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## Grundon Waste Management Ltd

BAT Assessment – HTI Facility

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# 1 Introduction

An Environmental Permit (EP) was granted by the Environment Agency (EA) to New Earth Energy (West) Operations Limited for the operation of the Avonmouth Energy Facility in January 2013. The EP includes for the operation of a Schedule 1, Section 5.1 (A1) (c) activity:

*The incineration of non-hazardous waste in a pyrolysis and gasifier plant with a capacity of 1 tonne or more per hour*

The EP was subsequently transferred to Avonmouth Bio Power Limited in October 2015.

Whilst the gasification plant was constructed and commissioned, it did not operate as it was intended. The gasification plant was eventually mothballed by Avonmouth Bio Power Limited in 2016. Grundon Waste Management Limited (Grundon) subsequently acquired the site from Avonmouth Bio Power Limited in February 2021.

Grundon has removed all of the gasification process equipment, including the waste feed and flue gas treatment systems. Grundon is currently installing a new waste incineration combustion technology, and associated waste and flue gas treatment systems to process a mix of non-hazardous, clinical and hazardous wastes which require high temperature incineration, herein referred to as the Facility.

In accordance with the requirements of Environment Agency Guidance, titled 'Incineration of waste (EPR5.01): additional guidance' (herein referred to as EPR5.01), this report presents a quantitative BAT assessment for the primary abatement system for acid gases, including the selection of reagents; the abatement of oxides of nitrogen (NO<sub>x</sub>); and the waste combustion technology for the Facility.

As required by the IPCC Directive, each assessment provides an explanation of how the Facility will comply with indicative BATs presented in EPR 5.01.

## 1.1 Assumptions

The Facility will have an availability of approximately 8,000 hours per annum. Therefore, the Facility will have a nominal design capacity of approximately 20,000 tonnes per annum (tpa). However, allowing for the Facility operating to allow for operating on a low range NCV the Facility could process up to 28,500 tpa.

For the purposes of this BAT assessment, the nominal design capacity is considered to be most reflective of 'normal' operations. It is not expected that the conclusions of the BAT assessment would change with the maximum case.

The Facility will generate approximately 1.5 MWe with a parasitic load of 0.4 MWe.

In addition, urea will be used for the Selective Non-Catalytic Reduction (SNCR) nitrous oxides (NO<sub>x</sub>) abatement system.

For the purposes of this report we have undertaken a quantitative assessment of the available technologies for the proposed capacity using data obtained by Fichtner from a range of different projects using the technologies identified within this assessment.

The following unit costs have been assumed within the relevant operating costs sections of this assessment:

- Water ..... £1 per tonne
- Lime Slurry ..... £90 per tonne

- Lime..... £85 per tonne
- Sodium Bicarbonate..... £155 per tonne
- Activated Carbon ..... £575 per tonne
- Ammonia..... £203 per tonne
- Sand (with defined particle size distribution)..... £100 per tonne
- Bottom Ash Processing ..... £8.50 per tonne
- Lime APCR Disposal..... £125 per tonne
- Sodium bicarbonate APCR Disposal..... £150 per tonne
- Landfill Tax (1 April 2018) ..... £89 per tonne
- Imported power ..... £120 per MWh
- Electricity revenue ..... £60 per MWh

## 2 Combustion Techniques

### 2.1 Options Considered

The available technologies for the combustion of waste have been reviewed in a qualitative BAT assessment in section 3.6.1 of the supporting information. This assessment has been expanded to provide a more detailed qualitative analysis of two technologies identified as suitable for the combustion of waste at the Facility: stepped hearths and rotary kilns.

1. Stepped hearths are a commonly used technology in clinical waste incinerators across the UK and Europe. The waste is 'pushed' down each step by means of hydraulic rams, resulting in a tumbling action which exposes large surface areas of the waste to the combustion process.
2. Rotary kilns have been used within the healthcare sector in treating clinical waste. The continual movement of the waste promotes complete combustion.

### 2.2 Environmental Performance

#### 2.2.1 General

For low volumes of clinical waste, a stepped hearth design provides the ability to control residence time within the furnace to achieve good waste burnout, with the ability to control primary air. Stepped hearth designs have been used globally for the incineration of hazardous waste for many years, and are a well-proven and reliable method of processing clinical waste. One disadvantage with the technology is that there are various complex moving parts within the primary chamber, which introduces a higher potential for mechanical failure.

The energy conversion efficiency for some rotary kiln designs can be lower than that of other thermal treatment technologies due to the large areas of the refractory lined combustion chamber. However, as the proposed rotary kiln is a counter-current design with the burner being mounted at the end of the thermal processing cycle, less heat is required, resulting in a reduced consumption in auxiliary fuel.

Concerns have been raised regarding the ability of rotary kilns to handle substantial quantities of glass waste without excessive slagging. The waste feed can be mixed to ensure that there are not significant quantities of glass fed into the combustion chamber at the same time, therefore, preventing this from occurring.

Rotary kilns are considered to be well suited to processing liquid and sludge wastes, as proposed to be processed at the Facility.

It is possible for rotary kilns to deliver flexibility with good performance through the use of, for example, infra-red cameras to detect hotspots. This method would allow operators to control temperature by dosing suitable material. It is worth noting that the type of material to be incinerated strongly influences mass throughput, making it important to provide an optimum blend of wastes to control temperatures to those within the thermal design limits of the technology. The use of support fuel is a proven method of temperature control, however this reduces the throughput of waste to be incinerated overall.

### 2.2.2 Emissions to Air

The emissions to atmosphere of NO<sub>x</sub> would not be affected by the choice of combustion technology. Although NO<sub>x</sub> concentrations from the furnaces would be different, both options would require further abatement to achieve the necessary emission limits. This means that the actual effect would be to change the amount of reagent required to abate the NO<sub>x</sub>. This is considered in section 3.2.6.

### 2.2.3 Deposition to Land

Deposition from atmospheric emissions would also be unchanged.

### 2.2.4 Emissions to Water

There are no emissions to water for either system.

### 2.2.5 Photochemical Ozone Creation Potential

There would be no change to POCP for either system.

### 2.2.6 Global Warming Potential

The direct emissions of carbon dioxide are the same for each option.

### 2.2.7 Raw Materials

There is no significant difference in raw material consumption between the two systems.

### 2.2.8 Waste Streams

The two options produce several solid waste streams.

- It is assumed that the metal content of the waste will be identical for both options and has not been considered further.
- Both options produce APCr. For the purposes of this assessment it is assumed that both options will generate the same quantity of APCr.

The proposed counter-current design allows for close control of combustion air in the primary combustion chamber, which is essential for wastes with high CV's such as some of the wastes proposed to be processed at the Facility.

The proposed counter-current rotary kiln, with kiln bottom ash recirculation included. The bottom ash existing the combustion chamber does not need to be quenched as it is fully burnt out, and cooler than alternative combustion technologies.

The counter-current rotary kiln technology is specifically suitable to incinerate wastes with variable moisture content and variable calorific value, such as those which will be processed at the Facility, as the flue gas leaving the kiln directly preheats the incoming waste.

Ash discharged by the kiln into the ash chamber is returned to the inlet side of the kiln, which leads to a higher quality ash, with lower residual carbon content. The kiln bottom ash recirculation rate can be adjusted.



## 2.3 Costs

The capital cost for a rotary kiln is expected to be similar in scale to that of a stepped hearth.

## 2.4 Conclusions

Counter-current rotary kiln systems are suitable for the incineration of wastes with variable moisture content and variable calorific value, and allow for the control of residence time within the primary combustion chamber to achieve good waste burnout.

Rotary kilns enable the highest degree of flexibility, in terms of permitted waste types, and are better suited to processing the wastes types which will be processed at the Facility compared to stepped hearths. There can be difficulties with controlling primary air, the potential for slagging, higher PM emissions and the requirement for pre-treatment of waste. However, the technology provider for the Facility has extensive experience of designing plants to address these difficulties and has mitigated against them within its design. Furthermore, Grundon has an excellent knowledge of hazardous and clinical waste in its operation of the Colnbrook HTI and will utilise this experience to suitably control the waste feed at the Facility.

Taking the above into consideration, a counter-current rotary kiln is considered to represent BAT for the incineration of hazardous and non-hazardous waste at the Facility.

## 3 Nitrogen Oxides (NO<sub>x</sub>) Abatement

### 3.1 Options Considered

Three options have been considered for NO<sub>x</sub> abatement and are listed below.

1. Selective Catalytic Reduction (SCR), which involves the injection of ammonia solution or urea into the flue gases immediately upstream of a reactor vessel containing layers of catalyst.
2. Selective Non-Catalytic Reduction (SNCR), which involves the injection of ammonia solution or urea into the combustion chamber.
3. SNCR in combination with flue gas recirculation (SNCR+FGR).

As stated previously, for the purposes of this assessment, it is assumed that urea solution will be the reagent used in the NO<sub>x</sub> abatement system.

### 3.2 Environmental Performance

#### 3.2.1 Emissions to Air

The emission rates for nitrogen oxides, nitrous oxide and ammonia are shown in the table below together with the tonnages of nitrogen oxides abated.

Table 3-1: Air Emissions

	Units	SNCR	SCR	FGR + SNCR
Nitrous oxide	mg/m <sup>3</sup>	10	10	10
Ammonia slip	mg/m <sup>3</sup>	15	15	15
NO <sub>x</sub> , unabated concentration	mg/m <sup>3</sup>	350	350	315
NO <sub>x</sub> , unabated rate	tpa	100	100	90
NO <sub>x</sub> , abated concentration	mg/m <sup>3</sup>	120	80	120
NO <sub>x</sub> released after abatement	tpa	30	20	30
NO <sub>x</sub> removed	tpa	70	80	60

For the purposes of this assessment, a long-term abated emission concentration of 70 mg/Nm<sup>3</sup> (11% reference oxygen content) is used for SCR for the purposes of this BAT assessment, since this is the level that the technology can achieve on a long-term basis. The two SNCR systems, with and without Flue Gas Recirculation (FGR), would be required to achieve an emission limit of 120 mg/Nm<sup>3</sup>, in accordance with the proposed emission limits for the Facility.

The unabated emission with FGR is assumed to be 10% lower than the other two cases.

The tonnages of nitrogen oxides removed by the abatement options are also shown.

The impact of emissions to air is considered in detail within the air quality assessment, refer to Appendix E of the Application Pack. The table below shows the predicted ground level concentrations for the three options.

Table 3-2: Air Emissions

Abatement System:		SNCR	SCR	SNCR + FGR
<b>Long Term</b>				
Process Contribution (PC)	µg/m <sup>3</sup>	1.35	0.90	1.35
Background	µg/m <sup>3</sup>	12.33	12.33	12.33
Predicted Environmental Contribution (PEC)	µg/m <sup>3</sup>	13.67	13.22	13.67
Air Quality Objective	µg/m <sup>3</sup>	40	40	40
PC as % of AQO		3.37%	2.25%	3.37%
PEC as % of AQO		34.18%	33.06%	34.18%
<b>Short Term</b>				
Process Contribution (PC)	µg/m <sup>3</sup>	0.95	0.63	0.95
Background	µg/m <sup>3</sup>	24.65	24.65	24.65
Predicted Environmental Contribution (PEC)	µg/m <sup>3</sup>	25.60	25.28	25.60
Air Quality Objective	µg/m <sup>3</sup>	200	200	200
PC as % of AQO		0.47%	0.32%	0.47%
PEC as % of AQO		12.80%	12.64%	12.80%

It can be seen that there are no predicted exceedances of air quality objectives for any of the options. Using SCR reduces the long-term PEC by approximately 1% of the air quality objective and the short-term PEC by 0.16% of the air quality objective when compared to either SNCR or SNCR + FGR.

### 3.2.2 Deposition to Land

The impact of nitrogen deposition on sensitive habitats has been assessed in the Air Quality Assessment, refer to Appendix E of the Application Pack. As can be seen from the results presented in the report, whilst the impact of nitrogen deposition cannot be screened as insignificant at all European and National designated ecological features. Where the impact is not screened as insignificant at Local Wildlife Sites, due to the background concentrations the impact can be described as not significant.

### 3.2.3 Emissions to Water

There are no emissions to water from any of the NO<sub>x</sub> abatement systems.

### 3.2.4 Photochemical Ozone Creation Potential

Nitrogen dioxide (NO<sub>2</sub>) has a photochemical ozone creation potential (POCP) of 2.8 and nitrogen oxide (NO) has a POCP of -42.7. Assuming that 10% of NO<sub>x</sub> is released as NO<sub>2</sub> and the rest as NO, the POCP is -1,100 for the SNCR options and -800 for the SCR option, meaning that SCR is less favourable. This is because nitrogen oxide converts to nitrogen dioxide in the atmosphere by reacting with ozone, this removing ozone from the atmosphere. Hence, the abatement of NO actually has a negative impact on POCP.

### 3.2.5 Global Warming Potential

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. In particular, 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 power generated by the turbine.

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.

In order to calculate the global warming potential of electricity consumption, the figure of 371 kg CO<sub>2</sub> equivalent per MWh has been used<sup>1</sup>.

Table 3-3: Global Warming Potential

	Units	SNCR	SCR	SNCR + FGR
Power consumed	kWe	30	50	30
Power not generated	kWe	-	10	-
Change in exported power	MWh pa	200	500	200
GWP	t CO <sub>2</sub> eq pa	100	200	100

### 3.2.6 Raw Materials

The estimated consumption of raw materials for each option is shown below.

Table 3-4: Raw Materials

	Units	SNCR	SCR	SNCR + FGR
Water	tpa	2,100	1,930	1,900
Urea solution	tpa	800	750	690

### 3.2.7 Waste Streams

There will be no additional residues generated from any of the NO<sub>x</sub> abatement options.

## 3.3 Costs

The estimated costs associated with each option are presented below. In order for direct comparisons to be made, the costs are presented as annualised costs, with the capital investment and financing costs spread over a 30-year lifetime with a rate of return of 9%, using the method recommended in Technical Guidance Note EPR-H1.

Table 3-5: Costs

	SNCR	SCR	SNCR + FGR
Capital Cost	£49,000	£800,000	£100,000

<sup>1</sup> Department of Energy and Climate Change. UK Fuel Mix Disclosure data table (01 April 2022– 31 March 2023).

	SNCR	SCR	SNCR + FGR
Annualised Capital Cost	£5,000	£78,000	£10,000
Maintenance	£1,000	£16,000	£2,000
Water and reagents	£155,000	£263,000	£242,000
Loss of exported power	£11,000	£29,000	£11,000
<b>Total Annualised Cost</b>	<b>£172,000</b>	<b>£386,000</b>	<b>£265,000</b>

### 3.4 Conclusions

The table below provides a summary comparison of the three options.

Table 3-6: Comparison Table

Parameter	Units	SNCR	SCR	SNCR + FGR
NO <sub>x</sub> released after abatement	tpa	30	20	30
NO <sub>x</sub> removed	tpa	70	80	60
Photochemical Ozone Creation Potential (POCP)	t ethylene-eq pa	-1,100	-800	-1,100
Global Warming Potential	t CO <sub>2</sub> eq pa	100	200	100
Urea consumed	tpa	800	750	690
Total Annualised Cost	£ pa	£172,000	£386,000	£265,000
Average cost per tonne NO <sub>x</sub> abated	£ p.t NO <sub>x</sub> .	£2,460	£4,825	£4,420

As can be seen from the table above, applying SCR to the Facility:

1. increases the annualised costs by more than £114,000 per annum;
2. abates an additional 10 tonnes of NO<sub>x</sub> per annum;
3. reduces the benefit of the facility in terms of the global warming potential by approximately 100 tonnes of CO<sub>2</sub>;
4. reduces reagent consumption by approximately 100 tonnes per annum; and
5. costs nearly 100% more per additional tonne of NO<sub>x</sub> abated, compared to an SNCR system.

The additional costs associated with SCR are not considered to represent BAT for the Facility. On this basis, SNCR is considered to represent BAT.

Including FGR to the SNCR system to abate NO<sub>x</sub> increases the cost per tonne of NO<sub>x</sub> abated by nearly 80%, and has a small effect on the environmental impact of the Facility.

The proposed designs do not include FGR. Therefore, taking the above into consideration, the use of SNCR without FGR is considered to represent BAT for the abatement of NO<sub>x</sub> within the Facility.

## 4 Acid Gas Abatement

### 4.1 Options Considered

There are currently three technologies widely available for acid gas abatement on waste incineration plants in the UK:

1. 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 liquid effluent which require treatment, has high capital and operating costs and generates a visible plume. It is mainly used in the UK for facilities treating hazardous and clinical waste 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 to achieve the relevant emission limits.
2. 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. 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 and reaction products are collected on a bag filter, where further reaction can take place. Semi-dry systems use less initial reagent than a dry system, and hence produce less residues, however due to the small nature of the Facility, a semi-dry system introduces increased costs and issues associated with lime preparation. In addition, the lime cannot be re-circulated as in a dry system.
3. Dry, involving the injection of solid lime into the flue gases as a powder. The lime 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. In its basic form, the dry system consumes more lime 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. Therefore, the quantity of reagent used overall (and hence residues generated) is minimised. The dry method is considered to be cost effective and results in residues that are easier to dispose of.

A wet scrubber provides a secondary abatement measure to achieve the BAT-AELs for certain 'difficult' wastes. However, the primary abatement measure for acid gases utilises a dry acid scrubber. For the purposes of this assessment, dry and a semi-dry acid gas abatement systems have been considered for the primary abatement of acid gases.

### 4.2 Environmental Performance

#### 4.2.1 Emissions to Air

The impact of emissions to air is considered in the air quality assessment, which is presented in Appendix E of the Application Pack. The impact of the emissions of acid gases was assessed at the daily emission concentrations of 30 mg/m<sup>3</sup> for sulphur dioxide (SO<sub>2</sub>) and 6 mg/m<sup>3</sup> for hydrogen chloride (HCl).

The table below presents the emission concentrations at the stack and the predicted ground level concentrations for each option. For sulphur dioxide, the 99.18<sup>th</sup> percentile of the daily averages is shown. For hydrogen chloride, the maximum hourly mean is shown. The emission concentrations

for a semi-dry system are expected to be the same as for a dry system so the ground level impacts are also the same.

Table 4-1: Emissions to Air

Abatement System	Units	Dry		Semi-dry	
		SO <sub>2</sub>	HCl	SO <sub>2</sub>	HCl
Unabated emission concentration	mg/m <sup>3</sup>	480	900	480	900
Unabated emission rate	tpa	130	250	130	250
Abated emission concentration	mg/m <sup>3</sup>	30	6	30	6
Abated emission rate	tpa	10	2	10	2
Total emissions abated	tpa	120	248	120	248
Process Contribution (PC)	ug/m <sup>3</sup>	0.34	0.07	0.34	0.07
Background	ug/m <sup>3</sup>	6.48	0.82	6.48	0.82
Predicted Environmental Contribution (PEC)	ug/m <sup>3</sup>	6.82	0.89	6.82	0.89
Air Quality Objective	ug/m <sup>3</sup>	125	750	125	750
PC as % of AQO		0.27%	0.01%	0.27%	0.01%
PEC as % of AQO		5.45%	0.12%	5.45%	0.12%

The short-term impact of the plant is 0.27% of the daily average air quality objective for sulphur dioxide and 0.01% of the hourly air quality objective for hydrogen chloride. The impact of hydrogen chloride and sulphur dioxide is considered to be insignificant when applying the criteria stated in Environment Agency guidance note H1.

A more detailed assessment of impacts from the release of sulphur dioxide and hydrogen chloride is presented within the air quality assessment within Appendix E of the Application Pack.

#### 4.2.2 Deposition to Land

The impact of acid deposition on sensitive habitats has been assessed in the Air Quality Assessment, refer to Appendix E of the Application Pack. As can be seen from this assessment, the impact of acid deposition on sensitive receptors is not considered to be 'insignificant' at all habitat features. Further analysis has been undertaken and is presented in the Air Quality Assessment.

#### 4.2.3 Emissions to Water

There are no emissions to water for either the dry or the semi-dry systems, therefore the impact of these systems is the same.

#### 4.2.4 Photochemical Ozone Creation Potential

Sulphur dioxide has a photochemical ozone creation potential (POCP) of 4.8. Hence, the POCP for both the dry and semi-dry systems would be 50 tonnes ethylene equivalent.

### 4.2.5 Global Warming Potential

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 slightly 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.

The semi-dry system involves the evaporation of water. Since the reaction temperature of the lime and hence the outlet temperature should be the same, 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 and hence more power can be generated if a dry system is used.

In order to calculate the global warming potential of electricity consumption, the figure of 371kg CO<sub>2</sub> per MWh has been used, refer to section 2.2.6. The global warming potential is therefore calculated as follows:

$$\text{Carbon intensity of displaced electricity} \times \text{net power generation}$$

The global warming potential associated with each option is shown in the table below.

Table 4-2: Global Warming

	Units	Dry	Semi-Dry
Power consumed	kWh/t	30	28.5
	MWh pa	600	570
Generation lost (water evaporation)	MWh pa		600
Power not exported	MWh pa	600	1,170
GWP	t CO <sub>2</sub> pa	200	400

### 4.2.6 Raw Materials

The estimated consumption of raw materials for both options is shown below.

Table 4-3: Raw Materials

	Units	Dry	Semi-Dry
Additional water consumption compared to a dry system	tpa		28,000
Lime Slurry	tpa		850
Lime	tpa	1,100	
Powdered Activated Carbon (PAC)	tpa	170	170

### 4.2.7 Waste Streams

The only waste stream associated with the acid gas abatement treatment technologies is the Air Pollution Control Residues. These would be a hazardous waste. The production rate for both systems would be approximately 1,000 tonnes per annum.



### 4.3 Costs

The estimated costs associated with each option are presented below. In order for direct comparisons to be made, the costs are presented as annualised costs, with the capital investment and financing costs spread over a 30-year lifetime with a rate of return of 9%, using the method recommended in Technical Guidance Note EPR-H1.

Table 4-4: Costs

	Dry	Semi-Dry
Capital Cost	£1,200,000	£1,200,000
Annualised Capital Cost	£120,000	£120,000
Maintenance	£60,000	£60,000
Reagents and residues	£478,000	£432,000
Loss of exported power	£34,000	£67,000
<b>Total Annualised Cost</b>	<b>£692,000</b>	<b>£679,000</b>

### 4.4 Conclusions

The table below compares the options.

Table 4-5: Comparison Table

Parameter	Units	Dry	Semi-Dry
SO <sub>2</sub> abated	tpa	10	10
Photochemical Ozone Creation Potential (POCP)	t ethylene-eq pa	50	50
Global Warming Potential	t CO <sub>2</sub> eq pa	200	400
Additional water consumption compared to a dry system	tpa		28,000
APC Residues	tpa	1,000	1,000
Annualised Cost	£ pa	£692,000	£679,000

The performance of the options is very similar.

The dry system only requires a small quantity of water for conditioning of the lime so that it is suitable for injection into the reaction chamber, whereas the semi-dry system requires the lime to be held in solution (quick lime). This requires significantly more water than a dry system.

In addition, the dry system has a reduced global warming potential and a reduced annualised cost.

Due to the low water consumption, reduced global warming potential and reduced annualised cost, the dry system is considered to represent BAT for the Facility.

## 5 Reagent Selection – Acid Gas Abatement

### 5.1 Options Considered

Within this assessment, reagents for wet scrubbing have not been considered as wet scrubbing systems have been discounted as representing BAT for the abatement of acid gases in Section 4.1 of this assessment. Therefore, only the two alternative reagents for a dry system have been considered – lime and sodium bicarbonate.

### 5.2 Environmental Performance

#### 5.2.1 Emissions to Air

There is no change in emissions to atmosphere between the two reagents. Both would achieve the same level of abatement.

#### 5.2.2 Deposition to Land

Again, there is no change between the two reagents.

#### 5.2.3 Emissions to Water

There are no emissions to water associated with either of the two reagents.

#### 5.2.4 Photochemical Ozone Creation Potential

There would be no change to POCP for either system.

#### 5.2.5 Global Warming Potential

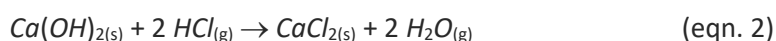
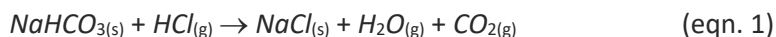
Sodium bicarbonate has a higher optimum reaction temperature than lime, which means that less heat can be recovered in the boiler. However, this can be resolved by recovering additional heat after the acid gas abatement system. Therefore, it has been assumed that there is no impact on global warming potential from this operational difference.

The reaction of hydrogen chloride and sulphur dioxide with sodium bicarbonate results in an emission of CO<sub>2</sub> whereas the reaction with lime does not.

#### 5.2.6 Raw Materials

Sodium bicarbonate (NaHCO<sub>3</sub>) has better solid handling properties and a significantly lower stoichiometric ratio than hydrated lime (Ca(OH)<sub>2</sub>).

Sodium bicarbonate and lime react with the acid gases to produce alkaline salts as the following equations illustrate:



In order to promote the reactions above, excess quantities of sodium bicarbonate or lime will be required. The excess reagent is lost in the residue. The ratio between the quantity of reagent supplied and the minimum required for the reaction is called the “stoichiometric ratio”.

For sodium bicarbonate, a stoichiometric ratio of 1.30 is required, whereas for lime, a stoichiometric ratio of around 1.8 is required. This initially appears to be economically advantageous for sodium bicarbonate in comparison to lime. However, due to the higher relative molecular weight, and the fewer molecules of acid gas reacting per molecule of sodium bicarbonate, the overall consumption of sodium bi-carbonate is actually 64% higher than lime on a mass basis.

The reagent required to abate one kmol of hydrogen chloride was calculated as approximately 109 kg for sodium bicarbonate and approximately 67 kg for lime.

### 5.2.7 Waste Streams

The stoichiometric ratio indicates that the amount of residue will be higher with the lime option. However, due to the differences in relative molecular weight and the number of acid gas molecules reacting with each absorbent molecule, the lime system produces a similar amount of residue to the sodium bicarbonate option.

The residue production rate for abatement of one kmol of hydrogen chloride was calculated as approximately 84 kg for sodium bicarbonate and approximately 85 kg for lime.

Furthermore, there are limited waste disposal options for sodium bicarbonate based APCr.

## 5.3 Costs

There is little difference in capital cost between the two reagents.

The purchase cost of sodium bicarbonate is significantly higher than lime, with bicarbonate costing almost 65% more than lime per tonne. This makes sodium bicarbonate an uneconomic option in comparison to lime.

The cost of disposing of the residue must also be considered due to the differences in quantity. Sodium based residues are more difficult to stabilise than lime residues; it has been assumed that the cost per tonne to landfill the sodium-based residues is 20% higher than lime residues, giving a disposal cost for sodium bicarbonate of £155/tn.

The operating costs for the two options are compared below, for a stoichiometric ratio of 1.8 for lime and 1.3 for sodium bicarbonate, on the basis of the abatement of one kmol of hydrogen chloride:

Table 5-1: Costs per unit HCl abated

Item	Unit	NaHCO <sub>3</sub>	Ca(OH) <sub>2</sub>
Mass of reagent required	kg/kmol	109.0	67.0
Mass of residue generated	kg/kmol	84.0	85.0
Cost of reagent	£/tonne	155	110
Cost of residue disposal <sup>2</sup>	£/tonne	186	155
Overall Cost	£/op. hr/kmol	32.5	20.5

<sup>2</sup>The figure shown does not include landfill tax.

Item	Unit	NaHCO <sub>3</sub>	Ca(OH) <sub>2</sub>
Ratio of costs		1.58	

## 5.4 Conclusions

There is a small environmental benefit for using sodium bicarbonate, in that the mass of residues produced is smaller. However, there are a number of significant disadvantages of using sodium bicarbonate compared to lime:

- The residue has a higher leaching ability, which will limit the disposal options;
- The reaction temperature doesn't match as well with the optimum adsorption temperature for carbon, which is dosed at the same time;
- The use of sodium bicarbonate has a slightly higher global warming potential due to the reaction chemistry; and
- The costs per kmol of hydrogen chloride abated are almost 60% higher.

Considering the above, the use of lime as a reagent within the acid gas abatement system is considered to represent BAT for the Facility.

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