) Optimisation of the incineration process</td><td>Generally applicable</td></tr>
<tr><td>b) Flue-gas recirculation</td><td>Generally applicable</td></tr>
<tr><td>c) Low-NOX burners</td><td>Only applicable to liquid waste</td></tr>
<tr><td>d) Selective non-catalytic reduction (SNCR)</td><td>Generally applicable</td></tr>
<tr><td>e) Selective catalytic</td><td>There may be economic restrictions to retrofitting existi</td></tr>
</table></td><td>Yes</td><td>
<table>
<tr><th>Technique</th><th>Compliance Measure</th></tr>
<tr><td>a) Optimisation of the incineration process</td><td>The combustion process will be optimised by implementation of suitable design standards, and automated control via DCS which will monitor various combustion parameters continuously.</td></tr>
<tr><td>b) Flue-gas recirculation</td><td>Flue gas recirculation may be incorporated; however this is to be confirmed during the detailed design stage.</td></tr>
<tr><td>c) Low-NOX burners</td><td>As the installation will only combust solid fuel, this BATc is not applicable.</td></tr>
<tr><td>d) Selective non-catalytic reduction (SNCR)</td><td>The flue gas treatment system at the installation will comprise a SNCR for abatement of NOx emissions.</td></tr>
<tr><td>e) Selective catalytic reduction (SCR)</td><td>Not applicable as SNCR will be applied</td></tr>
</table></td></tr>
</table>

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	reduction (SCR) — plants f) Catalytic filter bags — Not applicable to existing plants that are not fitted with a bag filter g) Optimisation of the SNCR/SCR design and operation — Optimisation of the reagent to NOX ratio, of the homogeneity of reagent distribution and of the size of reagent drops. Only applicable where SNCR and/or SCR is used for the reduction of NOX emissions.		f) Catalytic filter bags — The FGT system will not comprise catalytic filter bags. The FGT system at the installation will comprise a bag filter system with dosing of lime and activated carbon for flue gas abatement. g) Optimisation of the SNCR/SCR design and operation — The SNCR system and the wider FGT system will be monitored continuously via the DCS, to optimise the operation and control emissions from the installation. The EfW facility will therefore comply with the BAT conclusion (BATc).
	Table 5.5: BAT-associated emission levels (BAT-AELs) for NOX and CO emissions to air from incineration and for NH3 emissions from the use of SNCR and/or SCR **Parameter** / **BAT-AEL (mg/Nm3) [for new plants]** / **Averaging period** NOX / 50–120 (1) / Daily average CO / 10–50 NH3 / 3–10 (3) 1. (1) The lower end of the BAT-AEL range can be achieved when using SCR. 2. (2) The higher end of the BAT-AEL range is 180 mg/Nm3 where SCR is not applicable. 3. (3) The lower end of the BAT-AEL range can be achieved when using SCR. 4. (4) For existing plants fitted with SNCR without wet abatement techniques, the higher end of the BATAEL range is 15 mg/Nm3	Yes	It is proposed to install a SNCR at the EfW facility. The emissions from the installation following flue gas treatment will be compliant with the required BAT-AELs. The EfW facility will therefore comply with the BAT conclusion (BATc).

BAT No.	BATc Requirements			Operating to BAT	Demonstration of BAT	
30.	**Emissions to air - Emissions of organic compounds** BAT 30. In order to reduce emissions to air of organic compounds including PCDD/F and PCBs from the incineration of waste, BAT is to use techniques (a), (b), (c), (d), and one or a combination of techniques (e) to (i) given below.			Yes		
	Technique	**Description**	**Applicability**		**Technique**	**Compliance Measures**
	a) Optimisation of the incineration process	See Section 5.2.1. Optimisation of incineration parameters to promote the oxidation of organic compounds including PCDD/F and PCBs present in the waste, and to prevent their and their precursors’ (re)formation	Generally applicable		a) Optimisation of the incineration process	The combustion system will be automatically controlled via DCS to optimise the process. The control system will use a number of parameters including the gas temperatures and oxygen content, together with the load on the boiler (the steam flow). Furthermore, the speed of the grate, the fuel feed rate and the various air flows are controlled from these measurements.
	b) Control of waste feed	Knowledge and control of the specifications of the waste being fed into the incineration chamber, including their combustion characteristics, to ensure homogeneous, stable and optimal incineration conditions			b) Control of waste feed	Only permitted RDF and similar fuels (indicative list available in Appendix 3 of the permit supporting document) will be combusted at the facility. Fuel procurement, management and handling processes will ensure fuel fed to the furnace is homogenous. The fuel feed rate, the grate control and the primary air flows are controlled to ensure that by the time the ash falls off the end of the grate it is completely burnt.
	c) On-line and off-line boiler cleaning	Efficient cleaning of the boiler bundles to reduce the dust residence time and accumulation in the boiler, thus reducing PCDD/F formation in the boiler. A combination of on-line and off-line boiler cleaning techniques is used			c) On-line and off-line boiler cleaning	Online boiler cleaning systems will be installed within the boilers that are able to operate with the facility in operation. It is expected that the will include the following elements: • Water spray cleaning in the radiative passes; • Pneumatic rapping systems for cleaning of any horizontal boiler sections; and • Shockwave generators or soot-blowers for cleaning of any vertical boiler

BAT No.	BATc Requirements				Operating to BAT	Demonstration of BAT		
								sections. In addition to the online cleaning system, the boiler will undergo regular scheduled maintenance, which will be undertaken when the boiler is taken offline.
	d)	Flue-gas quenching	Use of a quench system for the rapid cooling of the flue-gas from temperatures above 400 °C to below 250 °C before dust abatement to prevent the de novo synthesis of PCDD/F			d)	Flue-gas quenching	The flue gas exit temperature is expected to be 120°C; and therefore does not require additional quenching.
	e)	Dry sorbent injection	See Section 5.2.2. Adsorption by injection of activated carbon or other reagents, generally combined with a bag filter where a reaction layer is created in the filter cake and the solids generated are removed	Generally applicable		e)	Dry sorbent injection	The flue gas treatment system will comprise an acid scrubber consisting of hydrated lime (or sodium bicarbonate) injection. Activated carbon will be injected in to the flue gas for the absorption and removal of dioxins, mercury, and heavy metals from the flue gas.
	f)	Fixed-bed adsorption	Adsorption by passing the flue-gas through a fixed-bed filter where activated coke or activated lignite is used as the adsorbent	The applicability may be limited by the overall pressure drop associated with the flue-gas cleaning system configuration		f)	Fixed-bed adsorption	Not applicable as dry sorbent technology will be applied.
	g)	Multi-layer SCR	Where SCR is used for NOX abatement, the adequate sizing of a multi-layer SCR system provides for effective PCDD/F and PCB control	There may be economic restrictions to retrofitting existing plants		g)	Multi-layer SCR	The installation will install a SNCR plant as part of the flue gas treatment system; therefore SCR installation is not proposed.
	h)	Catalytic filter bags	See Section 5.2.2	Not applicable to existing plants that are		h)	Catalytic filter bags	The FGT system will not comprise catalytic filter bags, emissions of dioxins and furans will be managed via activated carbon injection. Non-catalytic bag filters will be installed within the FGT system for the removal of particulates.

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	not fitted with a bag filter i) Carbon adsorption in wet scrubber – PCDD/F and PCBs are adsorbed by carbon sorbent added to the wet scrubber, either in the scrubbing liquor or in the form of impregnated packing elements. The technique is particularly used to prevent and/or reduce the re-emission of PCDD/F accumulated in the scrubber (the so-called memory effect) occurring especially during shutdown and start-up periods – Not applicable to existing plants that are not fitted with a wet scrubber		i) Carbon adsorption in wet scrubber – As dry scrubbing will be implemented to the facility, additional wet scrubbing is not considered to be required. The EfW facility will therefore comply with the BAT conclusion (BATc).

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
	Table 5.6: BAT-associated emission levels (BAT-AELs) for emissions to air of TVOC, PCDD/F and dioxin-like PCBs from incineration	Yes	As the facility is a new plant, the flue gas treatment system will be designed to ensure that the BAT-AELs specified in Table 5.6 are achieved. The EfW facility will therefore comply with the BAT conclusion (BATc).

Parameter	Unit	BAT-AEL (mg/Nm3) [for new plants]	Averaging period
TVOC	mg/Nm3	3 – 10	Daily average
PCDD/F (1)	ng I-TEQ/Nm3	< 0.01–0.04	Average over the sampling period or long-term sampling average
PCDD/F + dioxin-like PCBs (1)	ng WHO-TEQ/Nm3	< 0.01–0.06	Average over the sampling period or long-term sampling average

(1) Either the BAT-AEL for PCDD/F or the BAT-AEL for PCDD/F + dioxin-like PCBs applies.

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr>
<td>31.</td>
<td>
Emissions to air - Emissions of mercury
BAT 31. In order to reduce mercury emissions to air from the incineration of waste, BAT is to use one or a combination of the techniques given below.
<table>
<tr><th>Technique</th><th>Description</th><th>Applicability</th></tr>
<tr><td>a) Wet scrubber (low pH)</td><td>A wet scrubber operated at a pH value below 1.
The mercury removal rate of the technique can be enhanced by adding reagents and/or adsorbents to the scrubbing liquor, e.g.:
• oxidants such as hydrogen peroxide to transform metallic mercury to a water-soluble oxidised form
• sulphur compounds
• carbon sorbent to adsorb metallic mercury</td><td>There may be economic restrictions to retrofitting existing plants burning non-hazardous waste with a capacity of <250 000 tonnes/year</td></tr>
<tr><td>b) Boiler bromine addition</td><td>Bromide added to the waste or injected into the furnace is dissociated at high temperatures into elemental bromine to enhance the oxidisation of mercury while the flue-gas passes through the boiler, thereby promoting the transformation of elemental gaseous mercury to HgBr2, which is water-soluble and highly adsorbable.</td><td>Generally applicable</td></tr>
</table>
</td>
<td>Yes</td>
<td>
<table>
<tr><th>Technique</th><th>Applicability</th></tr>
<tr><td>a) Wet scrubber (low pH)</td><td>As dry scrubbing will be implemented to the facility, additional wet scrubbing is not considered to be required.</td></tr>
<tr><td>b) Boiler bromine addition</td><td>The facility FGT system will include injection of activated carbon to remove heavy metals, dioxins and furans, and is considered to be sufficient to abate the emissions of mercury; bromine injection in to the boiler is therefore not considered to be required, at this stage.</td></tr>
<tr><td>c) Dry sorbent injection</td><td>The flue gas treatment system will comprise an acid scrubber consisting of hydrated lime or sodium bicarbonate injection. The facility FGT system will include injection of activated carbon to remove heavy metals, dioxins and furans.</td></tr>
<tr><td>d) Fixed-bed adsorption</td><td>As dry scrubbing, including addition of activated carbon, will be implemented to the facility, additional adsorption is not considered to be required.</td></tr>
</table>
The EfW facility will therefore comply with the BAT conclusion (BATc).
</td>
</tr>
</table>

BAT No.	BATc Requirements			Operating to BAT	Demonstration of BAT
		The technique is used in combination with a downstream abatement technique such as a wet scrubber or an activated carbon injection system			
	c) Dry sorbent injection	See Section 5.2.2. Adsorption by injection of activated carbon or other reagents, generally combined with a bag filter where a reaction layer is created in the filter cake and the solids generated are removed	Generally applicable		
	d) Fixed-bed adsorption	Adsorption by passing the flue-gas through a fixed-bed filter where activated coke or activated lignite is used as the adsorbent	The applicability may be limited by the overall pressure drop associated with the flue-gas cleaning system configuration		

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td></td><td>Table 5.7: BAT-associated emission levels (BAT-AELs) for emissions of mercury to air from incineration
<table>
<tr><th>Parameter</th><th>BAT-AEL (mg/Nm3) [for new plants]</th><th>Averaging period</th></tr>
<tr><td>Hg</td><td>5–20</td><td>Daily average,
Long-term sampling average, or
Average over the sampling period</td></tr>
<tr><td colspan="3">NB: The lower end of the BAT-AEL ranges can be achieved when using fixed-bed adsorption or a wet scrubber enhanced with the use of oxidants; the higher end of the BAT-AEL ranges can be achieved when using dry sorbent injection.</td></tr>
</table></td><td>Yes</td><td>The facility will apply activated carbon injection as part of the FGT system for removal of dioxins, mercury, and heavy metals from the flue gas. The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
<tr><td>32.</td><td>Emissions to water
BAT 32. In order to prevent the contamination of uncontaminated water and to reduce emissions to water, BAT is to segregate waste water streams and to treat them separately, depending on the pollutant content.</td><td>Yes</td><td>The installation will implement segregated drainage systems for process and surface waters. In normal operation all process water will be directed to the process water tank for reuse in the process, primarily for ash quenching. Surface water drains will direct uncontaminated surface water runoff to an attenuation pond in the east of the Site for discharge to one of the drainage ditches adjacent to the installation at greenfield discharge rate.
The facility may discharge to the foul sewer during abnormal operating conditions under a Trade Effluent Discharge Consent; all such discharges will be monitored to ensure compliance with the consent.
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
</table>

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td>33.</td><td>Emissions to water
BAT 33. In order to reduce water usage and to prevent or reduce the generation of waste water from the incineration plant, BAT is to use one or a combination of the techniques given below.
<table>
<tr><th>Technique</th><th>Description</th><th>Applicability</th></tr>
<tr><td>Waste-water-free FGC techniques</td><td>Use of FGC techniques that do not generate waste water (e.g. dry sorbent injection or semi-wet absorber, see Section 5.2.2)</td><td>Generally applicable</td></tr>
<tr><td>Recycling of boiler drain water</td><td>Recycling of boiler drain water (e.g. for its use in a wet scrubber, or a quench system)</td><td>Generally applicable</td></tr>
<tr><td>Recycling of waste water from the wet scrubber</td><td>The waste water originating from the wet scrubber is treated and recycled to the wet scrubber</td><td>Only applicable to plants fitted with a wet scrubber</td></tr>
</table></td><td>Yes</td><td>Under normal operating conditions, all boiler blow-down and liquid effluent produced will be fed to the ash discharger via the process water system. In normal operation, all process water will be reused on site, and will not be discharged to controlled waters. Process water tank will therefore require to only be topped up using towns main occasionally.
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
<tr><td>34.</td><td>Emissions to water
BAT 34. In order to reduce emissions to water from flue-gas cleaning and/or from the treatment of slags and bottom ashes, BAT is to use an appropriate combination of the techniques given below, and to use secondary techniques as close as possible to the source in order to avoid dilution.
Table 5.8: BAT-AELs for direct emissions to a receiving water body
<table>
<tr><th>Parameter</th><th>Process</th><th>Unit</th><th>BAT-AEL (mg/Nm3) [for new plants]</th></tr>
</table></td><td>N/A</td><td>The installation will not discharge any process effluent to controlled waters under normal operating conditions. In normal operation, all process effluent will be reused on site, primarily for ash quenching.
The facility may discharge to the foul sewer during abnormal operating conditions under a Trade Effluent Discharge Consent; all such discharges will be monitored to ensure compliance with the consent.
This BATc is therefore not applicable.</td></tr>
</table>

BAT No.	BATc Requirements					Operating to BAT	Demonstration of BAT
	Total suspended solids (TSS)		FGC Bottom ash treatment	mg/l	10 – 30		
	Total organic carbon (TOC)		FGC Bottom ash treatment		15 – 40		
	Metals and metalloids	As	FGC		0.01 – 0.05		
		Cd	FGC		0.005 – 0.03		
		Cr	FGC		0.02 – 0.08		
		Cu	FGC		0.03 – 0.15		
		Hg	FGC		0.001 – 0.01		
		Ni	FGC		0.03 – 0.15		
		Pb	FGC Bottom ash treatment		0.02 – 0.08		
		Tl	FGC		0.005 – 0.03		
		Zn	FGC		0.01 – 0.5		
	NH4-N		Bottom ash treatment		10 – 30		
	SO42-		Bottom ash treatment		400 – 10000		
	PCDD/F		FGC Bottom ash treatment	ng I-TEQ/l	0.01 – 0.1		

BAT No.	BATc Requirements	Operating to BAT	Demonstration of BAT
35.	**Material efficiency** BAT 35. In order to increase resource efficiency and improve the recovery of useful materials from the incineration residues, BAT is to handle and treat bottom ashes separately from fly ashes and from other FGC residues, and to use a combination of the techniques given below. **Technique** / **Description** / **Applicability** a) Screening and sieving / Oscillating screens, vibrating screens and rotary screens are used for an initial classification by size before further treatment / Generally applicable b) Aeraulic separation / Aeraulic separation uses differences in density, particle size and particle shape to sort commingled materials. A narrow range of particle sizes is needed for effective separation. / Generally applicable c) Recovery of ferrous and non-ferrous metals / Different techniques are used, including: • magnetic separation for ferrous metals • eddy current separation non-ferrous metals • induction all-metal separation / Generally applicable	Yes	IBA and FGT residue produced from the EfW operations will be handled separately. IBA will be conveyed from the grate directly to a bottom ash bunker for storage. Ash will be collected in hoppers and conveyed back to bottom ash ejector which will include ash quenching equipment for cooling down the IBA. IBA will either be landfilled or recycled as an aggregate, depending on identification of suitable outlets. As the fuel combusted at the facility will be processed prior to delivery to the facility, it is expected that most materials recoverable via screening and aeraulic separation will have been separated during the pre-treatment and therefore be unavailable for recovery at the facility. Any ferrous metals in the IBA will be removed from the bottom ash by means of magnetic separators and discharged to a separate storage pit or skip prior to being sent off for recycling. The FGT residue will be stored in a sealed silo adjacent to the FGT plant. Due to the alkaline nature of the FGT residues, they are classified as hazardous waste. As a result, the residues will be transported by road in a sealed tanker to an appropriate treatment facility. The EfW facility will therefore comply with the BAT conclusion (BATc).

BAT No.	BATc Requirements				Operating to BAT	Demonstration of BAT
	d)	Ageing	The ageing process stabilises the mineral fraction of the bottom ashes by uptake of atmospheric CO2, draining of excess water and oxidation. Bottom ashes, after metal separation, are stored in open air or in covered buildings for several weeks, generally on a concrete floor allowing for drainage and run-off water to be collected for treatment. The stockpiles may be wetted, if required, to prevent dust emissions and to favour the leaching of salts and the carbonisation if the bottom ashes are not sufficiently wet	Generally applicable		
	e)	Washing	Washing of bottom ashes enables the production of a material for recycling with minimal leachability of metals and anions (e.g. salts)	Generally applicable		
	f)	Crushing	Mechanical treatment operations intended to prepare materials for subsequent use, e.g. road and earthworks construction.	Generally applicable		

<table>
<tr><th>BAT No.</th><th>BATc Requirements</th><th>Operating to BAT</th><th>Demonstration of BAT</th></tr>
<tr><td>36.</td><td>Noise and vibration
BAT 36. In order to prevent or, where that is not practicable, to reduce noise and vibration emissions, BAT is to use one or a combination of the techniques given below.
<table>
<tr><th>Technique</th><th>Description</th><th>Applicability</th></tr>
<tr><td>a) Appropriate location of equipment and buildings</td><td>Noise levels can be reduced by increasing the distance between the emitter and the receiver and by using buildings as noise screens</td><td>Generally applicable to new plants. In the case of existing plants, the relocation of equipment may be restricted by lack of space or by excessive costs</td></tr>
<tr><td>b) Operational measures</td><td>These include:
• improved inspection and maintenance of equipment
• closing of doors and windows of enclosed areas, if possible
• equipment operated by experienced staff
• avoidance of noisy activities at night, if possible
• provisions for noise control during maintenance activities</td><td>Generally applicable</td></tr>
</table></td><td></td><td>The detailed design process will review the noise prevention and abatement measures required to ensure noise is appropriately controlled to achieve the design criteria.
A noise assessment has been undertaken for the facility based upon the design criteria and concluded that noise levels from the facility will be insignificant. It is considered that noise mitigation measures to be implemented at the facility will be sufficient to minimise any impact on sensitive receptors in the vicinity of the facility.
The EfW facility will therefore comply with the BAT conclusion (BATc).</td></tr>
</table>

BAT No.	BATc Requirements			Operating to BAT	Demonstration of BAT
	c) Low-noise equipment	This includes low-noise compressors, pumps and fans	Generally applicable when the equipment is new or replaced		
	d) Noise attenuation	Noise propagation can be reduced by inserting obstacles between the emitter and the receiver. Appropriate obstacles include protection walls, embankments and buildings	Generally applicable to new plants. In the case of existing plants, the insertion of obstacles may be restricted by lack of space		
	e) Noise-control equipment/ infrastructure	This includes: • noise-reducers • equipment insulation • enclosure of noisy equipment • soundproofing of buildings	Generally applicable to new plants. In the case of existing plants, the applicability may be restricted by lack of space		

3.0 COMBUSTION TECHNIQUES

3.1 Options Considered

3.1.1 The Incinerator Sector Guidance Note (EPR5.01) discusses a number of alternative technologies for the combustion of fuel.

1. **Reciprocating Moving Grate Furnaces:** Reciprocating moving-grate systems are widely adopted for incineration facilities for refuse derived fuel (RDF) and similar fuels, and as such are considered well proven and reliable. There are a number of designs available, but typically the systems are characterised by the use of a grate system which includes a mechanism for distributing the waste across it, moving the waste forward and facilitating waste mixing as the material is moved – this means that freshly fed waste can be mixed with that already burning.

   In a reciprocating moving grate furnace, waste is agitated by the reciprocating and vertical movements. Waste is burned with an excess of air, which is frequently drawn from above the fuel bunker, providing a source of odour control. Primary air is normally fed through the grate, with a secondary air supply above the grate to create turbulence and provide sufficient air to combust volatile organics and carbon monoxide in the flue gas leaving the grate.

   The moving-grate system is capable of burning RDF as received, thereby avoiding the need for pre-treatment. Exhaust gases from the furnace will require treatment in order to achieve compliance with the emission limit requirements of the Industrial Emissions Directive (IED), and two waste streams, incinerator bottom ash (IBA) and Flue Gas Treatment (FGT) residues (including fly-ash), will be produced.

2. **Fluidised Bed**: Fluidised Bed (FB) systems operate by feeding waste onto a bed of 'fluidised' sand particles, where combustion is thermally more efficient than traditional technologies, such as moving-grate. The waste lies on a distribution plate covered with sand or limestone, and is mobilised by air being blown through it from beneath.

   These are designed for the combustion of relatively homogeneous waste. They tend to have a higher capital cost than an equivalent grate system. However for large capacity plants this can be counteracted by the fact that multiple grate units would be required to give the same capacity as one large fluidised bed unit.

   This design works effectively with wet fuels or homogenous fuels having variable calorific values, including pre-treated RDF feed. However, the RDF and similar fuels proposed for SHBEC facility will consist of various types of municipal, commercial and industrial waste fed directly to the bunker which although generally homogenous, may result in a greater risk of introducing metal and glass etc., which can cause the bed to segregate and sinter. Fluidised beds also cannot cope with material which tends to clinker, as the whole bed can become one sintered mass.

   While fluidised bed combustion can lead to slightly lower NOx generation, the injection of ammonia solution or urea is still required to achieve the emission limits specified in the waste incineration articles of the IED and relevant BAT Reference Notes.

3. **Rotary Kiln:** Incineration using rotary kiln technology requires a separate secondary combustion chamber to meet the required regulatory standards. Waste is moved through the kiln by a tumbling action, caused by the rotation of the kiln,

which exposes the fresh waste to heat and oxygen. Rotary kiln systems can operate at higher temperatures than other systems, due to the absence of exposed metal surfaces, and this makes them viable for incineration of hazardous, clinical and industrial wastes.

In relation to emissions, the rotary kiln system can lead to higher emissions of fine particles, due to the disturbance caused by the tumbling action on the waste. Additionally, there can be increased levels of un-burnt residue leading to bottom ash levels in excess of 5% and restriction on throughput capacity to less than 5tph. Consequently the technology would not be viable for the SHBEC facility.

4. **Gasification:** Gasification is a process whereby the fuel is subject to partial thermal degradation in a limited supply of air. The heat generated by this process is then used to decompose the remaining waste into hydrocarbon gases (and some inert gas), known as 'syngas'. After cleaning, the syngas can be utilised in a number of ways for heat and electricity generation, including internal combustion engines, steam raising boilers or other energy conversion processes. The majority of processes opt to combust the syngas after gasification to produce steam for electricity production.

   Operationally, to obtain consistent gas quality, a less heterogeneous incoming waste stream is required, and some pre-treatment of fuel is therefore necessary.

   Emissions to atmosphere can be controlled by cleaning the gases prior to combustion, although the gas may contain organic compounds which are difficult to remove. Residue from gasification process includes char and ash, which can trap the metals and inorganics in the molten slag.

5. **Pyrolysis:** Pyrolysis is similar to gasification, but the thermal degradation of fuel is carried out in the absence of added oxygen. The resulting syngas offers more innovative uses than immediate combustion to produce heat, but the system relies on energy input from supplementary combustion to achieve the temperature required for thermal treatment.

   The pyrolysis process also produces a tar which can contain problematic acids, heavy metals and toxic compounds, although useful by-products such as metals or some chemicals can be recovered.

   There have been issues applying the technology to the proposed fuel sources for the SHBEC facility, and pre-treatment stages would be required to ensure effective treatment is achieved. Currently there is limited experience with RDF and similar fuels, and its use remains unproven as an option at the time of writing.

6. **Plasma Applications:** This is a high temperature process, whereby plasma processing is used to create a high-temperature ionized gas which breaks organic matter primarily into syngas (predominantly carbon monoxide and hydrogen) and solid waste (vitrified slag) in a controlled vessel (reactor). The reactor for such a process typically operates at temperatures in excess of 4,000°C and at these temperatures molecular bonds break down into basic elemental components in a gaseous form, and complex molecules are separated into individual atoms. Depending on the input waste, the syngas, may be refined into various fuels at a later stage or burnt on site to provide power.

   A handful of RDF and similar wastes plants are operational worldwide, but the largest single stream plant only has the capacity to treat approximately 50,000 tonnes per annum. To achieve the maximum capacity of 753,500 tonnes per annum based on a nominal lifetime availability to combust fuel of 89.6% would require multiple streams or plant scale-up that would introduce unacceptable project risk and cost.

3.2 Assessment of Furnace Technology Options

3.2.1 The summary assessment of the technology options is presented in the Table 3.1 below.

Table 3.1. Summary Assessment of Technology Options

Assessment Criteria	**Technology Options**				
	Moving Grate	**Fluidised Bed**	**Gasification**	**Pyrolysis**	**Plasma**
Emissions	IED emission levels achievable through use of secondary abatement.	Lower thermal NO_x generation than moving grate but still need secondary abatement to meet IED emission levels.	Lower emission levels reported as achievable (1) although performance has also been reported as limited (2). Metal aerial emissions should be lower as these are transferred to solid residues.	Lower emission levels reported as achievable (1) although performance has also been reported as limited (2). Metal aerial emissions should be lower as these are transferred to solid residues.	IED emission levels will be met and lower emission levels are reported as achievable including dioxin and furan emissions which are reported to be almost undetectable (4).
Global Warming Potential (GWP)	GWP is associated with: release of CO_2 from waste combustion release of nitrous oxides associated with the NOx use of power to operate the plant.	GWP source is similar to moving grate; however the need for pre-treatment will introduce higher parasitic load needs increasing GWP associated with power use.	GWP source is similar to moving grate; however the need for pre-treatment will introduce higher parasitic load needs increasing GWP associated with power use.	GWP source is similar to moving grate; however the need for pre-treatment will introduce higher parasitic load needs increasing GWP associated with power use. Also, additional GWP is associated with the burning of support fuel to maintain process temperatures.	Lower GWP due to higher energy efficiency.

Assessment Criteria	**Technology Options**				
	Moving Grate	**Fluidised Bed**	**Gasification**	**Pyrolysis**	**Plasma**
Odour	Odour management controls to be used to mitigate fugitive odour.	Similar to moving grate, but pre-treatment may cause additional odours.	Similar to moving grate, but pre-treatment may cause additional odours.	Similar to moving grate, but pre-treatment may cause additional odours.	Odour management controls to be used to mitigate fugitive odour.
Noise	Site/Plant Appropriate noise abatement to successfully control noise.	Similar to moving grate, but pre-treatment plant will introduce additional noise sources.	Similar to moving grate, but pre-treatment plant will introduce additional noise sources.	Similar to moving grate, but pre-treatment plant will introduce additional noise sources	Site/Plant Appropriate noise abatement to successfully control noise.
Residue Generation	Produces bottom ash and FGT residues.	Use of sand in fluidised bed contributes to higher volumes of residue	Similar to moving grate although residues contain higher levels of metals.	Similar to moving grate although residues contain higher levels of metals.	Produces vitrified slag hat can potentially be recovered.
Energy Efficiency (electricity generation only)	22 - 28%	21%	14 - 20 % (3)	14 - 20% (3)	30 – 42% (5)
Raw Materials (Reagents and Water)	Can be higher due to higher raw gas pollutant concentrations, but level will depend on flue gas treatment selected.	Variable, depends on flue gas treatment selected but expected to be higher due to capture of ash and some sand from the fluidised bed process	Variable, depends on flue gas treatment selected.	Variable, depends on flue gas treatment selected.	Variable depends on option chosen to convert syngas for energy production.

Assessment Criteria	**Technology Options**				
	Moving Grate	**Fluidised Bed**	**Gasification**	**Pyrolysis**	**Plasma**
Costs	Has the lowest cost per tonne.	Additional pre-treatment plant and requirements for additional residue collection results in significantly higher capital costs.	Widely variable, but generally higher (1).	Widely variable, but generally higher (1).	Widely variable, but generally higher
Technology Application	Technology relatively well proven with a large number of long-term operational facilities.	Some operational experience although mixed performance and not proven for throughput required.	No large scale operational plants. Largest capacity plant treating MSW is 80,000 tpa (Sweden).	No large scale operational plants treating MSW.	Technology developed on an international basis on mixed waste streams – only large scale operational plants treating RDF.

Notes:

(1) 'Review of BAT for New Incineration Issues, Part 1 Waste Pyrolysis and Gasification Activities.' P4-100/TR, Environment Agency, 2001
(2) 'The Viability of Advance Thermal Treatment of MSW in the UK.' Fichtner Consulting Engineers Limited, 2004
(3) 'Advanced Thermal Treatment of Municipal Solid Waste.' DEFRA, 2005
(4) 'Pyrolysis and Gasification of Waste' Juniper
(5) Efficiencies for Plasma technology based on pilot or plants using biomass so not directly comparable – limited experience on MSW.

3.3 Conclusion

3.3.1 The above assessment of the different thermal treatment options available has shown that:

- Although there is some difference in pollutant levels in raw gas (e.g. lower NOx but higher particulate with fluidised bed), each of the options performs in accordance with IED emission limits with the use of appropriate secondary abatement technologies;
- The GWP signature for plasma systems indicates that this is lower than the other technologies, however, it is not proven technology in the UK as a large scale RDF facility;
- The GWP signature for the remaining technologies is broadly similar, however consideration of the relative energy generation efficiency of the process, the need for supplementary combustion fuel to support the thermal treatment process and parasitic load requirements to drive supporting plant and equipment shows that moving grate systems have similar or improved performance to the other technologies; and
- Moving-grate has a similar or improved level of performance to other technologies in respect of electrical efficiency, residue generation, raw materials and noise impact.

3.3.2 Therefore, taking the above into consideration, along with its proven performance at a commercial scale, moving grate technology has been selected as a cost effective option and is considered BAT for SHBEC.

4.0 FLUE GAS TREATMENT OPTIONS

4.1 Data for the Assessment

4.1.1 An indicative BAT Assessment has been undertaken for the flue gas treatment options for the EfW facility. This includes a qualitative assessment of options for acid gas and NOx abatement. Baseline unabated emission data for the assessment is based on typical performance levels for the various options for similar facilities, due to lack of information in the WI BRef . Data used in the assessment is based on:

- Previous AECOM experience for similar facilities; and
- Standard reference materials, such as the WI BREF note.

4.1.2 The dispersion factor used for the determination of the process contribution has been determined from the Air Dispersion Report (see Chapter 7 of the Environmental Statement Volume I, presented in Appendix 6 of the Environmental Permit Application Supporting Statement)

4.2 Acid Gas Abatement

Options Considered

4.2.1 Options for abatement of acid gases within the flue gas include application of secondary abatement measures. There are currently three technologies widely available for acid gas treatment on incineration plants for RDF and similar fuels in the UK for compliance with BAT-AELs:

- Wet Scrubbing;
- Semi-dry scrubbing; and
- Dry scrubbing.

4.2.2 Key Considerations in determining the best available technique for acid gas treatment at the EfW facility are as follows:

- Pollutant removal efficiency;
- Ability to achieve BAT-AELs;
- Initial investment costs and operational costs;
- Reagent use;
- Energy use and global warming potential (GWP);
- Potential for visible plume generation; and
- Waste generated.

4.2.3 The direct emissions of greenhouse gases are the same for each option, since the carbon dioxide and nitrous oxide emission concentrations are unchanged. However, the energy consumption for each of the three options is different, which would change the power exported from the plant. This means that the reduction in greenhouse gas emissions due to the displacement of power generated by other power stations would be different in each case.

4.2.4 A summary of the available acid gas treatment options are provided below.

Wet Scrubbing

4.2.5 Wet scrubbing, involving the mixing of the flue gases with an alkaline solution of sodium hydroxide or hydrated lime. This has a good abatement performance, but it consumes large quantities of water, produces large quantities of hazardous effluent which require treatment, and has high capital and operating costs.

4.2.6 These systems also require specific temperature profiles to operate, as high combustion gas temperatures can lead to evaporation of the reagent, thereby causing a loss in efficiency of the system. In order to implement this option at the facility, cooling systems would need to be installed prior to the gases being transferred to the scrubber to reduce the temperature of the gases to around 50-60°C. Due to the low outlet temperature (approximately 70 °C), the flue-gas may need to be reheated for subsequent FGT systems, and for appropriate flue gas dispersion and avoidance of a visible plume. Therefore, if this option is considered, it would involve a significant amount of additional energy use, first to reduce the combustion gas temperatures and subsequently to raise the combustion gas temperatures.

4.2.7 The GWP of wet scrubbing systems is likely to be the highest amongst the three scrubbing options, on account of the highest energy requirement leading to a considerable parasitic loading on the plant, and therefore a lower amount of power exported from the facility.

4.2.8 This scrubbing system is mainly used in the UK for hazardous waste incineration plants where high and varying levels of acid gases in the flue gases require the buffering capacity and additional abatement performance of a wet scrubbing system.

4.2.9 Wet scrubbing is not considered to be suitable for the EfW facility, due to the temperature profile of the combustion process, the production of a large volume of hazardous liquid effluent, a reduction in the power generating efficiency of the plant and the generation of a visible plume.

Semi-Dry Scrubbing

4.2.10 Semi-dry, involving the injection of lime as a slurry into the flue gases in the form of a spray of fine droplets. The acid gases are absorbed into the aqueous phase on the surface of the droplets and react with the lime (or sodium bicarbonate). The fine droplets evaporate as the flue gases pass through the system, cooling the gas. This means that less energy can be extracted from the flue gases in the boiler, making the steam cycle less efficient. The lime (or sodium bicarbonate) and reaction products are collected on a bag filter, where further reaction can take place.

4.2.11 The benefits of the semi-dry scrubbing system include relatively good performance and good reliability, and lower water consumption than wet systems. However, semi-dry scrubbing systems generate higher solid waste residues than wet systems, higher water consumption than dry systems, and high flue-gas inlet temperature requirement which limits the scale of flue gas heat recovery. Although capital costs for semi-dry systems are lower than that for wet scrubbing systems (and in the same range as for a dry system), the operating costs for these systems, are higher than that dry systems, as recycling of the reagent in the process is not proven, therefore requiring a higher quantity of reagent, whilst generating significantly more waste than wet systems.

4.2.12 Reagents usually require a specific temperature for optimal reaction conditions. It is reported that there may be operational problems when semi-wet FGT systems are used with very highly acidic polluted raw gases as this can lead to an increased risk of filter clogging. Due to the low outlet temperature the flue-gas may need to be reheated for subsequent FGT systems, and for appropriate flue gas dispersion and avoidance of a visible plume. Therefore, if this option is considered, it would involve a significant amount of additional energy use to raise the flue gas temperatures.

4.2.13 The semi-dry system involves the evaporation of water. Since the reaction temperature of the lime (or sodium bicarbonate) (and hence the outlet temperature) should be the same for both dry and semi-dry scrubbing systems, this means that the flue gas temperature at the inlet to the abatement system is higher for the semi-dry system than the dry system to account for the loss of energy through evaporation, and hence more power can be generated if a dry system is used, thereby semi-dry scrubbing systems having a higher GWP than dry scrubbing systems. Compared to the wet scrubbing systems, the GWP of semi-dry scrubbing systems is lower.

4.2.14 Therefore, semi-dry systems may be suitable for use at the EfW facility.

Dry Scrubbing

4.2.15 Dry, involving the injection of solid alkaline reagents like lime or sodium bicarbonate reagent (selection of reagent is dependent on site specific requirements) into the flue gases as a powder. The used reagent is collected on a bag filter to form a cake and most of the reaction between the acid gases and the lime takes place as the flue gases pass through the filter cake. Acid gas emissions from dry scrubbing systems are compliant with the required BAT-AELs, however the emissions are relatively higher than those from semi-dry and wet systems.

4.2.16 In its basic form, the dry system consumes more reagent than the semi-dry system. However, this can be improved by recirculating the flue gas treatment residues, which contain some unreacted lime, and reinjecting this into the flue gases. Although initial reagent injection rates are higher than that for wet and semi-dry systems, the recirculation of used reagent leads to an overall low reagent use.

4.2.17 These systems are capable of operating at higher combustion gas temperatures, and therefore do not require cooling and subsequent reheating for efficient operation. These systems do not produce any effluent like wet systems, and considerably lower quantities of waste residues than semi-dry systems.

4.2.18 The overall parasitic loading of dry scrubbing systems is lower than both wet and semi-dry systems, as combustion gases do not requiring cooling or reheating. Therefore, installation of dry scrubbing systems would achieve the highest amount of power exported from the facility. The GWP of dry scrubbing systems is therefore considered to be the lowest of the three options for the EfW facility.

4.2.19 It is therefore considered that dry scrubbing systems would be suitable for acid gas treatment at the EfW facility.

Comparison of Options

4.2.20 The relative performance of each of the options above is summarised in Table 4.1 below for ease of comparison. Each option is rated “best”, “average” or “worst” for each category assessed. As all three options would enable the EfW facility to comply with the required BAT-AEL for acid gases, this has not been included as an assessment criterion.

Table 4.1. Comparison of SHBEC Acid Gas Treatment Options

Parameter	Wet Scrubbing	Semi-dry Scrubbing	Dry Scrubbing
Pollutant removal efficiency	Best	Average(1)	Average(1)

Parameter	**Wet Scrubbing**	**Semi-dry Scrubbing**	**Dry Scrubbing**
Capital cost	Worst	Best	Average
Operational costs	Worst	Average	Best
Reagent use	Worst	Average	Best
Energy use and GWP	Worst	Average	Best
Potential for visible plume generation	Worst	Average	Best
Waste generated	Worst	Average	Best
Overall ranking	Worst	Average	Best
Notes: (1) Both semi-dry scrubbing and dry scrubbing have similar pollutant removal efficiency , and therefore have been classified as 'average'.			

4.2.21 On the basis of the above assessment it is concluded that:

- Wet scrubbing ranks first in terms of environmental performance but worst in terms of costs (both capital and operational). Wet scrubbing is considered technical unfeasible for the EfW facility due to the required temperature profile of the combustion gases;
- Dry scrubbing offers an environmental performance which is the second best, whilst demonstrating the second lowest cost performance and the best GWP, energy, and waste performance;
- Semi-dry scrubbing offers the worst performance in terms of environmental performance and cost. Performance ranking is affected by pollutant levels achieved, GWP and the highest waste production.

4.2.22 The Operator therefore could implement either dry or semi-dry scrubbing option, on the basis that:

- It offers significant reduction in unabated SO_2 emissions and achieves BAT-AEL;
- GWP is lower than wet scrubbing and semi-dry scrubbing; and
- Dry scrubbing option would allow the facility to export maximum energy compared to the other scrubbing options.

4.2.23 Therefore on the basis this assessment, it is concluded that dry and semi-dry scrubbing represents BAT for this installation. The final technology will be determined during the detailed design stage.

4.3 Nitrogen Oxides Abatement

Options Considered

4.3.1 It is anticipated that primary measures applied to the EfW facility would not be able to achieve BAT-AEL, and consideration of secondary abatement techniques is required. Secondary techniques generally use an appropriate reagent to chemically reduce the NO_x that is formed during combustion. The potential options for reduction of NO_x are identified in SGN S5.01 "*Guidance for the Incineration of Waste and Fuel Manufactured From or Including Waste*" and are outlined below:

- Selective Non-Catalytic Reduction (SNCR); and
- Selective Catalytic Reduction (SCR).

4.3.2 Key Considerations in determining the best available technique for NOx abatement at the EfW facility are as follows:

- Pollutant removal efficiency;
- Ability to achieve BAT-AELs for NOx and ammonia (NH_3);
- Initial investment costs and operational costs;
- Reagent use;
- Energy use and global warming potential (GWP); and
- Impact of ammonia deposition.

4.3.3 The direct emissions of greenhouse gases are the same for each option, since the carbon dioxide and nitrous oxide emission concentrations are unchanged. However, the energy consumption is different in each option, which would change the power exported from the plant in each case.

4.3.4 Both options may include the use of flue gas recirculation (FGR) as an integral part of the combustion control system. The use of FGR will be confirmed during the detailed design stage.

4.3.5 SCR imposes an additional pressure drop on the flue gases, leading to an increase in power consumption on the ID Fan. In addition, SCR requires the flue gases to be reheated which reduces the efficiency of the water-steam cycle.

4.3.6 This means that the reduction in greenhouse gas emissions due to the displacement of power generated by other power stations would be different in each case. The estimated thermal and electrical requirements for the two options are drawn from the WI BREF.

4.3.7 A summary of the two options is provided below.

Selective Non-Catalytic Reduction (SNCR)

4.3.8 Selective Non-Catalytic Reduction (SNCR) uses either ammonium hydroxide or urea as a reagent, which is injected into the system and chemically reacts with NOx to reduce it to nitrogen and water. It is possible to use ammonia as a reagent in SNCR systems; however, there are several issues related to using ammonia. The storage of ammonia requires consideration of health and safety impacts, in addition use of ammonia leading to the generation of ammoniated waste residue which is typically a hazardous waste requiring treatment.

4.3.9 When dosing is optimised, ammonia will give rise to lower NOx formation than urea, which tends to be easier to handle and effective over a slightly wider temperature window. The reduction reactions are dependent on an optimum temperature of around 900°C, and retention time sufficient to allow the reagents to react.

4.3.10 SNCR can be installed integrated with the boiler system, and therefore requires relatively less infrastructure than SCR. The capital costs for SNCR is lower than SCR.

4.3.11 When using ammonium hydroxide or urea as a reagent, the quantity of reagent used by SNCR is higher than that for SCR using ammonia, however, as SNCR in this mode would produce waste residue generally classified as non-hazardous waste, the waste treatment/disposal costs associated with SNCR use are lower than that for SCR.

4.3.12 Although this is a well-established technique, it requires both higher temperatures and that the reagents need to be added in excess of the stoichiometry of the reaction, which if control is not optimised, may lead to ammonia 'slippage' and increased ammonia (NH_3) emissions. It is generally accepted that ammonia slippage is much lower for SNCR systems using ammonium hydroxide or urea as a reagent compared to SCR systems using ammonia. Ammonia slippage can lead to negative impacts on ecological receptors in the vicinity of the site and need consideration, when selecting a NOx abatement technology.

Selective Catalytic Reduction (SCR)

4.3.13 Selective Catalytic Reduction (SCR) uses a catalyst, along with the addition of ammonia, to reduce the temperature at which the reaction takes place to around 300-400°C.

4.3.14 Given the potential range of pollutants present in the flue gas, SCR would need to be installed downstream of other flue gas treatment techniques (e.g. dry sorbent addition and bag filters) to minimise the potential for 'catalyst poisoning' by other pollutant species. As a result of this the flue gas leaving the initial FGT systems may well be at reduced temperatures (<250°C for bag filter systems) and may need to be reheated to achieve the temperature profile required for SCR to be effective.

4.3.15 Installation of SCR requires significant space, and therefore may be an issue for existing sites. Storage of ammonia requires consideration of health and safety risks, and would require consideration of COMAH Regulations. Ammonia use can also lead to odour issues.

4.3.16 Although SCR reduces the quantity of reagent required, additional capital and operating costs are associated with the use of an expensive catalyst and increased energy consumption required to facilitate flue gas reheating before discharge. Issues with ammonia 'slippage' can also occur with this technique. Ammonia slip for SCR using ammonia is considerably higher than that for SNCR systems using ammonium hydroxide or urea.

4.3.17 Considering the location of several sensitive sites in the vicinity of the Site, it is considered that the potential ammonia slip from SCR would have significant adverse impact on the sensitive ecological receptors in the vicinity of the facility.

Comparison of Options

4.3.18 The relative performance of both options above is summarised in Table 4.2 for ease of comparison. Each option is rated "best", or "worst" for each category assessed. As both options would enable the EfW facility to comply with the required BAT-AEL for Nitrogen Oxides abatement, this has not been included as an assessment criterion.

Table 4.2. Comparison of SHBEC NOx Abatement Options

Parameter	**SNCR**	**SCR**
Pollutant removal efficiency	Worst	Best
Capital costs	Best	Worst
Operational costs	Best	Worst
Reagent use	Worst	Best
Waste generation	Best	Worst
Energy use and GWP	Best	Worst

Impact of ammonia deposition	Best	Worst
Overall ranking	Best	Worst

4.3.19 On the basis of the above assessment it is concluded that:

- SCR option offers the better environmental option in respect of the air quality impact of NO_x emissions; this is however negated by the adverse impact of the deposition of ammonia on the nearby ecological receptors (statutory European designated sites);
- SNCR options provide similar performance in respect of NO_x reduction, in addition to a lower ammonia slip and therefore reduced ammonia deposition impacts;
- Energy recovery in terms of exported power is lower for SCR than that provided by SNCR options, and energy consumption is higher;
- SNCR utilises nearly twice as much reagent as SCR;
- The waste residues generated by SNCR are typically non-hazardous, whereas SCR waste and spent catalyst will be hazardous in nature; and
- The capital investment and operational costs for SCR are significantly higher than those for SNCR.

4.3.20 The Operator has therefore chosen the option to install SNCR with ammonium hydroxide or urea as the reagent, as its preferred secondary abatement technique, on the basis that:

- It offers a significant reduction in unabated NO_x emissions, allowing achievement of the required BAT-AEL;
- The option consumes relatively less power than SCR, therefore producing more energy for export; and
- Wastes generated will be non-hazardous in nature
- The annualised costs of using SNCR are considerably lower than those of SCR.

4.3.21 Therefore, on the basis this assessment, it is concluded that SNCR represents BAT for this installation

5.0 INDICATIVE BAT - CONCLUSION

5.1.1 In preparing the individual aspects of the application, an assessment was undertaken in respect of the relevant part of the BAT guidance documents, and the detailed conclusion of this assessment is summarised in Table 5.1:

Table 5.1. Summary Assessment against BAT Standards

Parameter	**Comment**
In-process Controls	The chosen technology was found to meet the necessary requirements for: • Waste handling, reception and storage; • Furnace system type and design; • Cooling system; and • Boiler design. In addition the requirements specified under IED were found to have been met including the requirements pertaining to process control, monitoring and interlocks.
Emissions Control	Emissions control include a range of recognised primary and secondary control techniques for control of pollutant emissions to atmosphere and will meet the required BAT AEL's.
Management	The Operator will revise the existing environmental management system (EMS) designed to meet the requirements of BS EN ISO14001 – Environmental Management. The EMS will be certified against the relevant standards during the first year of operation.
Raw Materials	Raw materials will be selected in accordance with relevant guidance standards and their ongoing use will continue to be monitored during the lifetime of the plant. Water use includes use of mains water (for boiler), and the reuse of process water where possible. Water use across the process will be established at the time of commissioning and a water audit will be completed at least every 4 years in accordance with SGN S5.01.
Waste Handling, Recovery and Disposal	The design of the process optimises the recovery and recycling of materials including bottom ash. Disposal to landfill will be minimised where possible. A waste minimisation audit will be completed at least once every 4 years in line with SGN S5.01.
Energy	The process facilitates the generation of electricity from the EfW facility and comparison of the process in line with the WI BREF indicates that the proposed EfW facility operation is comparable to the sector in terms of: • Energy consumption; • Energy production; and • Energy export.
Noise	The design of the process will consider the relevant noise levels

Parameter	**Comment**
	produced by individual items of plant and provision will be made for: • Acoustic enclosures where necessary (e.g. turbines); • Cladding of the appropriate attenuation specification; • Appropriate levels of plant maintenance; and • Operation of the plant with enclosed buildings.
Monitoring	Monitoring for the process includes both process monitoring and emissions monitoring. Techniques to be employed include: • Continuous air emissions monitoring; and • Extractive air emissions monitoring. Techniques and equipment to be employed will be in accordance with MCERTs and recognised standards as specified in SGN S5.01.
Emissions Benchmarks	Emissions from the process have been evaluated by a combination of techniques including H1 assessment and dispersion modelling. Evaluation of the typical emission levels associated with the process has confirmed that plant performance is anticipated to be better than IED emission limits and will comply with the BAT AEL's proposed within the draft Waste Incineration EU BAT Reference Note. Modelling at IED emission levels as a worst case scenario has confirmed there should be no significant impact from plant emissions to either the environment or to human health.

5.1.2 Based on the assessment against BAT standards it has been confirmed that the requirements outlined in the guidance documents and requirements of IED and the draft WI BRef were demonstrated as being met.

South Humber Bank Energy Centre

South Marsh Road, Stallingborough, DN41 8BZ

Environmental Permit Application – Cooling BAT Assessment

Environmental Permit (England and Wales) Regulations 2016 (as amended)

Applicant: EP SHB Limited
Date: December 2018

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GLOSSARY OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	**Description**
ACC	Air Cooled Condenser
BAT	Best Available Techniques
BREF	Best Available Techniques Reference document
CCGT	Combined cycle gas turbine
CHP	Combined heat and power
DH	District Heating scheme.
EA	Environment Agency
EPUKI	EP UK Investments Limited
EU	European Union
Fichtner	Fichtner Consulting Engineers Limited
FGT	Flue Gas Treatment
RDF	Refuse Derived Fuel
SAC	Special Area of Conservation
SHBPS	South Humber Bank Power Station
SHBEC	South Humber Bank Energy Centre
SNCI	Site of Nature Conservation Importance
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WFD	Waste Framework Directive

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1.0 INTRODUCTION

1.1 Purpose of Report

1.1.1 This report has been prepared by AECOM Infrastructure & Environment UK Limited (“AECOM”) of behalf of EP SHB Limited (EP SHB) and provides an assessment of the cooling options for the proposed South Humber Bank Energy Centre (SHBEC) plant against indicative Best Available Techniques (BAT) as outlined in published guidance. The purpose of this report is to inform which potential cooling technology represents BAT for the SHBEC installation when considering environmental, capital and operating costs against potential benefits for each cooling option.

1.1.2 AECOM has prepared this BAT assessment using concept engineering information provided by Fichtner Consulting Engineers Limited (“Fichtner”) related to the initial design parameters of the proposed development, available information about the local environment and the existing standards and guidelines presented in published guidance, including:

- EU Reference Document on the application of Best Available Techniques for Waste Incineration (August 2006);
- EU Best Available Techniques (BAT) Reference Document on Waste Incineration (Draft 1) (May 2017);
- EU Reference Document on the application of Best Available Techniques to Industrial Cooling Systems (December 2001);
- Waste Framework Directive; and
- Environment Agency (EA) Sector Guidance Note for Combustion Activities EPR 1.01 (March 2009).

1.2 Installation Overview

1.2.1 Following the variation proposed by this environmental permit variation application, the South Humber Bank Power Station (SHBPS) installation would include:

- The existing CCGT Power Station , which consists of two combined cycle gas turbine phases fired by natural gas with an approximate gross electrical capacity of 1375MW; and
- A new, two-stream, EfW facility fired by refuse derived fuel (RDF) with a combined thermal input of 240MW_{th}, a gross electrical output of 49.9MW_e and a thermal export capacity of approximately 84MW_{th}.

1.2.2 The proposed EfW facility would be expected to export heat, either as high pressure (live) steam to the adjacent CCGT power station, or as heat to neighbouring industrial users (as steam or hot water), or to residential users as part of a District Heating (DH) scheme. A combined heat and power (CHP) assessment has been undertaken in accordance with the EA CHP Ready Guidance (2013). The requirement to export heat is defined by the gross efficiency condition defined in the Waste Framework Directive (WFD).

1.2.3 The proposed EfW facility would be expected to include a flue gas treatment (FGT) system including acid-gas abatement (lime or similar reagent addition), abatement of dioxins, mercury and heavy metals (activated carbon addition), oxides of nitrogen abatement (selective catalytic or non-catalytic reduction with aqueous ammonia or urea) and bag filters for the removal of ash and FGT residue. The live steam temperature would be limited to approximately 430°C for the protection of system components. The treated flue gas would be vented to atmosphere via a dedicated flue and stack for each of the two streams.

2.0 INDICATIVE BAT

2.1 Energy Efficiency at Installation Level

2.1.1 The application of BAT in industrial cooling systems necessitates the optimisation of energy efficiency, primarily through use of surplus heat, and thereby reducing the discharge of heat to the environment. However, in the case of temperature sensitive applications, such as power generation, the maximisation of the overall energy efficiency within the generation process is directly affected by the discharge heat capacity of the condenser.

2.1.2 Condensing the steam to the lowest temperature results in a pressure differential across the steam turbine (creating a vacuum), which increases the work done by the turbine. The thermal efficiency of the steam cycle is maximised and thus the highest electrical efficiency is obtained per unit of fuel consumption. A reduction in the temperature differential between the steam system and the cooling medium would result in a decrease in overall electrical efficiency, through poorer vacuum generation.

2.1.3 For plant exporting thermal power, as steam or hot water, the cooling requirement is dictated by the end-user requirement for high, medium or low pressure steam or hot water.

2.1.4 It therefore follows that, for co-generation plants the cooling capacity requirement, and hence the choice of cooling technology, depends on the split in export of electrical and thermal power.

2.1.5 During normal operation the EfW facility is expected generate up to 49.9MW electrical power, and to supply the neighbouring CCGT power station with high pressure steam (95bar (absolute)) approximately 84MW thermal power, to utilise more of its existing capacity and potentially reduce the required natural gas consumption in the CCGT untis, while still achieving the same electrical output.. It is anticipated that the steam would be extracted from the EfW facility before the steam turbine so that the pressure is sufficient to match the high-pressure steam of the CCGT. The volume of steam supplied to the CCGT power station will depend on the instantaneous waste throughput of the EfW facility.

2.1.6 Alternative users for thermal power export have been reviewed as part of the CHP readiness assessment[1], which identifies the preferred DH network solution as the potential supply of hot water to light industrial and warehousing consumers local to the plant, with additional future consumer options from potential commercial and residential development within the area.

2.1.7 As detailed in paragraph 1.5, due to the corrosive nature of the flue gases, the live steam temperature is limited to approximately 430°C. Since the live steam pressure is 95 bar (absolute), this temperature limitation results in the enthalpy of the live steam decreasing and the moisture at the steam turbine exhaust increasing. To avoid erosion of the steam turbine back stage blades the exhaust pressure should remain above approximately 100 mbar (absolute). For this reason the potential capacity of the cooling system is lower than would be required for similar waste fired plants with a lower live steam pressure.

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[1] Fichtner Report Ref: S2522-0400-0001SY, South Humber Bank Energy Centre – CHP Study, November 2018

2.2 Cooling Systems

2.2.1 BAT for cooling systems is defined in the Industrial Cooling BREF document. This document is referenced in the Waste Incineration BREF and the Environment Agency's guidance. Techniques to consider include air cooling, evaporative water cooling (cooling towers) and water cooling by convection (direct, once through).

2.2.2 The cooling system would be sized according to the maximum cooling requirement, defined as operation at full boiler load and maximum power output (49.9MW$_e$), but with the steam turbine out of operation no steam exporting to the CCGT power station, nor export of heat to a DH scheme. In this operational mode, all of the steam generated would bypass the steam turbine passed directly to the condenser.

2.2.3 The cooling options for the proposed EfW facility that have been considered include:

- Air Cooled Condenser (ACC);
- Cooling towers – wet cooling and hybrid cooling; and
- Once-through cooling (direct cooling).

2.2.4 Closed circuit wet cooling systems (with primary and secondary cooling media) are discounted as these are typically suited to much lower heat loads (<2.5MW$_{th}$). There will be a closed circuit cooling water system at the facility for the cooling of auxiliaries such as the steam turbine lubricating oil.

2.3 Dry Air Cooled Condensers (ACC)

2.3.1 Dry air cooling is the condensation of the steam from the turbine exhaust through transfer of heat to the atmosphere, by indirect cooling via a bank of condensing heat exchangers. These banks of heat exchangers are normally mounted in an elevated structure to allow good and even air flow across the heat exchange surfaces; the air flow is created by large fans.

2.3.2 The steam is condensed in the heat exchangers and is then recovered as condensate to be reused in the steam cycle.

2.3.3 The air-cooled condensers (ACC) require no off-site infrastructure and rely solely on the supply of electrical energy to operate the fans.

2.3.4 A large heat-exchange surface is required, because the heat transfer capacity of air is low; this is typically achieved by the addition of fins to the heat exchange tubes. ACC cooling capacity, and hence turbine pressure drop, is limited by the size of the heat transfer surface and the air flow rate. The large heat-exchange surface results in a higher space requirement.

2.3.5 The typical ambient conditions in the location of the proposed development are considered to be suitable for efficient operation of the ACC.

2.3.6 ACCs have the disadvantage of the noise generated by the fans. However, ACCs offer benefits in other areas such as avoiding the environmental impacts associated with water abstraction and associated infrastructure construction, and blow-down discharge; and heat is discharged directly to the air without the generation of visible plumes created by wet methods.

2.4 Wet Cooling

2.4.1 Wet cooling condenses the steam using water as the main cooling medium. The heat load in the cooling water, from steam condensation, is removed by evaporation within a cooling tower and the cooled water is recirculated within the system via a reservoir. A percentage of the cooling water is lost through evaporation and the system level is maintained through make-up water from an external source. Wet cooling is typically employed for rejected heat capacities of more than $200MW_{th}$.

2.4.2 Cooling water from the steam condenser is pumped to the top of the cooling tower and the water is distributed, by spray, over the cooling tower packing to maximise the contact with air flow though the packing.

2.4.3 Several alternative designs for the water-air evaporative cooling stage can be employed, including:

- Natural-draft air flow, which relies on a pressure differential between the top and bottom of the tower, generated by the change in density of the air, to induce a draft of air up the tower in a counter-flow to the cooling water;
- Mechanical-draft air flow, which uses mechanically generated air flow using fans either at the top (induced-draft), or bottom (forced-draft), of the tower; and within these systems the air flow can be perpendicular to the water flow (cross-current) or in the opposite direction to the water flow (counter-current).

2.4.4 Drift eliminators are employed at the top of the tower to prevent entrainment of water droplets within the air flow.

2.4.5 The air exiting the tower will be saturated with water, and therefore visible plumes will occur as the warm air mixes with colder atmospheric air causing condensation of the water vapour. The extent of the plume formation is dependent on weather conditions, with colder or more humid air resulting in larger plumes.

2.4.6 Over time a proportion of the cooling water will need to be purged to remove concentrated salts (blow-down), with additional fresh water make-up.

2.4.7 Natural draft towers are typically much larger than mechanical-draft towers for the same cooling capacity; both emit continuous plumes and therefore can present significant visual impact.

2.5 Hybrid (‘Wet-Dry’) Cooling

2.5.1 Hybrid cooling uses water as the main cooling medium. The heat load in the cooling water is removed in the hybrid cooling towers by a combination of dry air cooling, and evaporative cooling.

2.5.2 The cooling water is first dry-cooled, by passing through tube banks in the hybrid cooling towers over which air is drawn by forced draft fans; the cooling water then passes to a wet cooling stage where it is sprayed over packed bed elements, to provide an extended, and therefore more efficient, air/water contact surface area. In the wet cooling stage the water is cooled by two effects: the direct contact of the cold air flow with the water, and the cooling effect of the evaporation of a small proportion of the water.

2.5.3 This method of cooling is generally more efficient than ACC; it benefits from the more efficient water cooling heat exchange characteristics but still relies on the ambient air conditions to achieve some cooling.

2.5.4 Hybrid tower systems are typically more compact, lower units than for other cooling systems. In common with ACC, noise generation from fans may need to be mitigated depending on local characteristics.

2.5.5 The hybrid tower system requires make-up water to compensate the losses through evaporation and the blowdown of concentrated salts in the recirculated water, however the water consumption is typically 25% of that for wet cooling systems.

2.5.6 Hybrid cooling towers can generate visible plumes of water vapour under certain weather conditions, in particular during cold or humid weather, however the incidence of such plumes is significantly less than for wet-cooling systems.

2.6 Direct Once-Through Cooling

2.6.1 Direct, once-through cooling uses water pumped from a river (or other surface water feature) via large water inlet, directly to a heat exchanger or condenser, after which the heated water is discharged directly back into the surface water. Once through cooling is typically used for large cooling capacity (>1,000MWe).

2.6.2 Once-through systems are affected by the availability of sufficient surface water and such water quality, as well as discharge limitations, for example the effect of the heat emission on surface water ecology. Other environmental considerations include the use of energy for pumping, the risk of fish intake and silting-up of sieves at water intake, bio-fouling, scaling or corrosion and the use of additives with discharge to surface water.

2.6.3 The existing CCGT power station employs once-through (direct) cooling via an abstraction from the River Humber to the east of the Site.

2.6.4 The existing abstraction licence restricts volume as follows:

- 99,000 m^3/hour;
- 2,376,000 m^3/day
- 869,616,000 m^3/year

2.6.5 The plant is designed to operate at a rate that complies with the requirement for a maximum difference of 8°C across the condensers, and therefore there is currently no spare capacity within the existing abstraction licence.

3.0 EXISTING ENVIRONMENT

3.1 Overview

3.1.1 This section describes the local environment, in particular that with the potential to be impacted by the cooling options under consideration for the EfW facility.

3.1.2 The Main Development Area of the proposed facility is to the immediate east of the existing CCGT power station, with commercial and industrial facilities to the north and south, and the Humber Estuary located approximately 175m to the east.

3.1.3 The wider area is characterised by agricultural land use interspersed with smaller urban conurbations, and industrial use along the bank of the Humber Estuary. A number of receptors have been identified within the vicinity of the Site as described below. All distances are given as the shortest distance between the receptor and the closest point of the proposed installation boundary.

3.2 Residential Receptors

3.2.1 Nearby residential communities include:

- Stallingborough and Healing villages, located approximately 2.5km south-west;
- Grimsby, located approximately 3 km to the south-east;
- Immingham, located approximately 4km north-west.

3.2.2 Additionally there are a small number of individual residential properties, including

- Poplar Farm, located 1.4km west;
- “Grassmere”, located 1.6km west; and
- Primrose Cottage and Cress Cottage, located 1.6km south-west.

3.3 Protected Conservation Areas

3.3.1 The Humber Estuary, located to the east of the Site is an internationally designated ecological receptor, with designations for Wetlands (Ramsar), Special Area of Conservation (SAC), Special Protection Area (SPA) and Site of Special Scientific Interest (SSSI).

3.3.2 There are four Local Wildlife Sites within 2 km of the Site:

- Healing Cress Beds Stallingborough LWS – approximately 0.7 km south-west;
- Sweedale Croft Drain LWS – approximately 0.8 km south-east;
- Laporte Road Brownfield Site LWS – approximately 1 km north-west; and
- Fish Ponds to the West of Power Station, Stallingborough LWS – approximately 1 km south-west.

3.3.3 There are two Sites of Nature Conservation Importance (SNCI) identified within 2 km of the Site:

- Field West of Power Station Stallingborough SNCI (approximately 30 m south); and
- North Moss Lane Meadow SNCI (approximately 0.9 km north-west).

3.3.4 The CCGT power station currently employs direct cooling via abstraction from, and discharge to the Humber Estuary.

3.4 Key Considerations

3.4.1 Of the identified receptors, the Humber Estuary protected conservation area is considered to be the most sensitive to impacts from the cooling options. Potentially significant impacts would be:

- The abstraction of water, with mitigation required to avoid entrainment of organisms;
- Impacts on water chemistry and biodiversity from the discharge of water with thermal plume and potential water treatment chemicals;
- Noise impacts from fans with potential disturbance of bird-life; and
- Temporary construction impacts from installation of additional intake and outfall pipework. However, noise disturbance of birds may be considered a temporary effect as it is anticipated that this impact would be adapted to over time.

3.4.2 Noise and visual impacts on local residential receptors from any of the cooling options are considered to be of lower importance because of the distance to receptors, and the existing built environment in which the proposed development would be located. It is considered that such impacts could be adequately mitigated for with appropriate design and selection of equipment.

4.0 COSTS AND BENEFITS OF COOLING OPTIONS

4.1 Air Cooled Condensers (ACC)

4.1.1 ACCs have less efficient heat transfer mechanism than wet methods, and the air cooling medium is typically higher temperature and subject to greater fluctuation, than water used in wet cooling techniques; this can reduce the thermal efficiency of the system as the temperature differential across the steam turbine can potentially be lower, as described in Section 2.

4.1.2 However, as discussed, the proposed operational mode of the EfW facility would tend towards a higher condensation pressure (270mbar (absolute)), on account of the proposed export of large volume, high pressure steam to the CCGT power station, and the cap on gross power generation of 49.9MW$_e$.;

4.1.3 The required minimum condenser pressure can be reached using ACC.

4.1.4 The potential benefits of an ACC system for the facility include:

- **No water consumption:** The water consumption would be minimal and there are no associated visible plumes.
- **No impact on the local ecological environment:** there would be no additional pollutant loading or thermal plume to the Humber Estuary protected conservation area and no abstraction requirement; the construction would not affect the foreshore area and therefore would have negligible impact on feeding birds.
- **Low maintenance**: Maintenance costs are typically lower compared with water cooling as the cooling medium is less likely to cause fouling of the heat exchange surface.

4.1.5 The potential drawbacks of ACC for the plant include:

- **High noise emission:** The cooling fans represent an additional noise source. The relatively rural nature and flat terrain of the immediate surroundings, and the proximity of sensitive receptors mean that noise emissions need to be carefully considered within the design phase.
- **Size and appearance:** ACCs typically require a larger footprint than the equivalent hybrid cooling systems, in order to accommodate the larger surface area required with the low specific heat capacity of air, and to allow adequate space to avoid recirculation of air.
- **Parasitic load:** The cooling fans have a considerable parasitic electrical energy load.

4.2 Wet Cooling Towers

4.2.1 The potential advantages of a wet cooling system for the EfW facility include:

- **Availability of water:** Abstracted water from the River Humber could be used for cooling, as is currently used for the existing CCGT power station. However the existing system operates at capacity, and lower flow through the system when the CCGT power station iss not operational could result in significant silting; therefore an additional abstraction licence and pumping equipment would need to be obtained.

4.2.2 The potential drawbacks of a wet cooling system for the facility include:

- **Visual impact:** Wet cooling towers typically give rise to continuous visible plumes and can cause fogging and icing on local roads during certain weather conditions.

- **Operational impact of the local environment:** Abstraction of significant water volume from the Humber would require careful management to avoid impact on the local river ecology.
- **Thermal effects on the local environment:** There is a need for discharge of intermittent blow-down water via direct discharge to river. A large thermal plume discharge from the outfall may impact on the river ecology.

4.3 Hybrid Cooling Towers

4.3.1 The potential benefits of a hybrid cooling system for the plant include:

- **Availability of water:** Abstracted water from the River Humber could be used for cooling, as is currently used for the existing CCGT power station. The existing system operates at capacity, and lower flow through the system when the CCGT power station is not operational could result in significant silting; therefore an additional abstraction licence and pumping equipment would need to be obtained.
- **Reduced impact on the local water environment:** The system requires a lower make-up water volume than an equivalent wet system, and lower blow-down volume discharge.

4.3.2 The potential drawbacks of a hybrid cooling system for the plant include:

- **Potential visible plumes:** Hybrid cooling towers can give rise to visible plumes during certain weather conditions, notably low ambient temperatures and high humidity. However, these can be minimised by appropriate design and sometimes by operational control - the system may be optimised for dry heat transfer, to limit plume formation, or for wet heat transfer during periods of high ambient temperature when the dry section is less efficient. The design and operation of the towers in this way minimises the length and frequency of visible plume formation and impacts are considerably lower than from natural draught cooling towers. Nevertheless this is an additional plume impact over the use of ACCs.
- **Noise:** The cooling fans represent an additional noise source. The relatively rural nature and flat terrain of the immediate surroundings, and the proximity of sensitive receptors mean that noise emissions need to be carefully considered within the design phase.
- **Thermal effects on the local environment:** There is a need for discharge of intermittent blow-down water via direct discharge to river, albeit at a lower rate than for wet cooling.
- **Parasitic load:** The system requires both cooling fans and water pumps resulting in a high parasitic electrical energy load, which increases as fouling of the heat exchange surfaces occurs, hence regular maintenance will be required to minimise fouling.

4.4 Direct Cooling

4.4.1 The potential benefits of direct cooling for the plant include:

- **Availability of water:** Abstracted water from the River Humber could be used for cooling, as is currently used for the existing CCGT power station. The existing system operates at capacity, and lower flow through the system when the CCGT power station is not operational could result in significant silting; therefore an additional abstraction licence would need to be obtained and additional abstraction infrastructure installed.

- **Lower parasitic load:** Direct cooling represents the most efficient of the cooling processes due to the low cooling water temperature and increased heat transfer characteristic of water-cooled condensers, and therefore whilst the water pumping power is significant, it is likely to be slightly lower than for the ACC fans.

4.4.2 The potential drawbacks of direct cooling system for the plant include:

- **Operational impact of the local environment:** Abstraction of significant water volume from the Humber would require careful management to avoid impact on the local river ecology.
- **Maintenance:** One of the issues with direct cooling is the scaling of the heat exchanger, which is caused when the concentration of salt in the water film within the heat exchanger exceeds its solubility thereby leading to precipitation. Scaling reduces the performance of the heat exchanger. The fouling of heat exchanger would require more frequent maintenance works, reducing the operational efficiency of the plant.
- **Thermal effects on the local environment:** There is a need for discharge of intermittent blow-down water via direct discharge to river. An additional, thermal plume discharge from the outfall may impact on the river ecology.

4.5 Comparison of Options

4.5.1 Table 4.1 shows the performance and other operating parameters of ACC, wet, hybrid and direct cooling options, based on data presented in the EU Reference document on Best Available Techniques for Industrial Cooling Systems, 2001 and information available from Fichtner.

4.5.2 The gross electrical efficiency of the plant as a result of the application of the cooling technique is considered to be comparable across all options, as the limit on electrical power export and the required minimum pressure within the condenser. The cooling system will be sized according to the maximum thermal load that would be generated during steam turbine bypass (assumed circa 84MW; for maximum plant load and maximum electrical power export).

Table 4.1. Estimated Cooling Option Performance

Parameter	Dry ACC	Wet Cooling Tower	Hybrid (‘Wet-Dry’) Tower	Direct Once-Through Cooling
Noise emission (dBA)[1]	90-130	90-100	80-120	-70-100
Fan / pump energy (kWe)	0.42	0.92	1.34	0.11
Relative water use (Mt/y)[2]	0	1.2	1.1	66
Footprint (m²)	660	560	830	20
Capital cost[3]	£6.2 million	£9.3 million	£10.9 million	£7.3 million
Notes: 1. Based on guidance for noise emissions of different cooling systems without noise attenuation, Industrial Cooling Systems BRef, December 2001 2. Existing SHBPS abstraction licence: 870Mt/y. The estimated water use reflects the				

Parameter	**Dry ACC**	**Wet Cooling Tower**	**Hybrid (‘Wet-Dry’) Tower**	**Direct Once-Through Cooling**
use based on operation with the export of steam to the CCGT power station (normal operation). 3. The estimated capital costs do not include the costs associated with the construction of an outfall or burying of pipework.				

4.5.3 The relative performance of each of the options above is summarised in Table 4.2 below for ease of comparison.

4.5.4 Each option is rated “best”, “average” or “worst” for each category assessed

Table 4.2. Comparison of SHBEC Cooling Options

Parameter	**Dry ACC**	**Wet Cooling Tower**	**Hybrid (‘Wet-Dry’) Tower**	**Direct Once-Through Cooling**
Generation efficiency	Comparable – not all of the steam generated is condensed by SHBEC’s steam turbine			
Noise emissions	Worst	Average	Average	Best
Emissions to water	Best	Average	Average	Worst
Emissions to air	Best	Worst	Average	Best
Visual impact	Average	Worst	Average	Best
Water use	Best	Average	Average	Worst
Capital cost	Best	Average	Worst	Average
Operating cost	Best	Average	Average	Worst
Overall ranking	Best	Worst	Average	Average

4.5.5 Direct once-through cooling represents the greatest potential for impact on the water environment, followed by wet-cooling, and these options are also likely to require significant capital cost for the upgrade or addition of water abstraction infrastructure, screening of entrained organisms and discharge infrastructure, and operating cost from the use of water treatment techniques, and maintenance to avoid heat-exchange surface fouling. Once-through cooling and wet cooling tower options are therefore discounted as BAT.

4.5.6 The ACC and hybrid cooling tower options are likely to be comparable for noise emissions as both require the use of fans. The visual impacts on the local landscape associated with both the tower structures and visible plumes, are considered to be of lesser importance as the plant is located within an area with existing tall commercial and industrial infrastructure, although the flat nature of the landform makes it more sensitive to visual change.

4.5.7 Typically hybrid cooling is considered in place of ACC for power generation because of the higher gross output of the plant associated with more efficient cooling, however as discussed, the generation efficiency is considered comparable for the operational mode of the proposed development. Furthermore, the capital investment required for the installation of hybrid cooling tower option is likely to considerably higher than that for ACC on account of additional water abstraction infrastructure being required.

4.5.8 Dry ACC is therefore ranked higher than hybrid cooling, as there are no impacts to water, and no visible plumes generated from ACC.

5.0 SUMMARY

5.1.1 Dry air-cooled condensation (ACC) is considered to represent BAT for the proposed EfW facility for the following reasons:

- Comparable gross electrical efficiency to other options as the plant has a high thermal export capacity and therefore operates at a lower pressure differential that can be achieved using ACC;
- Negligible impact on the nearby protected conservation areas, with no pollutant loading or thermal discharge, nor abstraction impacts on the Humber Estuary; disturbance of feeding grounds from construction and operation would also be negligible; and
- Limited visual impact within the existing commercial/industrial landscape, with few nearby receptors.

5.1.2 Dry ACC is therefore proposed on the basis of the BAT review.