BAT Review

Introduction

The TEGCO Immingham Ltd Installation at Netherlands Way, Stallingborough, Grimsby, DN41 8DF is an Energy from Waste (EfW) process. The installation is designed to consume 320,000 Te/yr of Refuse Derived Fuel (RDF) based on 10 MJ/kg (LHV), producing: -

- 12 MW electrical export,
- 51 MW thermal export (60 Te/hr) as steam (no condensate return).

The installation is a Combined Heat & Power (CHP) plant sized and is designed to replace the steam and electricity currently generated by an existing CHP plant on an adjacent industrial plant. The existing CHP plant is reaching the end of its operational life and will be decommissioned when the installation is operational.

The need to continue to take waste in the event that steam and/or electricity cannot be exported (e.g. customer is shutdown), the installation is designed such that all steam generated at normal waste feed can pass through the turbine and condenser resulting in 24 MW electrical export.

A proportion of the RDF is sourced from local waste management companies and transported to the installation by road. The remaining is sourced from further afield and transported by rail to 1 of 2 local railheads and the final transfer from the railhead to the installation is by road.

The installation will operate continuously (24 hr/day & 7 day/week) for >8,000 hr/yr.

The installation consists of 2 off 20Te/hr incineration lines (combustor, boiler & feed-water system) and a single turbine and air cooled condenser.

The installation is designed not to generate any waste water from the process during normal operation.

The installation is designed to be fully compliant with the 2019 European BREF for Waste Incineration (JRC 118637) and the associated BAT Conclusions published in the Official Journal of the European Union on 3rd December 2019.

Assessment against BAT Conclusions

The following table summarises the BAT Conclusions (as published in the Official Journal of the European Union on 3rd December 2019 for waste incineration) and how these are reflected in the design and operation of the process at the installation.

Appendix A summarises the main BAT aspects of the process and the main reasons for their selection

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
BAT 1	Implement an environmental management system (EMS) that incorporates the 28 features identified (where relevant). The EU eco-management and audit scheme (EMAS) is an example of an EMS that is consistent this BAT	The installation will have an EMS with certification to BS EN ISO 14001. This includes all the organisational and operational requirements of EMAS including external audit. The major difference is that EMAS extends the requirement for formal reporting of performance and adds additional further external auditing. Such an EMS is accepted as BAT within the UK. Features identified: - (i) - (xx) Are directly comparable to the requirements of BS EN ISO 14001, (xxi) – (xxviii) Are specific to incineration plants however effective implementation of BS EN ISO 14001 requires the EMS to address these.
BAT 2	Determine the gross electrical efficiency, gross energy efficiency or boiler efficiency (as appropriate for the plant type(s)) BAT 19 defines the associated BAT – AEELs to be achieved.	The installation is designed to achieve the gross electrical efficiency and the gross energy efficiency BAT – AEELs identified in BAT 19. A performance test (protocol to be agreed with the EA) will be completed as part of the commissioning program to confirm actual performance.
BAT 3	Monitor key process parameters relevant for emissions to air and water including those given below: - Flue gas from incineration of waste Combustion Chamber Waste water from wet FGC Waste water from bottom ash treatment plants	The following parameters are continuously measured at the relevant locations as required by BAT 3 Flow, oxygen content, temperature, pressure & water vapour content Temperature (at 7 locations) Not applicable Not applicable
BAT 4	Monitor channelled emissions to air with at least the frequency given and in accordance with EN Standards (or other suitable standards to ensure data is of an equivalent quality)	Monitoring is to be completed as identified (standards & frequency) in the table in BAT 4. N_2O: Continuously monitored as SNCR uses Urea, HF: Periodically monitored as HCl abatement is adequate (IED provision) and subject to confirmation of performance by relevant EA protocol, Hg: Periodically monitored subject to subject to confirmation of performance by relevant EA protocol,

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BAT 5	Appropriately monitor emissions during OTNOC	Hot standby CEMS installed connected to both stacks. In normal operation this alternates between stacks meaning that it can be calibrated against the 2 primary CEMS. In the event of CEMS failure, the "hot standby" is switched to remain monitoring the affected stack. In the event that no CEMS is available to monitor a stack the relevant line is shutdown irrespective of other operational conditions.
BAT 6	Monitor emissions to water from FGC and/or bottom ash treatment	Not applicable as: - FGC does not result in emissions to water, Bottom ash treatment is not included at the installation.
BAT 7	Monitor the unburnt substances in bottom ash/slags with the frequency and methods identified	Bottom ash/slags (IBA) will be sampled, analysed & characterised as defined in EA "Technical Guidance Note (Monitoring) M4" (Version 7, June 2016) commonly known as the "EA Ash Sampling Protocol." Burnout performance is established by total organic carbon (TOC) and the plant is designed to achieve the BAT-AEPL identified in BAT 14.
BAT 8	Determine POP content in output streams when incinerating hazardous waste	Not applicable as all waste burned at the installation is classified as non-hazardous RDF arising from processes treating non-hazardous wastes.
BAT 9	Input Waste Stream Management: BAT is use techniques (a) – (c) and where relevant techniques (d), & (f) identified: -	The installation will only burn non-hazardous RDF (EWC Codes 19 12 10 & 19 12 12). As such the waste is considered to be "low risk."
	(a) Determination of waste types	The supply contract requires that the RDF conforms with a commercial specification defining limits on parameters such as: - 1. Calorific values (target and acceptable range), 2. Water content (target and range), 3. Physical state (including fines and oversize etc.) 4. Metals content, 5. Sulphur, chloride and non-combustible materials content
	(b) Waste Characterisation and pre-acceptance procedures	RDF supply contract implements suitable waste characterisation and pre-acceptance procedures
	(c) Waste acceptance procedures	Waste acceptance procedures are included as outlined in BAT 11
	(d) Waste tracking system and inventory	All RDF movements are tracked using electronic tagging of individual loads. This allows RDF movements to be tracked and inventories to be monitored.
	(e) Waste Segregation	As all waste is solid non-hazardous RDF and there is no "storage" within the installation this technique is not applicable.

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	(f) Verification of compatibility	RDF is non-hazardous solid waste arising from the treatment of non-hazardous wastes to ensure consistent composition and characteristics. Further verification of compatibility is not required other than routine operator visual checks.
BAT 10	To improve overall environmental performance of bottom ash treatment plant BAT is to implement output quality management procedures outlined in the EMS (BAT 1)	There is no bottom ash/slag (IBA) treatment plant at the installation. IBA (& all other incineration residues) are subject to quality management as outlined in BAT 7 above.
BAT 11	Monitor waste deliveries as part of waste acceptance procedures depending on the risks posed by the incoming waste.	The installation will only burn non-hazardous RDF and therefore "Municipal solid waste and other non-hazardous waste" is the appropriate category. Monitoring is outlined below: -
	Municipal solid waste and other non-hazardous waste	• Radioactivity detection is not included as EA position is that it is not required due to effective regulation of radioactive wastes. However suitable equipment has been identified and potential retrofit has been incorporated (e.g. space etc.) in the installation design
		• All RDF deliveries are weighed on arrival and empty vehicle weighed on exit.
		• Waste deliveries are subject to visual inspection from control room and crane operators at point of delivery and when being transferred from Receipt Pits to feed bunker. Periodically, discharge of individual loads will be subject to specific closer visual inspection (i.e. staff present within Tipping Hall)
		• Periodic sampling of wastes will take place (e.g. samples taken during specific closer visual inspection) potentially including separate unloading.
	Sewage Sludge	Not applicable
	Hazardous waste other than clinical waste	Not applicable
	Clinical waste	Not applicable
BAT 12	To reduce risks associated with reception, handling and storage of waste, BAT is to use both the techniques identified below	All RDF reception, handling and storage takes place within the RDF Receipt and Storage Hall

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	(a) Impermeable surfaces with adequate drainage infrastructure	The hall is enclosed and has an impermeable concrete floor with cast upstanding (including vehicle doors) around the edge preventing the ingress of rainwater and retaining any liquids (e.g. housekeeping wash water etc.) generated within the building. The nature of RDF means that concrete provides adequate resistance to abrasion and chemical attack. Operational & maintenance procedures include routine inspection of the floor, Reception Pits and Storage Bunker.
	(b) Adequate waste storage capacity	The maximum storage capacity is clearly identified and has been limited at 3 days operation at design point to allow continuous operation through public holidays etc. At other periods, RDF inventory is significantly lower to allow RDF to be mixed and rotated (to minimise variability of feed to the grate) and ensure that Pits and Bunker are emptied on a regular basis.
BAT 13	To reduce risks associated with the storage and handling of clinical waste, BAT is to use a combination of the techniques identified below	Not applicable as no clinical waste is accepted at the installation
BAT 14	To improve the overall environmental performance of the incineration of waste, reduce the content of unburnt substances in IBA and to reduce emissions to air, BAT is to use an appropriate combination of the techniques given below: -	The RDF is provided by a number of suppliers and arrives at the installation in walking floor trailers or containers tipping trailers. By definition, RDF is a blend (to a specification) of wastes from treatment process.
	(a) Waste blending & Mixing	Each container is discharged into 1 off 3 Receiving pits, the contents of the receiving pits is transferred to (and spread across) the Storage bunker by crane and then into the feed chutes, again by crane. At each transfer there is mixing and blending between loads and the 2 off 100% capacity cranes means that the RDF in the Storage bunker can be turned etc. as required. There are no liquid or pasty wastes.
	(b) Advanced control system	An advanced control system is used that uses advanced learning algorithms based on numerous process variables (e.g. RDF feed, oxygen, temperature, abatement systems performance and CEMs) to optimise combustion conditions.
	(c) Optimisation of incineration conditions	The combustors are designed using CFD techniques to ensure optimal combustion chamber design. Supplier has an established track record of supplying incinerators that have proven to meet the requirements of IED.

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	BAT-AEPL quoted is 1 – 3 Dry wt-% for TOC.	As indicated in BAT 7, burnout performance is established by total organic carbon (TOC).
BAT 15	To improve the overall environmental performance of the incineration of waste and to reduce emissions to air, BAT is to set up and implement operational procedures for the adjustment of the plant settings.	An advanced control system is used that uses advanced learning algorithms based on numerous process variables (e.g. RDF feed, oxygen, temperature, abatement systems performance and CEMs) to optimise combustion conditions. As an example, the SNCR control system uses a real time temperature model (based on 7 points) to optimise the injection of urea via 21 injection points maximising NOx reduction & minimising NH_3 generation).
BAT 16	To improve the overall environmental performance of the incineration of waste and to reduce emissions to air, BAT is to set up and implement operational procedures to limit as far as practicable shutdown and start-up operations.	The use of RDF (to a common specification) from multiple suppliers helps to ensure reliable waste supply to the installation in the event of operational issues at a supplier. The use of 3 pits and a storage bunker allow further mixing and blending at the installation eliminating significant step changes in feed composition to the combustors reducing the potential for process instability and unplanned shutdowns. The 3 day RDF storage capacity allows RDF inventory to be ramped up when approaching periods of restricted supply (e.g. Bank holidays, transports issues etc.). The plant is designed to operate in CHP mode (design case) or full condensing mode (electricity export to the grid only) allowing continued operation in the event of loss of off-taker.

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BAT 17	To reduce emissions to air (& water if relevant) from the incineration plant, BAT is to ensure that the FGC system (and any WWTP) is appropriately designed	The FGC system is designed to process the flue gases arising from operating at 110% of design grate throughput at RDF specification range upper limits. The FGC system effectively abate emissions from RDF with: - • Sulphur content up to 133% of design range, • Chlorine content up to 125% of design range, • Fluorine content up to 200% of design range, • Moisture content up to 128% of design range. Other design features include duty and standby equipment (e.g. pumps), twin systems, internal buffer storage (e.g. bag-filter hoppers), excess capacity (e.g. Bag-filters provide full capacity with a section isolated) to allow operations to continue at design rate in the event of equipment failure. Planned and predictive maintenance regimes are used to ensure reliable operation and provide warning of failure to minimise unplanned “emergency” shutdowns.
BAT 18	To reduce the frequency of OTNOC of equipment critical to protection of the environment, BAT is to set up and implement a risk based OTNOC management plan as part of the EMS that includes the following elements.	An OTNOC management plan will be developed during final design and commissioning. The EMS requires that this be reviewed on a routine basis and following an OTNOC event.
	• Identification of potential OTNOCs, their root causes, their potential consequences and regular review/update,	Initial OTNOC management plan included in application.
	• Appropriate design of critical equipment,	Critical equipment has been identified and appropriate design measures included, example include :- • Main bag-filters are designed to provide full abatement with 1 section isolated, • Bag-filters are not bypassed at start-up and shutdown, • Duty & standby (with automatic start) arrangements are employed on critical equipment where practicable, • Duplicate systems installed for critical duties allowing operation to continue in the event of 1 system,
	• Set-up & implement preventative maintenance plan,	A preventative maintenance plan will be developed during final design and implemented during commissioning.

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	• Monitoring and recording of emissions during OTNOC and associated circumstances,	CEMs systems will continue to operate during many periods of OTNOC, ensuring that emissions data continues to be captured and recorded. Other process parameters (and equipment operational status) will continue to be monitored and recorded.
	• Periodic assessment of emissions during OTNOC and implementation of corrective measures	Periodic assessment (& development of corrective measures) will be completed as part of the annual performance report. All instances of OTNOC will be investigated and corrective measures developed where appropriate.
BAT 19	In order to increase resource efficiency, BAT is to use a heat recovery boiler	The installation includes heat recovery boilers on both incineration lines and the primary design mode is a CHP with steam & electricity off-take. The installation can also operate in full condensing mode maximising electricity production when the steam off-take is not required.
BAT 20	In order to increase energy η, BAT is to use an appropriate combination of the techniques below: -	Techniques used are (b), (c), (d), (f) & (g). Technique (a) not relevant.
	(a) Drying of Sewage Sludge,	Not applicable
	(b) Reduction of the fuel gas flow,	• CFD design optimises primary and secondary combustion air distribution, • Flue – recirculation is employed (circa 18.5%)
	(c) Minimisation of heat losses,	Heat is recovered as far as practicable, examples include: - • Combustion air is drawn from the boiler house recovering heat lost from hot surfaces, • Use of appropriate specification and thickness of refractory and insulation on hot surfaces, • Heat recovered from grate cooling water into condensate system, • Flue – recirculation is employed (circa18.5%).
	(d) Optimisation of boiler design,	CFD boiler design is optimised to maximise heat transfer including: - • Optimising flue gas velocity and distribution, • Using multi-pass steam system incorporating evaporators, super-heaters & economisers, • 3 off on-line cleaning systems (proprietary “shower cleaning” system, pneumatic & steam soot blowers) to optimise cleaning in different sections of the boiler, • Easy removal for boiler tubes allowing effective deep cleaning and minimising duration of boiler outage.

BAT Conclusion **Ref:**	**Summary of BAT Conclusion**	**Implementation at Installation**
	(e) Low temperature flue-gas heat exchangers,	Not employed, flue gas temperature post FGC system is relatively low and further reduction will :- • Adversely affect dispersion requiring taller stacks, • Increase likelihood of visible plume formation, particularly outside summer months due to flue-gas water vapour concentration.
	(f) High Steam Conditions (>45bar & 400°C)	The boilers generate steam @ 421°C & 56 $bar_{(a)}$ and therefore constitutes use of high steam conditions as defined in the BREF Conclusions.
	(g) Cogeneration	The primary design and operational mode of the installation is CHP or co-generation (export of steam and electricity to meet off-taker requirements)
	(h) Flue-gas condenser,	Not applicable as no demand for sufficiently low temperature heat identified.
	(i) Dry bottom ash handling,	Not incorporated into the design, The use of recovered water for bottom ash quench :- • Results in a dust free bottom ash minimising potential dust issues during handling and storage, • Is part of wider design considerations to eliminate waste water emissions from the incineration process.
	Relevant BAT-AEELs quoted for new plant are: -	The primary operational mode (i.e. design point) of the plant is CHP (steam & electricity export) however it can also operate in full condensing mode. The BAT Conclusions document suggests that “gross electrical η” is the relevant BAT-AEEL to assess BAT.
	Gross Electrical η: 25-35%	Based on design calculation is 30.49%. This is within the BAT-AEEL range quoted. EA guidance indicates that new plant should achieve at least 30% η.
	Gross Energy η: 72-91%	Based on design calculation is 75.94%. This is within the BAT-AEEL range quoted. This is largely determined by the off-takers requirements (i.e. the required electricity/steam balance)
BAT 21	Prevent or reduce diffuse emissions (including odour), BAT is to	
	• Store wastes that are odorous/prone to releasing volatile substances in enclosed buildings, at sub atmospheric pressure and use extracted air as combustion air/send to suitable abatement	All RDF storage and handling takes place in the RDF Receiving & Storage Hall. The hall is fitted with automated fast acting vehicle doors to minimise air ingress. Primary combustion air is drawn from the hall and adjacent boiler house.

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	• Store liquid wastes in tanks under appropriate ………………..	Not applicable, no liquid wastes received at the installation.
	• Control risk of odour during complete shutdown periods when no incineration capacity is available by: -	
	○ Venting/extracting air via alternative abatement system,	Alternative abatement system not considered to be required as no RDF present during shutdown periods.
	○ Minimising amount of waste in storage,	RDF inventory and deliveries are rundown prior to complete shutdown to ensure the pits and bunkers are empty. RDF deliveries are stopped/diverted during shutdown. The use of 2 lines means that a single line can be shutdown for maintenance etc. and the other continue to operate maintaining the sub atmospheric pressure in the hall. In the event of unexpected complete shutdown, RDF will be returned to suppliers or alternative licenced treatment facilities.
	○ Storing in properly sealed bales.	Not applicable, waste delivered in closed walking floor vehicles or closed containers.
BAT 22	Diffuse emissions from gaseous & liquid wastes	Not applicable as no gaseous or liquid wastes received at the installation.
BAT 23	To prevent/reduce diffuse emissions to air from treatment of bottom ashes/slags, BAT is………………………..	Not directly applicable as no treatment of IBA takes place at the installation. However IBA handling, storage and loading (for export) take place with closed buildings and export trailers are closed to prevent point and diffuse emissions. EMS includes procedures operational and maintenance procedures to control potential dust emissions from IBA storage & export.
BAT 24	To prevent/reduce diffuse dust emissions to air from the treatment of bottom ashes/slags, BAT is to use an appropriate combinations of the techniques below: -	Not directly applicable as no treatment of IBA takes place at the installation. However similar consideration can apply to IBA handling, storage and loading (for export).
	(a) Enclose and cover equipment,	All IBA handling, storage and export loading takes place within closed buildings
	(b) Limit height of discharge,	Height of discharge into bunker & into export trailers is minimised as far as practicable.
	(c) Protect stockpiles against prevailing winds,	IBA bunker/heap is within a closed building
	(d) Use water sprays,	Water sprays are not expected to be required, however these can easily be added if IBA is found to dry our resulting in dust issues when handling

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	(e) Optimise moisture content,	Wet quench system is used and this ensures that IBA is produced as a dust free solid.
	(f) Operate under sub atmospheric pressure	As combustion air is also drawn from boiler house, it is likely that most of the IBA handling system will actually operate in slight sub atmospheric environment.
BAT 25	To reduce channelled emissions to air of dust, metals and metalloids from the incineration of waste, BAT is to use one or a combination of the techniques below: -	Techniques (a) & (c) used at the installation.
	(a) Bag filter	Bag filters are used on both incineration lines.
	(b) Electrostatic precipitator	Electrostatic precipitators are not used as particulate loading is expected to result in sensible bag cycle times (i.e. clean to clean).
	(c) Dry sorbent injection	Dry sorbent injection (powdered activated carbon) is used as this works effectively with selected acid gas abatement selected.
	(d) Wet scrubber	Wet scrubber not used: - • Part of design is to prevent generation waste water emissions, • Wet scrubber produces cooler saturated flue gas adversely affecting dispersion and creating visible plume, • Flue gas reheat would adversely affect efficiency.
	(e) Fixed or moving bed adsorption	Not used as HG, metals, metalloids, organics (including PCDD/F etc.) are not present in high concentrations and activated carbon injection provides appropriate abatement.
	Relevant BAT-AELs quoted for new plant are: -	ELVs quoted are those requested in permit application and used for environmental impact assessment etc.
	Dust: 2 – 5 mg/Nm^3 (daily average).	ELV: 5 mg/Nm^3 (daily average).
	Cd & Tl: 0.005 – 0.022 mg/Nm^3 (average over sampling period).	ELV: 0.022 mg/Nm^3 (average over sampling period).
	Sb, As, Pb, Cr, Co, Cu, Mn, Ni & V: 0.01 – 0.3 mg/Nm^3 (average over sampling period).	ELV: 0.3 mg/Nm^3 (average over sampling period).
BAT 26	To reduce channelled emissions to air of dust, metals and metalloids from the treatment of bottom ashes/slags, BAT is to treat extracted air with a bag filter	Not directly applicable as no treatment of IBA takes place at the installation. However bag filters are used on all exhausts from solid raw material and residue systems.

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	BAT-AEL quoted is 2 – 5 mg/Nm^3 (average over sampling period).	Bag filter performance on solid raw material and residue systems expected to be at bottom of range. ELV 5 mg/Nm^3 (average over sampling period).
BAT 27	To reduce channelled emissions to air of HCl, HF & SO_2 from the incineration of waste, BAT is to use one or a combination of the techniques below: -	Option (c) used at the installation.
	(a) Wet Scrubber	Not selected as: - • Increases water consumption and generates waste water emission, • Unless flue gas is reheated results in poor dispersion (due to low flue gas temperature) and highly visible plume, • Flue gas reheat would adversely affect efficiency.
	(b) Semi-wet scrubber	Not selected as dry sorbent inject achieves required level of abatement and is simpler to operate and more cost effective.
	(c) Dry sorbent injection	Selected as: - • Achieves appropriate standard of abatement for stable acid gas concentrations arising from incineration of RDF, • Does not require use of water (resource efficiency), • Does not result in waste water emissions/discharge (part of design objective, • Flue gas temperature within efficient operating temperature range. • Is proven on similar plant and cost effective, • Hydrated lime used as commercial outlets available for residues (rather than disposal to landfill)
	(d) Direct desulphurisation	Only applicable to fluidised bed furnaces and these are not used at the installation.
	(e) Boiler sorbent injection	Not selected as primary use is upstream of other abatement when acid gas concentrations are high (not the case when incinerating RDF).
BAT 28	To reduce channelled emissions to air of HCl, HF & SO_2 from the incineration of waste while limiting the consumption of reagents and the amount of residues generated by dry sorbent and semi-wet adsorbers, BAT is to use technique (a) or both of the techniques given below: -	Techniques (a) & (b) used at the installation

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	(a) Optimised & automated reagent dosage	The control system automatically adjusts reagent dosage using algorithms based on expected RDF quality, process conditions and emissions. The use of RDF means consistent levels of Sulphur & Chlorine (over time) in the feed and steady combustion. This results in reduced variability of acid gas loading on the FGC system. The control system also receives data from the CEMS and uses this to further trim dosage rates.
	(b) Recirculation of reagents	A proportion of the FGCr is recirculated.
	Relevant BAT-AELs quoted for new plant are: -	ELVs quoted are those requested in permit application and used for environmental impact assessment etc.
	HCl: 2 - 6 mg/Nm^3 (daily average).	ELV: 6 mg/Nm^3 (daily average).
	HF: < 1 mg/Nm^3 (daily average) OR < 1 mg/Nm^3 (average over sampling period).	Requested derogation allowing HCl CEMS to be used as surrogate parameter for HF. Levels of Florine in RDF are expected to be low and consistent while HF has similar (but more reactive) chemistry to HCl. Proposing periodic monitoring subject to demonstration of HF performance via relevant EA protocol. ELV: < 1 mg/Nm^3 (average over sampling period).
	SO_2: 5 – 30 mg/Nm^3 (daily average).	ELV: 30 mg/Nm^3 (daily average).
BAT 29	To reduce channelled NO_X emissions to air while limiting the emissions of CO & N_2O from the incineration of waste and the emissions of NH_3 from the use of SNCR and/or SCR, BAT is to use an appropriate combination of the techniques given below: -	Options (a), (b), (c) & (f) are used at the installation.
	(a) Optimisation of the incineration process	The process equipment vendor has a proven record of supplying plants for the incineration of RDF (and other similar wastes) that have performed reliably and demonstrated a good compliance record. They have continually improved and optimised equipment design and control systems.
	(b) Flue-gas recirculation	Flue-gas recirculation (circa 18.5%) is used on both incineration lines at the installation.

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	(c) Selective non-catalytic reduction (SNCR)	SNCR is used on both incineration lines at the installation. The almost default use of SNCR for incineration plants burning non-hazardous wastes such as RDF and municipal/other non-hazardous wastes has resulted in more improved SNCR (efficiency and abatement performance) meaning that there is currently little justification (in terms of abatement performance) to use the more costly SCR abatement on most developments. The IED requirement for residence time and temperature when incinerating non-hazardous wastes are consistent with the optimal conditions for SNCR minimising capital costs and operational complexity.
	(d) Selective catalytic reduction (SCR)	The almost default adoption of SNCR for incineration plants burning non-hazardous wastes such as RDF and municipal/other non-hazardous wastes has resulted in more improved SNCR (efficiency and abatement performance) meaning that there is currently little justification (in terms of abatement performance) to use the more costly SCR abatement on most developments.
	(e) Catalytic filter bags	Not use at the installation as SNCR achieves required standard of abatement. Catalytic filter bags are also significantly more costly and there are additional environmental issues (due to the catalyst contained within the media) associated with their disposal. Should suitable non disposal options become established and/or NOx emissions need to be further reduced these can be retrofitted.
	(f) Optimisation of SNCR/SCR design and operation	SNCR system uses 7 temperatures to build up a 2D model of the chamber and 21 injectors to optimise the injection rates and locations to optimise NO_X abatement and minimise NH_3 generation.
	(g) Wet scrubber	Not used at the installation as: - • Increases water consumption and generates waste water emission, • Unless flue gas is reheated results in poor dispersion (due to low flue gas temperature) and highly visible plume, • Flue gas reheat would adversely affect efficiency.
	Relevant BAT-AELs quoted for new plant are: -	ELVs quoted are those requested in permit application and used for environmental impact assessment etc.

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	NO_X: 50 - 120 mg/Nm^3 (daily average).	EA guidance indicates that the presumed ELV for new plant using SNCR is 100 mg/Nm^3 (daily average). The equipment vendor has confirmed that SNCR system proposed can reliably achieve this. ELV: 100 mg/Nm^3 (daily average).
	CO: 10 - 50 mg/Nm^3 (daily average).	ELV: 50 mg/Nm^3 (daily average).
	NH_3: 2 – 10 mg/Nm^3 (daily average).	The equipment vendor has confirmed that SNCR system proposed can reliably achieve the BAT-AEL range. ELV: 10 mg/Nm^3 (daily average).
BAT 30	To reduce channelled 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: -	Techniques used are (a), (b), (c), (d) & (e)
	(a) Optimisation of the incineration process	The process equipment vendor has a proven record of supplying plants for the incineration of RDF (and other similar wastes) that have performed reliably and demonstrated a good compliance record. They have continually improved and optimised equipment design and control systems.
	(b) Control of waste feed	Use of RDF (i.e. waste of "known compositional range") together with blending of loads (pits and storage bunker).
	(c) On-line & off-line boiler cleaning	3 off boiler cleaning systems installed. Boiler tubes designed for easy removal to allow offline
	(d) Rapid flue-gas cooling	Boiler is designed using CFD to ensure: - • Rapid cooling through the "de novo" temperature range (400°C – 250°C), • Minimise dust impingement/deposition on internal boiler surfaces, • Minimisation of boiler surfaces operating within the de novo synthesis temperature range

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	(e) Dry sorbent injection	Selected as: - • Achieves appropriate standard of abatement for concentrations of organic compounds arising from incineration of RDF, • Does not require use of water (resource efficiency), • Does not result in waste water emissions/discharge (part of design objective, • Flue gas temperature within efficient operating temperature range. • Is proven on similar plant and cost effective, • Hydrated lime used as commercial outlets available for residues (rather than disposal to landfill)
	(f) Fixed or moving-adsorption	Not used as organic compounds (including PCDD/F etc.) are not present in high concentrations and activated carbon injection provides appropriate abatement.
	(g) SCR	The almost default adoption of SNCR for incineration plants burning non-hazardous wastes such as RDF and municipal/other non-hazardous wastes has resulted in more improved SNCR (efficiency and abatement performance) meaning that there is currently little justification (in terms of abatement performance) to use the more costly SCR abatement on most developments.
	(h) Catalytic filter bags	Not use at the installation as SNCR achieves required standard of abatement. Catalytic filter bags are also significantly more costly and there are additional environmental issues (due to the catalyst contained within the media) associated with their disposal. Should suitable non disposal options become established and/or NOx emissions need to be further reduced these can be retrofitted
	(i) Carbon sorbent in a wet scrubber	Not applicable as wet scrubber not used.
	Relevant BAT-AELs quoted for new plant are: -	ELVs quoted are those requested in permit application and used for environmental impact assessment etc.
	TVOC: 3 - 10 mg/Nm^3 (daily average).	ELV: 10 mg/Nm^3 (daily average).

BAT Conclusion		**Implementation at Installation**
Ref:	**Summary of BAT Conclusion**	
	PCDD/F & Dioxin like PCBs	Historically EA has required reporting of both parameters therefore ELVs proposed for both. PCDD/F, PCBs and their precursors in RDF are expected to be low and stable. Proposing periodic monitoring subject to demonstration of emissions performance via relevant EA protocol.
	PCDD/F: <0.01 – 0.04 ng I-TEQ/Nm^3 (average over sampling period).	ELV: 0.04 ng I-TEQ/Nm^3 (average over sampling period).
	PCDD/F + PCBs: <0.01 – 0.06 ng WHO-TEQ/Nm^3 (average over sampling period).	ELV: 0.06 ng WHO-TEQ/Nm^3 (average over sampling period).
BAT 31	To reduce channelled mercury emissions to air (including mercury emission peaks) from the incineration of waste, BAT is to use one or a combination of the techniques given below: -	Techniques used are (b) & (c). The increasingly stringent restrictions on the use of Hg over a long period mean that the risk of Hg being present in the non-hazardous wastes from which RDF is derived is extremely low and expected to continue to fall. Processes using & the use of products containing Hg are tightly regulated and resultant wastes are classified as hazardous (therefore excluded as precursors for RDF).
	(a) Wet scrubber (low ph).	Not used at the installation as: - • Increases water consumption and generates waste water emission, • Unless flue gas is reheated results in poor dispersion (due to low flue gas temperature) and highly visible plume, • Flue gas reheat would adversely affect efficiency, • Dry sorbent inject achieves adequate abatement for the Hg levels arising from RDF
	(b) Dry sorbent injection.	Dry sorbent injection has proven to achieve adequate abatement for Hg across many incineration plants burning RDF and non-hazardous wastes (as demonstrated by the recently reduced BAT AEL for existing plants)
	(c) Injection of special highly reactive activated carbon	Powdered activated carbon product used is specifically developed as an abatement sorbent for incineration and combustion processes.
	(d) Boiler bromine addition	Not adopted.
	(e) Fixed or moving-adsorption	Not used as Hg is not present in significant concentrations and activated carbon injection provides appropriate abatement.

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	Relevant BAT-AEL quoted for new plant is: -	ELVs quoted are those requested in permit application and used for environmental impact assessment etc. Proposing periodic monitoring subject to demonstration of emissions performance via relevant EA protocol.
	Hg: 5 - 20 mg/Nm^3 (average over sampling period).	ELV: < 20 mg/Nm^3 (average over sampling period).
Bat 32	To prevent contamination of uncontaminated water, reduce emissions to water and increase resource efficiency, BAT is to segregate waste water streams and to treat them separately, depending on their characteristics.	There are no emissions to water from the prescribed process. Wet scrubber not used to minimise water use and waste water generation. All waste water streams (treatment plant brine, blowdown, drains in process areas etc.) are collected and reused within the incineration process.
BAT 33	To reduce water usage and prevent/minimise generation of waste water from the incineration plant, BAT is to use one or a combination of techniques given below	Techniques used are (a) & (c)
	(a) Waste-water free FGC techniques	Dry sorbent injection used
	(b) Injection of waste water from FGC	Not applicable as dry sorbent injection FGC used
	(c) Water reuse/recycling	All water arising from incineration process operations are recycled via the Process water system.
	(d) Dry bottom ash handling	Not applicable, recycled water used in quench to produce dust free IBA.
BAT 34	To reduce emissions to water from FGC and or from the storage and treatment of slags and bottom ashes…………………………	Not applicable as dry sorbent FGC used and no treatment of bottom ash/slags
BAT 35	To increase resource efficiency, BAT is to handle and treat bottom ashes separately from FGC	No treatment of residue streams at the installation. However IBA, fly ash and FGCr are segregated to maximise opportunities for recycling etc. and minimise disposal to landfill.
BAT 36	To increase resource efficiency for the treatment of slags & bottom ashes, BAT is to…………………….…	Not applicable as no treatment of bottom ash/slags.
BAT 37	To prevent/reduce noise emissions, BAT is to use one or a combination of the techniques given below: -	Techniques used are (a), (b), (c), (d) & (e).
	(a) Appropriate location of equipment and buildings.	Process location largely determined by need to access the gas grid, electricity grid and be close to off-taker; however it is located away from sensitive receptors. Air conditioners and louvres are located on building façade facing away from sensitive receptors and towards the back of surrounding industrial buildings.

BAT Conclusion Ref:	Summary of BAT Conclusion	Implementation at Installation
	(b) Operational measures.	Planned preventative maintenance regime (as per equipment vendor's recommendations) is in place. As far as practicable all potentially noisy equipment is within buildings and all doors etc. are closed (to maintain sub atmospheric internal pressure). No HGV movements between 22:00 & 06:00 hrs
	(c) Low-noise equipment.	Noise generation considered when selecting equipment and all is appropriate design standards etc.
	(d) Noise attenuation	Building designed to achieve specified levels of attenuation. Flood bank on adjacent beck also acts as sound barrier for HGV movements etc.
	(e) Noise control equipment/infrastructure	Noisy equipment installed within building when possible or within noise enclosures. ACC structure includes noise baffles.

BAT Techniques Ref:	Summary of BAT Conclusion	Implementation at Installation
2.1	Advanced control system	Proven computer based combustion control system provided by equipment vendor.
	Optimisation of the incineration process	Use of RDF & blending in pits, storage bunker and feed chutes provides consistent feed composition. Grate used proven for wastes incinerated. Proven combustor design based on CFD design to optimise combustion conditions including :- • Primary & secondary combustion air injection, • Gas flow paths, temperature distribution and residence time, • Monitoring of temperature, O_2, & CO in combustion chamber
2.2	Bag filter	Bag filters used that are appropriate for the flue gas conditions present. These provide appropriate dust abatement (including sorbent & acid gas reagent residues) for the wastes burned.
	Boiler sorbent injection	Not used

BAT Techniques Ref:	Summary of BAT Conclusion	Implementation at Installation
	Catalytic filter bags	Not used as sorbent injection and standard bags provide appropriate abatement for the waste incinerated. Catalytic filter bags are considerably more expensive than standard filter bags and are a greater waste issue than standard bags, however these can be retrofitted if emissions performance of relevant species proves unsatisfactory.
	Direct desulphurisation	Not used
	Dry sorbent injection	Hydrated lime & powdered activated carbon used for acid gas & organic/volatile species
	Electrostatic precipitator	Not used, waste incinerated and combustor design mean that flue gas does not contain very high dust loading and bag filter provides appropriate abatement.
	Fixed- or moving-bed adsorption	Not used
	Flue-gas recirculation	Flue gas recirculated after ID fan (circa 18%)
	Selective catalytic reduction (SCR)	Not used, greater cost (capital and operational) than SNCR.
	Selective non-catalytic reduction (SNCR)	Modern SNCR system proven to provide appropriate abatement for the wastes incinerated.
	Semi-wet absorber	Not used.
	Wet scrubber	Not used, process design is to produce no emissions to water and "standard" SNCR, dry sorbent, bagfilter and FGR provides appropriate abatement for the waste incinerated. Wet scrubber :- • Increases water consumption and generates waste water emission, • Unless flue gas is reheated results in poor dispersion (due to low flue gas temperature) and highly visible plume, • Flue gas reheat would adversely affect efficiency.
2.3	Techniques to prevent/minimise emissions to water	Not applicable as no emissions to water. Process design includes reuse of all waste water stream generated.
2.4	Odour management plan	Use of BAT measures to minimise odour (enclosed buildings extracted via incineration lines etc.) and location of plant means that no specific additional odour management plan is considered necessary. Use of ISO 14,001 EMS includes generic requirements re odour and that additional measures etc. will be implemented if odour emissions are not adequately addressed by existing design and operational measures.

BAT Techniques Ref:	 Summary of BAT Conclusion	Implementation at Installation
	Noise management plan	Use of BAT measures to minimise noise (enclosed buildings, noise enclosures, equipment selection, etc.) and location of plant means that no specific additional noise management plan is considered necessary. Use of ISO 14,001 EMS includes generic requirements re noise and that additional measures etc. will be implemented if noise emissions are not adequately addressed by existing design and operational measures. Noise modelling indicates "negligible impact" at sensitive receptors: - • BS 4142: impact at sensitive receptors "low Impact" (minimum 5 dB below existing background), • Ambient Noise: No increase.
	Accident management plan	Appropriate accident management plan is requirement of ISO 14,001 EMS. Specific fire prevention plan produced in accordance with relevant guidance including :- • Fire detection, • Firefighting measures, • Management of fire water run-off, • Training.

BAT Review

Appendix 1

Main BAT Considerations

Introduction

The TEGCO Immingham Ltd installation is designed to be fully compliant with the 2019 European BREF for Waste Incineration (JRC 118637) and the associated BAT Conclusions published in the Official Journal of the European Union on 3rd December 2019.

The installation is a Combined Heat & Power (CHP) plant designed not to generate any waste water during normal operation.

The main BAT techniques are: -

- Pre-treatment and blending of waste prior incineration,
- Use of reciprocating plate grate,
- NO_X abatement using staged combustion with advance control, Flue gas recirculation and SNCR,
- Acid gas & organic species abatement by dry reagent injections (Hydrated Lime & Powdered activated Carbon),
- Particulate matter abatement by bag filter,
- Plume dispersion by suitably designed stack.

This selection of techniques is now almost "default" or standard design approach for plants incinerating solid non-hazardous waste in the UK.

Pre-Treatment & Blending of Waste

The use of RDF produced to an agreed specification reduces the variability of waste characteristics between batches from a single supplier and between different suppliers.

The use of Receiving Pits and Feed Bunker allow further blending between deliveries prior to feeding the incineration lines.

The more consistent the feed to the grate is, the more consistent the combustion conditions are and the more consistent and predictable the resultant emissions.

This is considered to be BAT for waste preparation and receipt.

Reciprocating Plate Grate

The grate used is of "forward feed design" using a combination of water and air cooled combustion zones. The water cooled zone is the main combustion zones while air cooled an air cooled grate is used in the burnout zone.

The BREF Note indicates that this type of grate is: -

- Very widely proven on large scales.
- Robust – low maintenance cost.
- Long operational history.
- Can take heterogeneous wastes without special preparation.

The grate is controlled by an advanced combustion control system to ensure consistent and stable combustion conditions (Controls include speed of waste feed rates, speed of grate movement, air flows, composition & temperature to the different sections of the grate.)

This grate is therefore considered to be BAT for the combustion stage

NO_X Abatement

The following techniques are incorporated into the design to minimise NO_X emissions: -

- Staged combustion.
- Flue gas recirculation (FGR).
- Advanced combustion control system (ACCS).
- Selective non-catalytic reduction (SNCR) using Urea solution.

Of these Staged combustion and FGR are essentially considered to be primary measures (i.e. should be included unless their omission can be justified. Similarly, the ACCS is considered to be BAT and minimising NO_X generation is only one of its benefits.

There are 2 off identified BAT options for active NO_X abatement these are SNCR and Selective catalytic re reduction (SCR). To select the most appropriate option requires review on a site and process specific basis. However in the UK, this assessment has almost invariably concluded that SNCR is considered to be BAT and is reflected in Environment Agency BREF guidance that indicates that the required ELV of 100 mg/Nm3 can be achieved using SNCR. The main factors to be considered are: -

- Capital costs.
- Direct operating costs.
- Indirect operating costs.
- Other considerations (e.g. H&S, emissions).

<u>Capital Costs</u>

The relative capital costs for abatement equipment of the 2 options are summarised in the table

	SNCR (Base Case)	SCR (Option)
Capital	£1,879,416.00	£6,603,720.00
Capital Ratio	1	3.51
Change in Capital Cost	N/A	+£4,724,304.00

Considering these costs it is clear that SCR is significantly more costly in terms of capital investment. This is largely due to the additional equipment that has to be installed for SCR (flue gas ducts, heat exchanger and associated civils and electrical works)

<u>Direct Operating Costs</u>

The direct operating costs arise from the operation of the systems and are due reagents and services etc. used to operate the system. These costs are related to operational hours and abatement achieved. The following comparison assumes: -

- Equivalent levels of abatement (i.e. emission concentration).
- Operation at 8,000 hrs per year.
- 2 incineration lines.
- Design life 25 years.

The costs of reagents and catalysts are summarised in the table below: -

Item	SNCR (Base Case)	SCR (Option)
Urea Solution: Hourly usage per line Total annual usage Cost Annual Cost	 190 kg/hr 3,040 Te/yr 229.20 £/Te 696,768.00 £/yr	 N/A N/A N/A N/A
Ammonia Solution: Hourly usage per line Total annual usage Cost Annual Cost	 N/A N/A N/A N/A	 104 kg/hr 1,664 Te/yr 196.80 £/Te 327,475.20 £/yr
Catalyst: Cost per year per line Annual Cost	 N/A N/A	 110,619.47 £/yr 221,238.94 £/yr
Electrical Consumption MWhr cost/value Annual Cost	20 kW 60.00 £/MWhr 9,600.00 £/yr	20 kW 60.00 £/MWhr 9,600.00 £/yr
Annual Direct Operating Cost	706,368.00 £/yr	558,314.14 £/yr
Operating Cost Ratio	1	0.79
Lifetime Direct Operating Cost	17,659,200.00 £	13,957,853.50 £
Change in lifetime Cost	N/A	-3,701,346.50 £

<u>Indirect Operating Costs</u>

The Directive includes the requirement to maintain the combustion gases at ≥850°C for ≥2 seconds when incinerating non-hazardous wastes which is consistent with the optimum operating temperature range for SNCR abatement.

SCR is installed after the flue gas cleaning (FGC) system to prevent the catalyst being poisoned by gaseous products of combustion (e.g. SO_2 etc.). The optimum operating temperature range for SCR is higher than the temperature of the flue gases following FGC meaning that the flue gases have to be reheated using steam. The additional heat exchangers, ductwork and catalysts also generate additional pressure drop in the flue gas path increasing load on the fans.

These factors adversely impact overall efficiency of the process, increasing parasitic loads resulting in the loss of 1.5MW electricity export.

Item	SNCR (Base Case)	SCR (Option)
Loss in Electrical Export: Instant Total Annual MWhr cost/value Annual Cost	 N/A N/A N/A N/A	 1.5 MW 12,000 MWhr/yr 60.00 £/MWhr 720,000 £/yr
Annual Indirect Electrical Cost	N/A	720,000.00 £
Lifetime Indirect Electrical Cost	N/A	+18,000,000.00 £

The total lifetime costs for the 2 options are summarised in the table below: -

Costs	SNCR (Base Case)	SCR (Option)
Capital Cost Direct Costs Indirect Costs	1,879,416.00 £ 17,659,200.00 £ N/A	6,603,720.00 £ 13,957,853.50 £ 18,000,000.00 £
Total lifetime Cost	19,538,616.00 £	38,561,573.50
Total Cost Ratio	1	1.97
Change in Cost	N/A	+19,022,957.50 £

Therefore, for the same level of NO_X abatement: -

- Lifetime cost of SCR is approximately twice that of SNCR.
- The additional lifetime cost is approximately 19 £million.
- The increase in cost is almost entirely due to value of the lost electricity production resulting from the need to reheat the flue gas.

<u>Other Considerations (e.g. H&S, emissions)</u>

There are other considerations to be considered including: -

- SCR generates additional waste stream (Spent Catalyst).
- H&S issues associated with the use of Ammonia (SCR).
- Potential odour issues due to volatility of Ammonia, making handling and storage activities more complex (SCR).
- Potential additional regulatory demands (e.g. additional emissions monitoring on raw material storage with ammonia (SCR)).
- Footprint, SCR has an additional footprint of at least 207 m^2 while SNCR is contained within the combustor/boiler footprint.
- The use of staged combustion, flue gas recirculation and advance combustion control system minimise NO_X formation (At high NO_X loadings SCR generally performs better than SNCR).
- Modern SNCR systems are now nearly as effective as SCR in terms of abatement efficiency.

<u>Conclusion</u>

SNCR is therefore considered to be BAT for NO_X.

Acid Gas & Organic Species Abatement

Dry sorbent injection (using Hydrated Lime) is used rather than a wet abatement system. The main reasons are: -

- To minimise water usage.
- To avoid generation of a liquid effluent.
- The use of non-hazardous RDF means that acid gas precursor inputs into the system are controlled preventing high concentrations of acid gas generation (for which wet abatement systems are better suited).
- Dry sorbent injection is a well proven, cost effective and reliable technique for non-hazardous waste incineration.

The primary reasons that Hydrated Lime has been selected as the reagent are: -

- It is more cost effective.
- The residues produced have lower leaching properties reducing potential disposal costs.
- There are greater opportunities for the residues to be recycled.

Further detail is included in the document Raw Materials.

Powdered activated Carbon is used to abate organic species this is almost the default design for dry sorbent flue gas cleaning systems on non-hazardous waste incinerators.

Dry sorbent injection (Hydrated Lime & Powdered activated Carbon) is therefore considered to be BAT for the abatement of acid gases and organic species.

Particulate Matter Abatement

Bag filters are used rather than a wet abatement system. The main reasons are: -

- To minimise water usage.
- To avoid generation of a liquid effluent.
- Bag filters are a well proven, cost effective and reliable technique for abating particulate matter emissions from non-hazardous waste incineration.
- Particulate matter loading in flue gas is not excessive resulting in sensible bag life (largely a function of cleaning frequency).
- The cake that builds up on bag filters contains unreacted sorbent. The flue gas passes through the cake bringing any acid gas species into close contact with the sorbent providing significantly increased abatement.
- The cake that builds up on bag filters contains unreacted sorbent. The flue gas passes through the cake bringing any organic species into close contact with the sorbent providing significantly increased abatement.

Bag filters are therefore considered to be BAT for the abatement of particulate matter.

Plume Dispersion by suitably designed stack.

The stacks are designed to achieve: -

- Exit velocity >15m/s to minimise the potential for downwash that results in reduced dispersion.
- Exit temperature of 170°C ensures plume buoyancy (improving dispersion) and reduces the plume visibility (due to condensation of water droplets).
- Stack height is sufficient to ensure good dispersion at the BAT_{AEL} ELVs in the latest BREF documents (demonstrated by air dispersion modelling using the UK Atmospheric Dispersion Modelling System (ADMS) dispersion model).
- Stack height is sufficient to ensure good dispersion during periods of “Other Than Normal Operation” as defined within the latest BREF documents (demonstrated by air dispersion modelling using the UK Atmospheric Dispersion Modelling System (ADMS) dispersion model).
- Expected emission concentrations are significantly below the BAT_{AEL} ELVs in the latest BREF documents.