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# KRONOSPAN

# KRONOSPAN CHP PLANT

# BAT ASSESSMENT

INSTALLATION NAME: CHIRK
PARTICLE BOAD FACTORY
PERMIT REF:
WCBC/IPPC/03/KR(V1)

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# 1 INTRODUCTION

This annex contains BAT assessments for acid gas abatement, nitrogen oxides abatement and combustion technologies. Each assessment follows the structure of Technical Guidance Note EPR-H1 and includes comments on all of the environmental parameters mentioned in EPR-H1.

In the operating costs sections, the following unit costs have been assumed:

| | |
|---|---|
| Water | £1 per tonne |
| Quick Lime | £90 per tonne |
| Hydrated Lime | £94 per tonne |
| Sodium Bicarbonate | £155 per tonne |
| Activated Carbon | £650 per tonne |
| Urea | £135 per tonne |
| Bottom Ash Processing | £10 per tonne |
| Standard APCR Disposal | £125 per tonne |
| Fly Ash Disposal | £100 per tonne |
| Electricity Revenue | £35 per MWh |

# 2 ACID GAS ABATEMENT

## 2.1 Options Considered

There are currently three technologies widely available for acid gas treatment on renewable energy 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 and has high capital and operating costs. It 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.

(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.

(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.

Wet scrubbing is not considered to be suitable, due to the production of a large volume of hazardous liquid effluent and a reduction in the power generating efficiency of the plant. The dry and semi-dry systems are considered further below.

## 2.2 Environmental Performance

### 2.2.1 Emissions to Air

Impacts of the emissions to air have been considered in the air quality assessment, which can be found in Annex 5. In addition, emissions concentrations have been taken at reference conditions of 6% oxygen, as presented in the air quality assessment. As stated within the EP application, the short term emission concentrations for acid gas emissions were taken at the emission limits of 75 mg/m$^3$ for sulphur dioxide and 15 mg/m$^3$ for hydrogen chloride, based on the use of a dry abatement system. The emission concentrations for a semi-dry system would be the same.

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

**Table 2.1 Emissions to Air, Acid Abatement Options**

| **Abatement System:** | | **Dry** | | **Semi-dry** | |
|---|---|---|---|---|---|
| **Pollutant** | **Unit** | **$SO_2$** | **HCl** | **$SO_2$** | **HCl** |
| Unabated emission concentration | mg/m³ | 400 | 800 | 400 | 800 |
| Unabated emission rate | te/year | 200 | 390 | 200 | 390 |
| Emission concentration | mg/m³ | 75 | 15 | 75 | 15 |
| Emission rate | te/year | 25 | 5 | 25 | 5 |
| Emissions abated | te/year | 175 | 385 | 175 | 385 |
| Process Contribution (PC) | µg/m³ | 0.97 | 0.52 | 0.97 | 0.52 |
| Background | µg/m³ | 3.80 | 0.26 | 3.80 | 0.26 |
| Predicted Environmental Contribution (PEC) | µg/m³ | 8.57 | 1.04 | 8.57 | 1.04 |
| Air Quality Objective | µg/m³ | 125.00 | 750.00 | 125.00 | 750.00 |
| PC as % of AQO | - | 0.78% | 0.07% | 0.78% | 0.07% |
| PEC as % of AQO | - | 6.86% | 0.14% | 6.86% | 0.14% |

The short-term peak for $SO_2$ is added to twice the annual average background concentration, to give a worst case Predicted Environmental Concentration of 6.86% of the air quality objective.

The hourly average for HCl is added to twice the annual average background concentration, to give a worst case Predicted Environmental Concentration of 0.14% of the air quality objective. Both cases can be considered insignificant.

### 2.2.2 Deposition to Land

The impact of deposition of atmospheric emissions on nearby sensitive environmental receptors has been evaluated within Annex 5 to the EP application. The deposition of atmospheric emissions does not lead to a breach of the Critical Loads for acidification at any sensitive environmental receptor.

### 2.2.3 Emissions to Water

There are no emissions to water for the dry and semi-dry systems.

### 2.2.4 Photochemical Ozone Creation Potential

Sulphur dioxide has a photochemical ozone creation potential (POCP) factor of 4.8. Hence, the POCP for both the dry and semi-dry systems would be 79,000 tonnes-ethylene eq.

### 2.2.5 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 into 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 (GWP) of electricity consumption, the 601 kg-$CO_2$ per MWh has been used, as specified the Greenhouse Gas Assessment, as presented in Annex 5.

This is shown in the table below.

**Table 2.2 – Global Warming Potential, Acid Abatement Options**

| Parameter | Unit | Dry | Semi-Dry |
|---|---|---|---|
| Power consumed | kWh/te | 30.0 | 28.5 |
| | MWh/year | 1,900 | 1,800 |
| Generation lost | MWh/year | 0 | 2,000 |
| Power not exported | MWh/year | 1,900 | 3,800 |
| GWP | te-$CO_2$/year | 1,100 | 2,300 |

### 2.2.6 Raw Materials

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

**Table 2.3 – Raw Materials, Acid Abatement Options**

| Parameter | Unit | Dry | Semi-Dry |
|---|---|---|---|
| Total site water use | te/year | 21,100 | 25,000 |
| Quick Lime | te/year | – | 360 |
| Hydrated Lime | te/year | 460 | – |
| PAC | te/year | 70 | 70 |

### 2.2.7 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 about 640 tonnes per annum.

## 2.3 Costs

The estimated costs associated with each option are presented in the table 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 Annex (k) to Technical Guidance Note EPR-H1.

**Table 2.4 – Costs, Acid Abatement Options**

| | Dry | Semi-Dry |
|---|---|---|
| Capital Cost | £4.2 million | £4.4 million |
| Annualised Capital Cost | £409,000 | £428,000 |
| Maintenance | £210,000 | £220,000 |
| Reagents and residues | £241,000 | £234,000 |
| Loss of exported power | £67,000 | £135,000 |
| Total Annualised Cost | £927,000 | £1,015,000 |

## 2.4 Conclusions

The table below compares the options.

**Table 2.5 – Comparison Table, Acid Abatement Options**

| Parameter | Unit | Dry | Semi-Dry |
|---|---|---:|---:|
| $SO_2$ abated | te/year | 175 | 175 |
| POCP | te-ethylene eq | 79,000 | 79,000 |
| Global Warming Potential | te-$CO_2$/year | 1,100 | 2,300 |
| Raw Materials | – | More lime, less water | Less lime, more water |
| APC Residues | te/year | 640 | 640 |
| Waste water | – | No | No |
| Annualised Cost | £/year | £927,000 | £1,015,000 |

The performance of both options is very similar. Therefore, both technologies would be suitable for the CHP Plant. The selection between these two types will be made during tendering process with the technology suppliers based on their performance. Upon selection of the combustion technology Kronospan will submit further information to WCBC confirming whether the acid gas abatement system will be a dry or a semi-dry system.

# 3 NITROGEN OXIDES ABATEMENT

## 3.1 Options Considered

(1) Selective Non-Catalytic Reduction involves the injection of ammonia or urea into the combustion chamber.

(2) Selective Catalytic Reduction involves the injection of ammonia or urea into the flue gases immediately upstream of a reactor vessel containing layers of catalyst.

(3) Selective Non-Catalytic Reduction as option 1, but with a proportion of the flue gas recirculated back to the combustion chamber.

Please note, the basis for this assessment has assumed that the CHP plant will use a moving grate. However, as explained in Section 3.4 of this report, the final decision of which technology to use has not been decided.

## 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. Note that an abated emission concentration of 270 mg/m$^3$ (rather than the emission limit of 300 mg/m$^3$) is used for SNCR for the purposes of this BAT assessment, since this is the typical level at SNCR installations. In addition, emissions concentrations have been taken at reference conditions of 6% oxygen, as presented in the air quality assessment. The tonnes of nitrogen oxides abated is also shown. For SNCR + FGR, this is the total abated compared to the non-FGR case.

**Table 3.1 – Air Emissions, NOx Abatement Options**

| Parameter | Unit | SNCR | SCR | FGR+SNCR |
|---|---|---|---|---|
| Nitrous oxide | mg/m$^3$ | <5 | <5 | <5 |
| Ammonia | mg/m$^3$ | 10 | 7.5 | 7.5 |
| NO$_x$, unabated emissions | mg/m$^3$ | 550 | 550 | 550 |
| NO$_x$, abated emissions | mg/m$^3$ | 270 | 105 | 270 |
| | t/a | 90 | 30 | 90 |
| NO$_x$ emissions abated | t/a | 90 | 150 | 90 |

The impact of emissions to air is considered in the air quality assessment, as included within Annex 5 to the EP application. For the purposes of this assessment, it has been assumed that the emissions of NOx will have been emitted from the man stack.

The table below shows the predicted ground level concentrations for each option. For the short term emissions, it has been assumed that the permitted emission limit for NOx is 300 mg/m$^3$.

**Table 3.2 – Air Emissions, NOx Abatement Options**

| Parameter | Unit | SNCR | SCR | FGR+SNCR |
|---|---|---|---|---|
| **Long Term** | | | | |
| Process Contribution (PC) | µg/m$^3$ | 0.50 | 0.19 | 0.48 |
| Background | µg/m$^3$ | 15.40 | 15.40 | 15.40 |
| Predicted Environmental Contribution (PEC) | µg/m$^3$ | 15.90 | 15.59 | 15.88 |
| Air Quality Objective | µg/m$^3$ | 40.00 | 40.00 | 40.00 |
| PC as % of AQO | – | 1.25% | 0.47% | 1.21% |
| PEC as % of AQO | – | 39.75% | 38.97% | 39.71% |
| **Short Term** | | | | |
| Process Contribution (PC) | µg/m$^3$ | 5.07 | 2.66 | 5.07 |
| Background | µg/m$^3$ | 15.40 | 15.40 | 15.40 |
| Predicted Environmental Contribution (PEC) | µg/m$^3$ | 35.87 | 33.46 | 35.87 |
| Air Quality Objective | µg/m$^3$ | 200.00 | 200.00 | 200.00 |
| PC as % of AQO | – | 2.54% | 1.33% | 2.54% |
| PEC as % of AQO | – | 17.94% | 16.73% | 17.94% |

It can be seen that there are no predicted exceedences of air quality objectives for any of the options. Using SCR reduces the long term PEC by 0.78% of the air quality objective and the short term PEC by 1.21% of the air quality objective.

### 3.2.2 Deposition to Land

The impact of deposition of atmospheric emissions on nearby sensitive environmental receptors has been evaluated within Annex 5 to the EP application. The deposition of atmospheric emissions does not lead to a breach of the Critical Loads for acidification or MDR at any sensitive environmental receptor. Where breaches of the Critical Load for nitrogen deposition are predicted, the background deposition rate already exceeds the Critical Load. The process contribution is deemed to be a minor contributor to any breach. Therefore, the reduction in nitrogen oxides emissions for SCR does not have a significant impact.

### 3.2.3 Emissions to Water

There are no emissions to water for any of the systems.

### 3.2.4 Photochemical Ozone Creation Potential

Nitrogen dioxide has a photochemical ozone creation potential (POCP) factor of 2.8 and nitrogen oxide has a POCP factor of -42.7. Assuming that 10% of NOx is released as $NO_2$ and the rest as NO, the POCP is −2,300 te ethylene-eq for the SNCR options and −900 te ethylene-eq for the SCR option. Thus, this identifies that SCR will have a greater potential for creation of photochemical ozone. This is because NO converts to $NO_2$ in the atmosphere by reacting with ozone, thus removing ozone from the atmosphere. Hence, the abatement of NOx 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.

- SCR imposes an additional pressure drop on the flue gases, leading to an increase in power consumption by the ID Fan. In addition, SCR requires the flue gases to be reheated which reduces the power generated by the turbine
- FGR requires an additional recirculation fan.

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 (GWP) of electricity consumption, the 601 kg-$CO_2$ per MWh has been used, as specified in the Greenhouse Gas Assessment in Annex 5.

This is shown in the table below.

**Table 3.3 – Global Warming Potential, NOx Abatement Options**

| Parameter | Unit | SNCR | SCR | FGR+SNCR |
|---|---|---|---|---|
| Power consumed | kW | 4 | 78.9 | 27.9 |
| Power not generated | kW | – | 95.4 | – |
| Change in exported power | MWh/year | 32 | 1,359 | 217 |
| GWP | te-$CO_2$ eq | 20 | 840 | 130 |

### 3.2.6 Raw Materials

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

**Table 3.4 – Raw Materials, NOx Abatement Options**

| Parameter | Unit | SNCR | SCR | FGR+SNCR |
|---|---|---|---|---|
| Urea | te/year | 161 | 85 | 95 |

### 3.2.7 Waste Streams

There are no waste streams associated with any of the 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 Annex (k) to Technical Guidance Note EPR-H1.

**Table 3.5 – Costs, NOx Abatement Options**

| | SNCR | SCR | FGR+SNCR |
|---|---|---|---|
| Capital Cost | £252,000 | £2,020,000 | £471,000 |
| Annualised Capital Cost | £25,000 | £197,000 | £46,000 |
| Maintenance | £5,000 | £40,000 | £9,000 |
| Reagents | £23,000 | £12,000 | £14,000 |
| Loss of exported power | £1,000 | £49,000 | £8,000 |
| **Total Annualised Cost** | **£54,000** | **£298,000** | **£77,000** |

## 3.4 Conclusions

The table below compares the three options:

**Table 3.6 – Comparison Table, NOx Abatement Options**

| | | SNCR | SCR | FGR+SNCR |
|---|---|---|---|---|
| NOx emissions abated | te/year | 90 | 150 | 90 |
| POCP | te-ethylene eq | -2,300 | -900 | -2,300 |
| Global Warming Potential | te-$CO_2$/year | 20 | 840 | 130 |
| Urea | te/year | 161 | 85 | 95 |
| Total annualised Cost | £/year | £54,000 | £298,000 | £77,000 |

- **SNCR vs FGR+SNCR**

  Some suppliers of grates have designed their combustion systems to operate with FGR and these suppliers can gain benefits of reduced NOx generation from the use of FGR. Other suppliers of grates have focussed on reducing NOx generation through the control of primary and secondary air and the grate design. Both designs abate the same quantity of NOx. Therefore suppliers which have designed there system to reduce NOx through controlling air supplies gain no benefit from the use of FGR.

  Introducing FGR increases the annualised cost by 43%, or about £23,000. It has no effect on the direct environmental impact of the plant, but it increases the impact on climate change by 110 tonnes of $CO_2$ while reducing urea consumption by 66 tonnes.

However, this is based on the assumption that FGR reduces the NOx generation by the furnace. As discussed earlier, this is not necessarily the case for all furnace manufacturers. Some designs can achieve lower levels of NOx without FGR.

- **SNCR vs SCR**

  Using SCR increases the annualised costs by £244,000 and the global warming potential by 590 tonnes of $CO_2$ while reducing urea consumption by 76 tonnes and abating an additional 36 tonnes of NOx. This gives an effective cost of £6,700 per additional tonne of NOx abated. When taken with the additional contribution to climate change, this is not considered to represent BAT.

  It is possible to achieve lower levels of NOx than 70 $mg/m^3$ with SCR, although this increases the urea consumption. However, this would not change the conclusion of this assessment. The cost per tonne of NOx abated would remain high and the impact on climate change combined with the extra cost is considered to outweigh the reduction in NOx emissions.

Therefore, SNCR is considered to represent BAT for this installation. FGR is considered to be BAT if it improves the performance of the furnace, but this will be dependent on the selected furnace manufacturer/supplier. Upon selection of the combustion technology Kronospan will submit further information to WCBC confirming whether the selected boiler design includes FGR.

# 4 REAGENT SELECTION

The selection of reagents for acid gas abatement is considered in Abatement Reagent Selection of the Supporting Information document contained within the EP Application. This assessment is expanded below.

## 4.1 Options Considered

We have not considered reagents for wet scrubbing, since this has been eliminated as a technique in section A.1.1 above. We have therefore only considered the two alternative reagents for dry and semi-dry systems – lime and sodium bicarbonate.

## 4.2 Environmental Performance

### 4.2.1 Emissions to Air

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

### 4.2.2 Deposition to Land

Again, there is no change between the two reagents.

### 4.2.3 Emissions to Water

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

### 4.2.4 Photochemical Ozone Creation Potential

There would be no change to POCP for any of the systems.

### 4.2.5 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 $CO_2$ whereas the reaction with lime does not. As a result the use of sodium bicarbonate has a higher global warming potential than lime.

### 4.2.6 Raw Materials

Sodium bicarbonate ($NaHCO_3$) has better solid handling properties and a significantly lower stoichiometric ratio than lime ($Ca(OH)_2$).

$NaHCO_3$ and $Ca(OH)_2$ react with the acid gases to produce alkaline salts as the following equations illustrate:

$$NaHCO_{3(s)} + HCl_{(g)} \rightarrow NaCl_{(s)} + H_2O_{(g)} + CO_{2(g)} \qquad \textbf{(Eq. 1)}$$

$$Ca(OH)_{2(s)} + 2HCl_{(g)} \rightarrow CaCl_{2(s)} + 2H_2O_{(g)} \qquad \textbf{(Eq. 2)}$$

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 $NaHCO_3$, the overall consumption of sodium bi-carbonate is actually 64% higher than $Ca(OH)_2$ on a mass basis.

The reagent required to abate one kmol of HCl was calculated as 109.2 kg of sodium bicarbonate and 66.6 kg of lime.

### 4.2.7 Waste Streams

The stoichiometric ratio indicates that the amount of residue will be roughly equal for both options. The residue production rate for abatement of one kmol of HCl was calculated as 84 kg for sodium bicarbonate and 85 kg for lime.

## 4.3 Costs

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

The cost of $NaHCO_3$ is significantly higher than $Ca(OH)_2$, with bicarbonate costing almost one and a half times as much as hydrated lime. 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 /tonnes.

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 HCl:

**Table 4.1 – Costs, Acid Gas Reagents**

| Item | Unit | $NaHCO_3$ | $Ca(OH)_2$ |
|---|---|---|---|
| Mass of reagent required | kg/h | 109 | 67 |
| Mass of residue generated | kg/h | 84 | 85 |
| Cost of reagent | £/te | 155 | 94 |
| Cost of residue disposal | £/te | 150 | 125 |
| Overall Cost | £/op. hr/kmol | 36.18 | 23.70 |
| Ratio of costs | - | 1.53 | 1.00 |

## 4.4 Conclusions

The use of sodium bicarbonate has a number of significant disadvantages:

- The residue has a higher leaching ability than lime-based residues, which will limit the disposal options. The residue from the lime neutralisation process has a very low solubility and the lime present in the residue raises the alkalinity which has the effect of chemically binding the heavy metals into the residue matrix. Therefore, the material is amenable to landfilling in a hazardous waste landfill site. The bicarbonate residue on the other hand has a much higher solubility and, without cementation, the residue is not suitable for landfilling due to the high leachability. In Europe, sodium bicarbonate is more frequently used for acid gas neutralisation. This is because the manufacturers sell the bicarbonate and takes back the bicarbonate residue for recycling. In the UK, there is no supplier able to recycle the bicarbonate residue and therefore the additional cost of “chemically fixing” the residue by cementation or other processes has to be included in the economic assessment;
- The reaction temperature doesn’t match as well with the optimum adsorption temperature for carbon. The optimum temperature for the sodium bicarbonate reaction is in the range 220 to 240°C whereas the efficiency of the lime reaction increases with reducing temperature. At the higher temperature, the efficiency of adsorption of heavy metals and complex organic compounds into activated carbon is reduced;
- The sodium bicarbonate system has a slightly higher global warming potential due to the reaction chemistry; and
- the costs are significantly higher.

Hence, the use of lime is considered to represent BAT for this installation.

# 5 COMBUSTION TECHNIQUES

## 5.1 Options Considered

The available techniques for fuel combustion are reviewed in the Combustion Technology Section of the supporting information. The assessment has been expanded to provide a cost-benefit analysis of moving grates, fluidised beds and rotary kilns.

(1) **Moving grates** are designed to handle large volumes of biomass. The moving grate comprises of inclined fixed and moving bars (or rollers) that will move the fuel from the feed inlet to the residue discharge. The grate movement turns and mixes the fuel along the surface of the grate to ensure that all fuel is exposed to the combustion process.

**(2)** **Fluidised beds** are also designed to handle large volumes of biomass. Often some pre-processing of the wood is required to ensure homogeneity in terms of the size of the wood chips.

Fluidised bed combustion can sometimes lead to slightly lower NOx generation, although injection of ammonia or urea is still required to achieve the emission limits specified in WID.

(3) Incineration in a **rotary kiln** (or oscillating kiln) is a two stage process consisting of a kiln and a separate secondary combustion chamber. The rotation of the kiln moves the fuel with a tumbling action which exposes fresh fuel to heat and oxygen. Rotary kilns can operate at higher temperatures than other systems due to the absence of exposed metal surfaces, and can therefore be used to incinerate hazardous, clinical and industrial wastes. The use of rotary kilns can lead to increased numbers of fine particles emitted due to the disturbance caused by the tumbling action on the fuel.

The energy conversion efficiency of a rotary kiln is lower than that of a moving grate due to the large areas of refractory lined combustion chamber. In addition, the capacity per unit is limited to 8 tonnes per hour and for this application it would need 2 furnaces to achieve the design throughput.

## 5.2 Environmental Performance

### 5.2.1 Emissions to Air

The emissions to atmosphere would not be affected by the choice of combustion technology. Although NOx concentrations from the furnaces would be different, all three 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 NOx. This is considered in a later section.

**Table 5.1 – NOx emissions, Combustion Techniques**

| Option | NOx emissions from furnace (expressed at 6% oxygen) (mg/Nm³) |
|---|---|
| Moving Grate | 480-570 |
| Fluidised Bed | 375-450 |
| Rotary Kiln | 450-525 |

### 5.2.2 Deposition to Land

Deposition from atmospheric emissions would also be unchanged.

### 5.2.3 Emissions to Water

There are no emissions to water from any of the systems.

### 5.2.4 Photochemical Ozone Creation Potential

There would be no change to POCP for any of the systems.

### 5.2.5 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, there are changes in energy consumption and energy production.

- A fluidised bed would have a higher thermal efficiency.
- A fluidised bed plant has a higher parasitic load than a moving grate system due to the shredders, sand system and fly ash separation system.
- A rotary kiln generates less power but has a similar parasitic load to a moving grate system.

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 (GWP) of electricity consumption, the 601 kg-$CO_2$ per MWh has been used, as specified the Greenhouse Gas Assessment, as presented in Annex 5.

This is shown in the table below. Note that GWP is negative and so a higher figure is better.

**Table 5.2 – Global Warming Potential, Combustion Options**

| Parameter | Unit | Grate | Fluidised Bed | Kiln |
|---|---|---|---|---|
| Power generated | MWh/year | 71,000 | 75,000 | 57,000 |
| Parasitic Load | MWh/year | 5,400 | 7,800 | 5,400 |
| GWP | te-$CO_2$/year | 39,000 | 40,000 | 31,000 |

### 5.2.6 Raw Materials

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

**Table 5.3 – Raw Materials, Combustion Options**

| Parameter | Unit | Grate | Fluidised Bed | Kiln |
|---|---|---|---|---|
| Urea | te/year | 161 | 89 | 134 |
| Sand | te/year | - | 955 | - |

### 5.2.7 Waste Streams

The three options produce two or three solid waste streams.

- The bottom ash production for moving grates and kilns is the same, but lower for fluidised beds.
- Fluidised beds have much greater carry-over of fine particles and so produce an additional fly ash stream, which is removed in a cyclone before the acid gas abatement reaction is added. This separate fly ash stream could be usable for building aggregate, but this is not certain and it is possible that it will need to be sent to a hazardous landfill.
- All three options produce APC residues. The fluidised bed option would generate less than the other two options, because more of the fly ash has already been removed from the gas stream.

Estimated figures are shown in the table below.

**Table 5.4 – Waste Streams, Combustion Options**

| Parameter | Unit | Grate | Fluidised Bed | Kiln |
|---|---|---|---|---|
| Bottom Ash | te/year | 2,120 | 670 | 2,120 |
| Fly Ash | te/year | - | 1,540 | - |
| APC Residues | te/year | 640 | 550 | 640 |

## 5.3 Costs

Capital costs are not readily available for the different options.

- We would expect a fluidised bed unit to be up to 5% more expensive due to the additional fuel preparation equipment, sand dosing and recycling equipment and fly ash separation, which would outweigh savings from reduced bottom ash quantities. Economies of scale might outweigh this for much larger plants.
- We would expect a rotary kiln to be up 5% more expensive due to the requirement for two streams rather than one.

We have estimated the relative operating costs in the table below. Please note this does not allow for increased capital and maintenance costs associated with the fluidised bed or the rotary kiln options. For the power, we have shown the lost revenue associated with reduced power export compared to the moving grate option.

**Table 5.5 – Operating Costs, Combustion Options**

| Parameter | Grate | Fluidised Bed | Kiln |
|---|---|---|---|
| Reagents | £23,000 | £13,000 | £19,000 |
| Residue disposal | £178,000 | £282,000 | £152,000 |
| Loss of exported power | £0 | £56,000 | £490,000 |
| **Relative Operating Cost** | **£201,000** | **£239,000** | **£661,000** |

### 5.3.1 Conclusions

The table below compares the three options.

**Table 5.6 – Comparison, Combustion Options**

| Parameter | Unit | Grate | Fluidised Bed | Kiln |
|---|---|---|---|---|
| Global Warming Potential | te-$CO_2$/year | 39,000 | 40,000 | 31,000 |
| Urea | te/year | 161 | 89 | 134 |
| Residues | – | – | Less bottom ash, more fly ash | – |
| Relative Operating Cost | £/year | £201,000 | £239,000 | £661,000 |

**Kiln**

The Rotary Kiln system is less efficient, and therefore will have a significant impact on the global warming potential and operating costs. In addition, the capital cost is likely to be higher for a kiln since more streams would be required. Thus Rotary Kiln technology is not considered to represent BAT for this type of installation.

**Fluidised Bed**

The main issues for consideration with fluidised beds are:

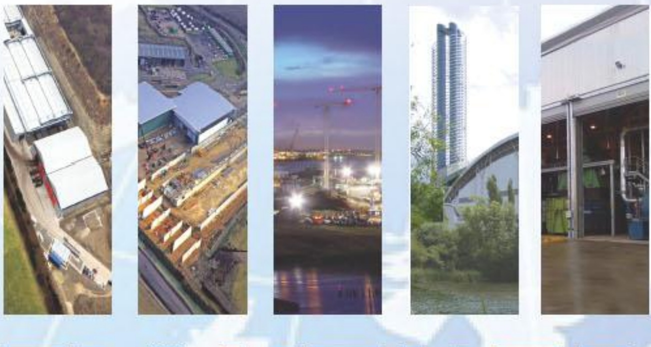
- Cost – generally a similar sized fluidised bed is likely to be slightly more expensive than a grate, but it is possible to have larger single stream fluidised beds which can reduce the overall cost;
- Fuel Size – whilst fluidised beds can have high fuel flexibility, they are sensitive to large or dense particles which must be minimised. In large quantities these cause the bed to defluidise. Generally a strict top-size for the fuel is needed and limits are set for impurities such as metal or large stones. However, fine particles are not a significant problem and can be burnt in quantities of up to 20%;
- Fuel Type – fluidised beds are extremely sensitive to low ash melting point fuels which can cause bed sintering. Generally straw is considered to be a very difficult fuel for a fluidised bed and other types of biomass with high alkali contents such as willow, are also viewed with concern.
- Combustion efficiency – fluidised beds, especially circulating beds, can generally achieve a higher thermal efficiency than grates and offer opportunities for better steam cycles with higher steam temperatures.
- Emissions – fluidised beds can generally operate with lower primary NOx levels than grates, but tend to release more nitrous oxide ($N_2O$) and still require the injection of ammonia or urea to achieve the emission limits specified in WID.

**Grate**

There are a number of wood based biomass plants which use grates. These are generally travelling grates or vibrating grates. There are a number of travelling grates being installed in Germany burning demolition wood using either the Detroit Stoker grate or the EVT travelling grate marketed by Alstom Power.

There are also a number of vibrating grates such as the Thetford plant burning poultry litter or the Ely plant burning straw.

Moving grate and fluidised bed technologies would are both considered to be suitable combustion technologies for this type of wood burning installation. The selection between these two types will be made during tendering process with the technology suppliers based on their performance. Upon selection of the combustion technology Kronospan will submit further information to WCBC detailing the technology selected and the expected performance of the facility.



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