Dunbar Energy from Waste (EfW) Facility

Application for a Permit to Operate Under the Pollution Prevention and Control (Scotland) Regulations 2000

Options Appraisal for NO_x Abatement

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1 Introduction

Background

1.1 Dunbar Energy from Waste (EfW) Facility is a proposed Installation which will utilise moving grate combustion technology and include a boiler to generate superheated steam to pass through three steam turbines to generate electricity, exported to the Grid at 22.7 MW. The Facility will be located at Dunbar Landfill, Oxwellmains, 4.5 km south of Dunbar town centre and will be operated by Viridor Waste Management Limited.

1.2 For the BAT assessment of NO_x abatement three options were considered, namely:

- No NO_x abatement;
- Selective Non-Catalytic Reduction (SNCR); and
- Selective Catalytic Reduction (SCR).

1.3 Each scenario assumed maximum annual plant load factor – representing a worst case scenario. The Facility is proposed to operate 7,800 hours per annum after routine shutdowns and maintenance.

1.4 For all three options it is assumed that the same primary measures are in place (see Section 3 of this report). These options are assessed using the IPPC Environmental Assessment Methodology.

1.5 The option for no secondary NO_x abatement (option 1 – base case) cannot meet the requirements for WID and therefore is not discussed further within this section as the legally required emission limits would not be complied with. However, the base case is used as a benchmark to evaluate other abatement option.

Scope of Assessment

1.6 This report comprises an assessment, which has been undertaken in response to the requirements of IPPC Sector Guidance Note IPPC S5.01[1]. Specifically this study considers the requirements referred to in the guidance note, section 2.2.1.2.

[1] IPPC Sector guidance Note S5.01 Guidance for the Incineration of Waste and Fuel Manufactured from or Including Waste (2004)

1.7 IPPC Guidance states that:

> *'Operators should provide a cost benefit study using the methodology in IPPC Environmental Assessments for BAT, to demonstrate the relative merits of primary measures, SNCR and SCR for the installation.*
>
> *The comparison will show the cost per tonne of NO_x abated over the projected life of the plant using typical discount rates.'*

1.8 This assessment comprises a review of available techniques for the reduction of NO_x emissions from the Installation, by way of a Best Available Technique or 'BAT' appraisal, and makes recommendations for the proposed abatement options.

Facility Description

1.9 The proposal is for the development of a two line facility with a total proposed capacity of 300,000 per annum.

1.10 The operational components will consist of a moving grate combustion technology and boiler which will generate superheated steam. Steam will pass to two steam turbines (one for each line) and generator which will generate electricity at a nominal rated output of 25.6 MW at design capacity. The output for sale to the Grid, net of auxiliary loads will be 22.7 MW.

1.11 Assuming shutdown periods and annual maintenance required, the design of each of the lines will ensure an availability of 7,800 hours per annum.

2 BAT Options Appraisal

Overview

2.1 The essence of PPC is that operators should demonstrate that the best option (or combination of options) has been chosen to achieve a high level of protection of the environment, taken as a whole. This is done by demonstrating that the technique or techniques chosen constitute BAT, and that taken together, they give the least environmental impact and meet all the statutory environmental quality standards, whilst not creating costs that are excessive for the protection they provide.

Approach

2.2 The IPPC Guidance for Environmental Assessment requires a review of the emissions from each abatement option presented. The rationale for the scope of the assessment is set out below in Table 2.1.

2.3 Factors which are not considered relevant to the BAT assessment for NO_x removal techniques are identified and justified where necessary.

Table 2.1 : Relevant Environmental Issues

Impact	Relevant to Assessment?	Justification
Emissions to air	✓	The techniques result in different concentrations of NO_x being emitted to air and therefore this will be a key factor in the BAT decision.
Emissions to surface water	×	There are no releases to water from either technique, so this factor is not relevant.
Deposition from air to land	×	Deposition % for NO_2 is provided in Table 4.2.
Noise and vibration	×	No significant difference between the techniques as all would be able to meet noise levels of < 85 dB(A) in 1 m distance, thus this factor is not relevant to the assessment.
Odour	×	No significant difference between the techniques.
Risk of accidents & consequences	✓	There is no significant difference between the options as similar raw materials would be used for each option. However, this is discussed in Section 4. The no abatement option eliminates the potential for groundwater contamination, which although considered extremely low, exists because of the storage of urea or ammonia solution on site for the other options. This risk cannot be quantified using the H1 methodology, and has therefore not been addressed. It has however been addressed in the main risk assessment, presented in Appendix 5, which confirms that the risk is insignificant.
Visual impacts	×	The SCR option requires additional heat input in order to reach the reactor temperature, and as such will raise the exhaust gas temperature, reducing potential plume visibility. To enable realistic comparison of NO_x performance, the data used in the assessment assumes the same exit temperature and therefore a similar risk of visible plume. Plume is therefore not included in the assessment, as options presented are considered to have a similar plume risk.
Global warming and energy	✓	Potentially significant differences between options, therefore relevant.
Ozone creation	✓	Potentially significant differences between options, therefore relevant

Impact	Relevant to Assessment?	Justification
Waste treatment and disposal	✓	Potentially significant differences between options, therefore relevant

2.4 A summary of the findings of above impacts with regard to each abatement option is presented in Table 7-1.

2.5 In reviewing the options available to Dunbar EfW Facility in each of the areas, consideration has been given to each of the environment impacts (given in Table 2.1) and are discussed in the Sections 4 and 5 of the document.

3 NO_x Reduction

Introduction

3.1 The BAT for NO_x abatement at the Dunbar EfW Facility was evaluated using IPPC Guidance. The assessment assumes primary measures are in place and evaluates only secondary abatement technology as discussed below.

Primary Measures for NO_x Reduction[2]

3.2 NO_x formation can be controlled using both primary measures that minimise its formation in the first instance and secondary measures which reduce further the generation of NO_x.

3.3 The plant design will minimise formation of NO_x by:

- the optimisation of the primary and secondary air feeds;
- design of the plant to ensure it is as air tight as possible; and
- control of the combustion stage to ensure that optimum combustion conditions are maintained.

3.4 CFD modelling has been used by the technology providers for the Facility to select optional primary and secondary air input regimes. Multiple secondary air nozzles will be selectively directed to optimise air flow, which will minimise the potential for hot-spots in the furnace which could lead to higher NO_x.

Secondary Measures for NO_x Reduction

3.5 Table 3.1 summarises the options that have been identified as having potential for reducing NO_x emissions and impacts from the Installation. The options show the base case (no abatement) and the two abatement options.

[2] Excerpt from Dunbar EfW Facility PPC Application

Table 3.1 : NO_x Reduction Techniques

Option		Technique
1	Base Case	No secondary flue gas treatment measures in place.
2	Selective Non-Catalytic Reduction (SNCR)	NO_x is chemically decomposed by injecting aqueous ammonia via nozzles into the combustion chamber. Using ammonia as the reduction reagent has the following advantages: • low temperature window for injection of reagent; • wider temperature window than urea; and • lower operation costs. The ammonia reduces NO_x in the exhaust gases producing nitrogen and water.
3	Selective Catalytic Reduction (SCR)	SCR is a catalytic process in which ammonia is mixed with air and added to the flue gas. Gases are passed over catalyst, typically a mesh. The ammonia reacts with NO_x present in flue gas to produce nitrogen and water vapour. Using SCR as the abatement technique has the following advantages: • it is a proven technology in the waste incineration sector; • can provide high NO_x reduction rates; and • It can also reduce VOCs, CO and dioxin emissions.

Alkaline Reagent Selection

3.6 Ammonia has been selected as the alkaline reagent for both SCR and SNCR. It is considered that the use of ammonia in larger units (such as the Dunbar Facility) is generally more effective[3].

[3] BREF (2005)

4 Quantifying Impacts

Overview

4.1 This section assesses each of the abatement options with regard to the relevant environmental impacts, previously identified in Table 2.1.

Emissions

4.2 Table 4.1 provides the long term emission concentrations used in this assessment. Estimated concentrations for each option were sought from the technology supplier, with the base case flue gas concentrations.

Table 4.1 : Assumed long-term Emission Concentrations (mg/Nm^3)

Option	NO_x (as NO_2)	Nitrous Oxide	Ammonia
1[a][b]	250	40	N/A
2[c]	180	30	25
3[c]	180	-	15

Notes: [a] Crude flue-gas concentrations taken from BREF, Table 3.6)
[b] Long term concentrations based on lower limits given in BREF.
[c] Emission concentrations provided by Keppel Seghers

4.3

Table 4.2 summarises the predicted air emission impacts for each option.

Table 4.2 : Air Emission Impacts

Option	1	2	3
	No Abatement	**SNCR**	**SCR**
Mass Emissions tpa			
NO_2	380.37	273.87	273.87
NO	60.86	45.64	-
NH_3	-	38.04	22.83
Long term % Process Contribution (PC)/Environmental Assessment Level (EAL)			
%PC/EAL NO_2	8.11	5.83	5.83
%PC/EAL NH_3		0.0106	0.103
Long term % Predicted Environmental Concentration (PEC)/Environmental Assessment Level (EAL)			
%PEC/EAL NO_2	43.2	40.9	40.9
Deposition % Predicted Environmental Concentration (PEC)/Environmental Assessment Level (EAL)			
%PC/EAL NO_2	8.11	5.83	5.83

Notes: Based on an background concentration of 14 mg/Nm^3 for NO_2

4.4 The results given above indicate that the NO_x emission impacts will be reduced by both types of abatement plant. For both control options, PECs remain well within the relevant AQS. The short-term effect of NO_x discharges to air is the same for both options.

Raw Materials

4.5 SCR requires the use of ammonia and a catalyst. SNCR utilises urea and does not require a catalyst. Estimated raw material consumption for each option is provided in Table 4.3.

4.6 The catalyst used for SCR typically has a lifetime of 3 to 5 years.

Table 4.3 : Raw Material Consumption

Option	SNCR	SCR
Ammonia (tonnes/yr)	967	538
Catalyst*	-	✓

* Catalyst is a mesh made typically made of platinum, rhodium, zeolites etc)

Waste

4.7 SNCR produces no wastes requiring disposal. SCR uses a catalyst which would periodically require disposal. The expected mass of waste equates to approximately 2 tonnes per year. The spent catalyst waste from the SCR system is classified as a hazardous waste and cannot be treated and recovered, therefore the material will require disposal at a hazardous waste landfill.

Accidents

4.8 In this instance, both options will use ammonia as a reagent. Ammonia is considered to have a higher accident impact than urea, another commonly used reagent for SNCR. SNCR incurs greater reagent use, and therefore it is assumed that there would be greater ammonia storage capacity at the Installation. Appropriate accident management systems would be implemented in the case of each option.

Energy

4.9 The energy requirements to operate the SCR system are significantly higher than those for SNCR (approximately 30,000 Mwh/yr and 15,000Mwh/yr respectively), due to the requirement to reheat the exhaust gases to between 300-400°C (the range at which the catalytic process operate), whilst SNCR does not require any reheating. The associated CO_2 emissions for SCR, calculated on the basis that heat is supplied from the facility, equated to 23,520 tonnes of CO_2 using the CO_2 factor calculated for the facility (see formula below). For SNCR, energy requirements would contribute to an emission of 11,760 tonnes of CO_2.

4.10 Based upon a CO_2 factor of 0.7484 (see formula below), the CO_2 derived from the NO_x abatement technique is significantly higher in the case of SCR than SNCR.

4.11 The CO_2 factor is derived from the following:

$$CO_2 \text{ factor} = \frac{(\text{total waste consumed x non biogenic carbon content of waste})}{(\text{Total electricity generated x plant operating hours})}$$

Global Warming

4.12 In this assessment of the options for NO_x abatement, global warming potential (GWP) is considered through the discharge of nitrous oxides. Emissions associated with CO_2 will be greater in the instance of SCR due to the energy requirements associated with this option. To avoid double counting, only GWP associated with nitrous oxides emissions have been considered. In terms of the GWP, there are there are no discharges of nitrous oxide from SNCR and therefore the GWP is 0 while SCR has GWP of 21,851.

Photochemical Ozone Creation Potential

4.13 According to IPPC guidance, for this assessment sulphur dioxide is considered and a Photochemical Ozone Creation Potential (POCP) factor for NO_2 of 2.8 was derived from the guidance. The calculated POCP for each option are given below in Table 4.4.

Table 4.4 : Comparison of POCP Values

Option	Annual Rate of NO_2 (tonne/yr)[(a)]	POCP[(b)]
1	380.37	1065.04
2	273.87	766.84
3	273.87	766.84

Notes: [(a)] assuming operating hours of 7800
[(b)] using a POCP factor of 2.8 for NO_2 specified in IPPC Guidance

4.14 These figures indicate that the POCP is reduced in the through the use of NO_x abatement systems. The costs associated with each option and the equivalent cost per tonne of POCP abated is discussed in Table 5-3.

5 Costs

Annualised Costs

5.1 The costs associated with the three possible options have been annualised for comparison and presented in Table 5-1. The upper level of capital expenditure estimates have been used to give the annualised costs. The calculation is as follows:

$$\textit{Equivalent Annual Cost Factor} = \frac{r}{(1+r)^n - 1} + r$$

where: r = discount rate expressed as a fraction, in this case 2.75% or 0.0275

n = operating life of the abatement equipment, in this case 25 years (maximum recommended typical asset / plant life)

Present Value Factor = 1 / *Equivalent Annual Cost Factor*

Present Value Cost of Option = (Annual average operating costs x *Present Value Factor*) + Capital costs

Equivalent Annual Cost = *Present Value Cost of Option* x *Equivalent Annual Cost Factor*

Table 5-1: Summary of NO_x Abatement Costs (£) using H1 Methodology

Option	Description	Capex	Opex / year	Present Value Cost	Equivalent Annual Cost
2	SNCR	746,667[(a)]	242,200	5,084,072	283,894
3	SCR	8,960,000[(a)]	422,333	16,523,292	922,660

Note: Capex = capital expenditure. Opex = operational expenditure.
[(a)] Keppel Seghers estimate. Based on operation of 2 lines.

5.2 Table 5-1 shows an increased investment cost when using SCR instead of SNCR. Investment costs for SCR for the facility are estimated at £8,960,000 compared to £746,667 for SNCR. The annual equivalent cost (capital and operating) is £922,660 for SCR against £283,894 for SNCR.

5.3 The equipment required for SCR treatment is larger and more complex than SNCR. It is installed after the flue gas treatment and includes all the equipment required for SNCR plus; a large gas heat exchanger, a burner, and a reactor.

5.4 The high investment costs for SCR corresponds to the additional equipment and therefore additional engineering, supply, erection and commissioning.

5.5 The operation cost is higher for SCR treatment because of higher maintenance time required on the additional equipment and because of the fuel consumption for re-heating the gases.

5.6 The cost per tonne of NO_x abated for both SNCR and SCR have been calculated and are presented in Table 5-2.

Table 5-2: Comparison of Costs per Tonne of NO_x

Option	**Description**	**Tonnes of NO_x abated per annum**	**Equivalent annual cost**	**Equivalent annual cost per tonne of NO_x abated per annum**
2	SNCR	106.5	283,894	£2,666
3	SCR	106.5	922,660	£8,663

5.7 Based upon this calculation which account for SCR costing significantly, whilst achieving the same NO_x abatement, SNCR is considered BAT for the Installation in relation to NO_x abatement.

5.8 A comparison of the relevant costs/benefits associated with POCP for the two abatement options is summarised in Table 5-3. The annual cost per unit of POCP avoided using SCR abatement is significantly higher than that of SNCR abatement.

Table 5-3: Comparison of Costs per Unit of POCP avoided

Option	**Description**	**POCP**	**Equivalent annual cost**	**Equivalent annual cost per unit of POCP avoided***
2	SNCR	766.84	283,894	£952
3	SCR	766.84	922,660	£3,094

* POCP avoided is based on a comparison with the POCP of Option 1 (no abatement) at 1065.04.

5.9 The Global Warming Potential of SCR is marginally lower than that for SNCR. Table 1.3 below provides an indication of the costs per unit of GWP avoided for the two options.

6 Benefits and Costs

6.1 The benefits and costs of each of the identified options have been tabulated below (see Table 6-1). Some of the benefits are intangible and some of the costs relate to negative aspects of the options, rather than only increased monetary costs. For each option a capital and operating cost range has been estimated by Keppel Seghers, the technology providers. Benefits are based upon industry experience of the likely change in performance. The balance of costs and benefits is therefore necessarily indicative.

Table 6-1: Significant Issues Related to NO_x Reduction

Option	1 - SNCR	2 - SCR
Benefit (Positive)	Lower energy consumption than other abatement options. Achieves NO_x emission limits at a low annual equivalent cost per tonne of NO_x abated. Large areas at the Facility not required.	High level of NO_x emissions reduction. Can achieve a reduction efficiency of over 80%.
Cost (Negative)	Technology providers, Keppel Seghers estimate investment of £746,667. Increased cost of reagent use.	Large investment costs associated with this option – estimated at approximately £8,960,000. High opex costs – in particular relating to energy consumption.
Practicality and Contribution	Use of ammonia instead of urea reduces N_2O emissions. Use of ammonia as the reagent can achieve lower levels than the use of urea. Can aid the reduction of PCDD/F formation. Safety issues associated with ammonia storage. Little waste produced.	Requires large area for SCR abatement plant. Catalyst must be periodically replaced to achieve high NO_x emissions reduction. Flue gases generally require reheating after earlier Flue Gas Treatment (FGT) stages (accounting for high energy consumption). Requires catalyst – which would require replacing every 3 - 5 years.

Note: [a] These data assume that current fuel burned has a S content of 0.2% and that the plant operates for 20% of the year as per the PPC Application.
[b] Valid at September 2007.

7 Summary and Conclusions

7.1 To establish BAT for the proposed facility the performance of each of the potential options needs to be considered for each of the relevant environmental areas considered. To summarise the assessment above, the performance of SNCR and SCR for each of the relevant issues are ranked in Table 7-1.

Table 7-1: Summary Ranking

	Ranking	
	SNCR	**SCR**
Performance Ranking		
NO_x performance	2	2
GWP performance	2	1
POCP performance	2	2
Waste	1	1
Energy	1	2
Performance Ranking including Cost Benefit Considerations		
NO_x cost benefit	1	2
POCP cost benefit	1	2
GWP cost benefit	2	1
Overall	**12**	**13**

7.2 If the costs associated with these releases are considered, then SNCR provides a significantly better cost benefit performance than SCR.

7.3 SNCR and SCR are both proven techniques for NO_x control and are both capable of reliably achieving NO_x emission below the emission limits specified within the WID. Whilst it is recognised that SCR has some benefits in performance of reduced releases to air, this is achieved at significant additional costs compared to the benefits achieved. Overall it is therefore concluded that SNCR is BAT for this Installation.