Energy from Waste, Combined Heat and Power Facility
North Yard, Devonport

Environmental Permit Application (Application EPR/WP3833FT/A001)

Assessment of Best Available Techniques
June 2011

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1 Report Context

Scott Wilson Ltd has been commissioned by MVV Environment Devonport Ltd (MVV hereafter) to prepare an application for an environmental permit for an Energy from Waste, Combined Heat and Power Facility located at Devonport Dockyard, Plymouth (Devonport EfW/CHP hereafter).

Within the Site, as defined in planning terms, and the Installation, as defined in permitting terms, the proposed facility will principally comprise:

- Tipping Hall;
- Waste Bunker Hall with Waste Handling Cranes;
- Bale Store/Baling System;
- Turbine Hall with Steam Turbine Generator;
- Boiler House with Grate, Boiler and Ancillary Systems;
- Flue Gas Cleaning System and Chimney;
- Air Cooled Condensers;
- Water Treatment Plant;
- Bottom Ash Handling System.
- Administration Block; and
- Workshop and Stores

This report has been prepared to support an application for an environmental permit and summarises the assessment of “best available techniques“ proposed for the site. The report should be read in conjunction with the other supporting application reports and risk assessments.

2 Introduction

2.1 Legislative Background

The Environmental Permitting (England and Wales) Regulations 2010 require that activities identified under Schedule 1 be subjected to an assessment to demonstrate that the technology/technique proposed can be considered to be the 'Best Available' at the time the application is being made.

This report provides the installation specific options appraisal and BAT assessment for the waste treatment facility at Devonport.

2.2 Definition of Best Available Technique

The Regulations define BAT as " the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and where that is not practicable, generally reduce emission and the impact on the environment as a whole".

Article 2 of the Integrated Pollution Prevention and Control Directive 1996 further defines the component parts of BAT as:

a) "available techniques" are those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the cost and advantages, whether or not the techniques are used or produced inside the United Kingdom, as long as they are reasonably accessible to the Operator.

b) "best techniques" are the most effective in achieving a high general level of protection of the environment as a whole.

c) "techniques" are both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

BAT may be demonstrated by either:

- Compliance with the sector-level, indicative BAT performance described in the Sector Guidance Notes (SGNs) produced by the Environment Agency and in the European Commission 'Reference Documents on BAT' (BREFs); or
- By conducting an installation-specific, options appraisal of candidate techniques.

The indicative BAT provided in the European BREF documents is based on an analysis of the costs and typical benefits for typical, or representative, plants within that sector. When assessing the applicability of the sectoral, indicative, BAT standards at the installation level, departures may be justified on the grounds of the technical characteristics of the installation concerned, its geographical location and the local environment.

2.3 Outline of BAT Appraisal

In undertaking the assessment of Best Available Technique (BAT) for the proposed technology the following was considered:

a) Treatment Technology Selection;

b) Appraisal of NOx control techniques;

c) Appraisal of acid gas control techniques;

d) Appraisal of particulate control techniques; and

e) Comparison of chosen solution against indicative BAT standards.

3 Treatment Technology Selection

3.1 Introduction

Thermal treatment of waste can be undertaken using traditional combustion technologies, such as moving grate and fluidised bed, or using the newer, advanced thermal technologies, such as pyrolysis and gasification. This section of the report provides an overview of the different combustion technologies that can be considered for the treatment of municipal solid waste (MSW).

3.2 Furnace Technology Description

3.2.1 Moving Grate

Moving-grate systems are widely adopted for MSW applications, and as such are considered well proven and reliable. There are a number of designs available, but typically the systems are characterised by the use of a grate system which includes a mechanism for distributing the waste across the grate, moving the waste forward and facilitating waste mixing as the material is moved – this means that freshly fed waste can be mixed with that already burning.

Waste is burned with an excess of air, which is frequently drawn from above the waste bunker, providing a source of odour control. Primary air is normally fed through the grate, with a secondary air supply above the grate to create turbulence.

The moving-grate system is capable of burning MSW as received, thereby avoiding the need for pre-treatment. Exhaust gases from the furnace will require treatment in order to achieve compliance with the emission limit requirements of the Waste Incineration Directive (WID), and two waste streams, bottom ash and Air Pollution Control (APC) residues (including fly-ash), will be produced.

3.2.2 Fluidised Bed

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

Although fluidised beds have theoretically higher combustion efficiencies than other grate systems, the technology requires a homogenous feedstock, with high calorific value, to be most effective. As such, the systems have been adapted for MSW by inclusion of a full pre-treatment (sorting, crushing, shredding) stage prior to combustion taking place. These pre-treatment stages are resource intensive, and can typically outweigh the combustion thermal efficiency advantages and decreased maintenance costs. If a lower calorific fuel is used, then the feedstock may have to be mixed with another fuel (e.g. oil, gas, RDF) within the fluidised bed, or require the pre-heating of the air used to fluidise the bed, in order to reach the required operating temperatures, both of which are energy intensive.

In respect of emissions, this technology can lead to higher emissions of fine particulate matter and larger amounts of flue gas treatment (FGT) residues. Typically the volume of reject material and ash can equate to around 5% by weight of the incoming waste prior to pre-treatment. Currently there is limited information regarding the composition and characterisation of these residues or their possible recovery. In addition, bottom ash, cyclone ash and APC residues are generally higher than moving-grate systems.

The technology is capable of achieving lower NOx emissions in the raw gas than is typically seen in moving-grate systems, due to the lower bed temperatures, thus reducing the level of thermal NOx formation. It should, however, be noted that additional abatement techniques, such as SNCR or SCR, will still be required to guarantee emissions standards can be complied with.

At the time of writing, the limited experience of this technology for a facility of this size leads to concerns over the commercial reliability of the technology for the proposed Devonport facility.

3.2.3 Rotary Kiln

Incineration using rotary kiln technology requires a separate secondary combustion chamber to meet the required regulatory standards. Waste is moved through the kiln by a tumbling action, caused by the rotation of the kiln, which exposes the fresh waste to heat and oxygen. Rotary kiln systems can operate at higher temperatures than other systems, due to the absence of exposed metal surfaces, and this makes them viable for incineration of hazardous, clinical and industrial wastes.

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

3.2.4 Gasification

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

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

Emissions to atmosphere can be controlled by cleaning the gases prior to combustion, although the gas may contain organic compounds which are difficult to remove. Gasification would therefore not be recommended for wastes with high quantities of halogenated substances.

In respect of residue production, this includes char and ash, which can trap the metals and inorganics in the molten slag.

In relation to use of gasification for thermal treatment of MSW waste streams:

- There is limited application of the technology in Europe, most facilities are used for the treatment of a range of MSW, industrial and commercial waste streams rather than MSW alone;
- There is limited full scale application of the process within the UK; currently Energos has retrofitted the technology to the treatment plant on the Isle of Wight, although at the time of writing this facility was experiencing difficulties with the control of organic species; and

- Many commercial organisations investigating the technology have changed focus to using it for gasification of biofuels or have abandoned it altogether (ref *"Thermal Methods of Municipal Waste Treatment"* C-Tech Innovation Limited, 2003).

3.2.5 Pyrolysis

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

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

There have been issues applying the technology to heterogenous feedstocks such as MSW, and pre-treatment stages would be required to ensure effective treatment is achieved. Currently there is limited experience with MSW, and its use remains unproven as an option at the time of writing.

3.3 Assessment of Furnace Technology Options

The summary assessment of the technology options is presented in the Table 3.1 below, and is supported by a more detailed assessment in Appendix A.

Table 3.1: Summary Assessment of Technology Options

Assessment Criteria	Technology Options			
	Moving Grate	Fluidised Bed	Gasification	Pyrolysis
Emissions	WID emission levels achievable through use of secondary abatement.	Lower thermal NOx generation than moving grate but still need secondary abatement to meet WID emission levels.	Lower emission levels reported as achievable (1) although performance has also been reported as limited (2). Metal aerial emissions should be lower as these are transferred to solid residues.	Lower emission levels reported as achievable (1) although performance has also been reported as limited (2). Metal aerial emissions should be lower as these are transferred to solid residues.
Global Warming Potential	GWP is associated with: • release of CO_2 from waste combustion • release of nitrous oxides associated with the NO_x • use of power to operate the plant.	GWP source is similar to moving grate, however the need for pre-treatment will introduce higher parasitic load needs increasing GWP associated with power use.	GWP source is similar to moving grate, however the need for pre-treatment will introduce higher parasitic load needs increasing GWP associated with power use.	GWP source is similar to moving grate, however the need for pre-treatment will introduce higher parasitic load needs increasing GWP associated with power use. Also, additional GWP is associated with the burning of support fuel to maintain process temperatures.
Odour	Odour management controls to be used to mitigate fugitive odour.	Similar to moving grate, but pre-treatment may cause additional odours.	Similar to moving grate, but pre-treatment may cause additional odours.	Similar to moving grate, but pre-treatment may cause additional odours.

Assessment Criteria	Technology Options			
	Moving Grate	Fluidised Bed	Gasification	Pyrolysis
Noise	Site/Plant Appropriate noise abatement to successfully control noise	Similar to MG, but pre-treatment plant will introduce additional noise sources	Similar to MG, but pre-treatment plant will introduce additional noise sources	Similar to MG, but pre-treatment plant will introduce additional noise sources
Residue Generation	Produces bottom ash and APC residues.	Use of sand in fluidised bed contributes to higher volumes of residue	Similar to moving grate although residues contain higher levels of metals.	Similar to moving grate although residues contain higher levels of metals.
Energy Efficiency (electricity generation only)	22-28.	21%	14-20%(3).	14-20%(3).
Raw Materials	Can be higher due to higher raw gas pollutant concentrations, but level will depend on flue gas treatment selected	Variable, depends on flue gas treatment selected but expected to be higher due to fluidisation sand requirements.	Variable, depends on flue gas treatment selected	Variable, depends on flue gas treatment selected
Costs	Has the lowest cost per tonne.	Additional pre-treatment plant and requirements for additional residue collection results in significantly higher capital costs.	Widely variable, but generally higher(1).	Widely variable, but generally higher(1).
Technology Application	Technology relatively well proven with a large number of long-term operational facilities.	Some operational experience although mixed performance and not proven for throughput required.	No large scale operational plants. Largest capacity plant treating MSW is 80,000 tpa (Sweden).	No large scale operational plants treating MSW.

1) '*Review of BAT for New Incineration Issues, Part 1 Waste Pyrolysis and Gasification Activities.*' P4-100/TR, Environment Agency, 2001
2) *'The Viability of Advance Thermal Treatment of MSW in the UK.'* Fichtner Consulting Engineers Limited, 2004
3) *'Advanced Thermal Treatment of Municipal Solid Waste.'* DEFRA, 2005

3.4 Conclusion

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

- Although there is some difference in pollutant levels in raw gas (e.g. lower NOx but higher particulate with fluidised bed), each of the options performs in accordance with WID emission limits with the use of appropriate secondary abatement technologies;
- The GWP signature for all technologies is broadly similar, however consideration of the relative energy generation efficiency of the process, the need for supplementary combustion fuel to support the thermal treatment process and parasitic load requirements to drive supporting plant and equipment shows that moving grate systems have similar or improved performance to the other technologies; and
- Moving-grate has a similar or improved level of performance to other technologies in respect of electrical efficiency, residue generation, raw materials and noise impact.

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

4 Appraisal of NOx Control Techniques

4.1 BAT Assessment Methodology

4.1.1 Methodology

The assessment of BAT has been undertaken in line with the Environment Agency H1 Guidance “Environmental Risk Assessment for Permits” (April 2010).

This methodology provides an objective approach to establishing the most appropriate technology for the proposed process, taking into account both the environmental consequences and costs associated with various design options. The assessment has been undertaken using a spreadsheet set up in accordance with the H1 Guidance, as there were technical problems with the latest H1 software tool which meant the full options appraisal could not be completed using it.

The assessment basically comprises 6 basic modules:

1. Definition of the objective of the assessment and the options to be considered;
2. Quantification of the emissions from each option;
3. Quantification of the environmental impacts resulting from the emissions;
4. Comparison of the options and ranking in order of best overall environmental performance;
5. Evaluation of the costs to implement each option; and
6. Identification of the option that represents BAT by balancing the environmental benefits against cost.

The spreadsheet (ref. “Devonport H1 BAT Assessment.xls”) has been provided to the Environment Agency along with this report to allow the verification of the results.

4.1.2 Objective of the Assessment

The objective of this assessment is to:

- Compare the environmental consequences of the proposed NOx control measures selected for this project (i.e. the base case) with several alternative options; and
- Evaluate the cost-benefit relationship of the different NOx control mechanisms.

4.1.3 Data for the Assessment

The data for the assessment is based on typical performance levels for the various options rather than at the WID emission limit values used in the environmental impact assessment. Data has been obtained from:

- Technology providers; and
- Standard reference materials, such as Incineration BREF note.

The dispersion factor used for the determination of the process contribution has been determined in line with the H1 methodology.

4.2 Techniques Considered As BAT

The potential options for reduction of NOx are identified in SGN S5.01 "*Guidance for the Incineration of Waste and Fuel Manufactured From or Including Waste"* and are outlined below.

4.2.1 Primary Techniques

Primary techniques are aimed at minimising the production of NOx in the combustion system and include:

Fuel Selection

This technique focuses on selection of low nitrogen fuels to minimise the generation of NOx during the combustion process. However, the nature of the sector means that there is little room for selection of different fuels, and as such this has been discounted as a feasible primary NOx control measure.

Burner Design

In relation to auxiliary burners used for start-up or supplementary firing, it is BAT to use low NOx burners. As low NOx burners will be used for the Devonport facility it is deemed to be BAT and no further assessment is required.

Combustion Air Control

In relation to the control of combustion air, it is acknowledged that high-excess air can increase NOx production, and as such the following techniques which will be employed at Devonport are generally recognised as BAT:

- All chambers and ducting will be sealed to prevent fugitive air ingress, and be held at slight negative pressure to prevent release of combustion gases;
- Primary and secondary combustion air supplies will be optimised and distributed by the automatic combustion control system to ensure that oxidative combustion of gases in line with WID is achieved, while not being over excessive resulting in higher NOx production;
- Flue gas recirculation (FGR) will be provided to optimise combustion efficiency, reduce excess oxygen and hence NOx production.
- Generic computational fluid dynamics (CFD) modelling is used as a basis for the design of the combustion chamber and boiler to select the optimal air input regimes;
- The combustion chamber will be operated with multiple secondary air injection points with nozzle arrangements optimised to achieve the required combustion conditions and
- The combustion chamber will be operated such that a minimum oxygen content of 6% will be achieved.

Temperature Control

In respect of temperature control, it is acknowledged that for a process to be BAT, combustion temperatures must meet the requirements of the relevant Directive – in this case greater than 850 °C for non-hazardous waste streams. Additionally, this minimum temperature should be maintained for the required residence time of 2 seconds after the last injection of combustion air at all times, when waste is burned.

The Devonport Facility will meet the required temperature and residence time requirements of WID, and additional temperature controls, also considered as BAT, which will employed include reducing periods of excessive or uneven temperatures, which can contribute to higher NOx production..

Flue Gas Recirculation

Flue gas recirculation is acknowledged as BAT, whereby flue gas is re-circulated as a replacement of 10 -20% of the secondary air. This technique also provides the additional benefit of reducing reagents used for secondary NOx control, and may assist with increasing overall energy recovery by retaining heat from the chimney gases.

4.2.2 Secondary Techniques

Where European emission limits cannot be guaranteed to be achieved using primary techniques alone, consideration must be given to employing a relevant secondary technique. Secondary techniques generally employ use of an appropriate reagent to chemically reduce the NOx that is formed during combustion, and are outlined below.

Selective Non Catalytic Reduction (SNCR)

Selective Non-Catalytic Reduction (SNCR) uses either urea or ammonia as a reagent, which is injected into the system and chemically reacts with NOx to reduce it to nitrogen and water. The reactions involved are shown below:

- $CO(NH_2)_2$ (aq) + $\frac{1}{2}O_2 \rightarrow CO_2 + 2NH_2$
- $CO(NH_2)_2$ (aq) + $H_2O \rightarrow CO_2 + 2NH_3$
- $2NO + 2NH_3 + O_2 \rightarrow 2N_2 + 3H_2O$
- $2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$

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

Although this is a well established technique, it requires both higher temperatures and that reagents need to be added in excess of the stoichometry of the reaction, which if control is not optimised may lead to ammonia slippage and increased NH_3 emissions.

Selective Catalytic Reduction (SCR)

Selective Catalytic Reduction (SCR) uses a catalyst, along with the addition of ammonia or urea reagent, to reduce the temperature at which the reaction takes place to around 300-400^{o}C. The reactions involved are:

- $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$ or
- $2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$
- $NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

With several secondary reactions:

- $2SO_2 + O_2 \rightarrow 2SO_3$

- $2NH_3 + SO_3 + H_2O \rightarrow (NH_4)_2SO_4$
- $NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$

The reaction for urea instead of either anhydrous or aqueous ammonia is:

- $4NO + 2(NH_2)_2CO + O_2 \rightarrow 4N_2 + 4H_2O + 2CO_2$

Although SCR reduces the quantity of reagent required, additional capital and operating costs are associated with the use of an expensive catalyst and increased energy consumption required to facilitate flue gas reheating before discharge. Issues with ammonia slippage can also occur with this technique.

4.3 Identification of Options

4.3.1 Introduction

The principal feature of a quantitative BAT assessment is the comparison of a base case with alternative options. Consideration should be given to the practicability of the option, and the use of the 'cleanest' feasible technique when selecting options.

Theoretically this can generate a large number of permutations, and to avoid unnecessary evaluation of a large number of process options, the number of techniques is reduced by the 'application of technical assessment and professional judgement' such as 'technical viability', 'excessive cost' and 'availability of particular techniques'.

This section sets out the identification of appraisal options associated with the selection

4.3.2 Appraisal Options

Alternative options have been selected to represent a realistic range of plausible alternatives to the base case, as agreed with the Environment Agency during pre-application discussions. The range of options cannot include all possible alternatives and permutations because these would be too numerous to assess, but it does include enough alternatives to enable a comprehensive assessment of the plausible best available techniques.

The options for Devonport are presented in Table 4.1 below – the base case is option No 1 and the solution chosen by MVV is represented by Option 6.

Table 4.1: Appraisal Options

NOx Control Option	Option Number							
	1	2	3	4	5	6	7	8
No Abatement	✓							
Flue Gas Recirculation (FGR)		✓				✓	✓	✓
SNCR with urea			✓			✓		
SNCR with ammonia				✓			✓	
SCR with ammonia					✓			✓

In terms of this assessment, the base case is assumed to be operation of the process without specific NOx controls in place; that is NOx emissions are unabated.

4.3.3 Identification of Factors to be Considered

The factors to be considered during the assessment are summarised in Table 4.2 below, with justification provided where the factor is not considered relevant.

Table 4.2: Assessment Factors to be Considered

Factor	Relevant	Comment
Emissions to Air	✓	Techniques being considered give rise to different NOx emission levels and may give rise to secondary emissions of NH_3 and N_2O. Therefore this is a key factor in BAT determination.
Emissions to Water	×	No releases to water are associated with any of the techniques proposed.
Global Warming Potential	✓	Potentially significant differences between options due to secondary emissions of NH_3 and N_2O and energy efficiency; therefore relevant to BAT determination.
Ozone Generation	✓	Potentially significant differences between options due to secondary emissions of NOx; therefore relevant to BAT determination.
Odour	×	No significant difference between options.
Noise and Vibration	×	No significant difference between options.
Visual Impact	×	No significant difference between options.
Waste	×	No significant difference between options assuming SCR catalyst is regenerated.

4.4 Environmental Assessment

4.4.1 Abated NOx Emissions for Each Option

In terms of the long term emissions from the process in comparison with the baseline condition (i.e. no NOx abatement):

- The baseline level where no primary or secondary NOx control is employed is 500 mg/Nm^3.
- FGR offers up to a 10% reduction on the baseline NOx level although it should be noted that this is an integral part of the design.
- Both SNCR options (No 6 and No 7) offer a 68% reduction on the baseline when used in combination with FGR. When SNCR options are used without FGR (Options No 3 and No 4) the modelled assessment shows a 64% reduction on the baseline although in practice it is possible to achieve the same level of performance as options No 6 and No 7 using increased amounts of reagent.
- SCR offers around an 80% reduction on the baseline when used with FGR. Similar to SNCR, the reduction without FGR (Option No 5) is slightly less at 78% reduction although again increased amounts of reagent would achieve the same level of performance as option No 8.

Performance of the different options is shown in Table 4.3 below.

Table 4.3: Performance of Different Options

Option	mg/Nm^3	g/s	Annual NOx Tonnes Generated	Annual NOx Tonnes Abated
1. Base Case	500	22.6	641.44	0.00
2. FGR	450	20.34	577.30	64.14
3. SNCR with Urea – No FGR	180	8.136	230.92	410.52
4. SNCR with ammonia – No FGR	180	8.136	230.92	410.52
5. SCR – No FGR	110	4.972	141.12	500.32
6. SNCR with Urea – with FGR	160	7.232	205.26	436.18
7. SNCR with ammonia – with FGR	160	7.232	205.26	436.18
8. SCR with FGR	100	4.52	128.29	513.15

As can be seen from the above table, although FGR on its own offers a 10% NOx reduction it does not achieve the emissions standards specified in WID and as such this option is not considered further.

4.4.2 Emissions to Air – Long Term NOx Impact

In respect of the H1 assessment, the results for each option in respect of long term impact are presented in Table 4.4 below and assume that 100% of the NOx is converted to NO_2.

Table 4.4: Results of Long Term Impact

Option	EAL µg/m^3	PC µg/m^3	PC % of EAL	Background µg/m^3	PEC µg/m^3	PEC % of EAL
1. Base Case	40	2.98	7.46	15.3	18.28	45.71
2. FGR	40	2.68	6.71	15.3	17.98	44.96
3. SNCR with Urea – No FGR	40	1.07	2.68	15.3	16.37	40.93
4. SNCR with ammonia – No FGR	40	1.07	2.68	15.3	16.37	40.93
5. SCR – No FGR	40	0.66	1.64	15.3	15.96	39.89
6. SNCR with Urea – with FGR	40	0.95	2.39	15.3	16.25	40.64
7. SNCR with ammonia – with FGR	40	0.95	2.39	15.3	16.25	40.64
8. SCR with FGR	40	0.60	1.49	15.3	15.90	39.74

As can be seen, on the basis of this assessment, all of the options exceed the 1% process contribution criteria and could not therefore be considered as insignificant on this basis. Taking the assessment further by considering the background air quality with the process contribution to determine the predicted environmental concentration (PEC), it can be seen that the PEC for all the options are in the range of 39.74 – 45.71% of the EU air quality limit for NO_2 as an annual mean. This means that none of the options exceed this air quality standard and all options are below the 70% PEC criteria in H1.

4.4.3 Emissions to Air – Short Term NOx Impact

Emissions rates used for the short term NOx impact are shown in Table 4.5 below and assume that 50% of the NOx is converted to NO_2.

Table 4.5: Emission Rates

Option	mg/Nm^3	g/s
1. Base Case	250	11.3
2. FGR	225	10.17
3. SNCR with Urea – No FGR	90	4.068
4. SNCR with ammonia – No FGR	90	4.068
5. SCR – No FGR	55	2.486
6. SNCR with Urea – with FGR	80	3.616
7. SNCR with ammonia – with FGR	80	3.616
8. SCR with FGR	50	2.26

In respect of the H1 assessment, the results for each option in respect of short term impact are presented in Table 4.6 below and, as can be seen on the basis of this assessment, all of the options exceed the H1 process contribution criteria and could not therefore be identified as insignificant.

Table 4.6: Results of Short Term Impact

Option	EAL µg/m^3	PC µg/m^3	PC % of EAL	Background µg/m^3	PEC µg/m^3	PEC % of EAL
1. Base Case	200	110.74	55.37	29.9	140.64	70.32
2. FGR	200	99.67	49.83	29.9	129.57	64.78
3. SNCR with Urea – No FGR	200	39.87	19.93	29.9	69.77	34.88
4. SNCR with ammonia – No FGR	200	39.87	19.93	29.9	69.77	34.88
5. SCR – No FGR	200	24.36	12.18	29.9	54.26	27.13
6. SNCR with Urea – with FGR	200	35.44	17.72	29.9	65.34	32.67
7. SNCR with ammonia – with FGR	200	35.44	17.72	29.9	65.34	32.67
8. SCR with FGR	200	22.15	11.07	29.9	52.05	26.02

As can be seen, on the basis of this assessment, all of the options exceed the 10% process contribution criteria and could not therefore be considered as insignificant on this basis. Taking the assessment further by considering the background air quality with the process contribution to determine the predicted environmental concentration (PEC), it can be seen that the PEC for all the options using secondary abatement are in the range of approx. 26 – 35% of the EU air quality limit for NO_2 as a 1 hour mean. This means that none of the options exceed this air quality standard.

4.4.4 Emissions to Air – Other Emissions Associated with NOx Control

In relation to other emissions affected by use of secondary NOx control techniques, it is noted that due to the use of ammonia or urea reagents there is:

- An increased risk of ammonia slip occurring and increased emission levels of ammonia from the process; and
- Potential for nitrous oxide emissions from the abatement processes.

Each of these is assessed further below.

Ammonia Emissions

Emissions rates used for the assessment of impact are shown in Table 4.7 below.

Table 4.7: Emission Rates used for Assessment of Impact (Ammonia)

Option	mg/Nm^3	g/s	Long Term EAL µg/m^3	Short Term EAL µg/m^3	Background µg/m^3
1. Base Case	0	0	1	3	1.765
2. FGR	0	0	1	3	1.765
3. SNCR with Urea – No FGR	7.5	0.339	1	3	1.765
4. SNCR with ammonia – No FGR	10	0.452	1	3	1.765
5. SCR – No FGR	5	0.226	1	3	1.765
6. SNCR with Urea – with FGR	7.5	0.339	1	3	1.765
7. SNCR with ammonia – with FGR	10	0.452	1	3	1.765
8. SCR with FGR	5	0.226	1	3	1.765

The H1 impact assessment is presented in Table 4.8 below and it shows that both SNCR and SCR options contribute to ammonia releases from the process, with SCR producing less than SNCR options. SNCR with urea is marginally better than SNCR with ammonia.

Table 4.8: H1 Impact Assessment (Ammonia)

Option	PC µg/m^3	Long Term			Short Term		
		PC % of EAL	PEC µg/m^3	PEC % of EAL	PC % of EAL	PEC µg/m^3	PEC % of EAL
1. Base Case	0.00	0.00	1.77	176.50	0.00	3.53	117.67
2. FGR	0.00	0.00	1.77	176.50	0.00	3.53	117.67
3. SNCR with Urea – No FGR	0.04	4.47	1.81	180.97	110.74	6.85	228.41
4. SNCR with ammonia – No FGR	0.06	5.97	1.82	182.47	147.65	7.96	265.32
5. SCR – No FGR	0.03	2.98	1.79	179.48	73.83	5.74	191.49
6. SNCR with Urea – with FGR	0.04	4.47	1.81	180.97	110.74	6.85	228.41
7. SNCR with ammonia – with FGR	0.06	5.97	1.82	182.47	147.65	7.96	265.32
8. SCR with FGR	0.03	2.98	1.79	179.48	73.83	5.74	191.49

Nitrous Oxide Emissions

Emissions rates used for the assessment of impact are shown in Table 4.9 below.

Table 4.9: Emission Rates used for Assessment of Impact (Nitrous Oxide)

Option	mg/Nm^3	g/s	Long Term EAL µg/m^3	Short Term EAL µg/m^3	Background µg/m^3
1. Base Case	0	0	30	75	41
2. FGR	0	0	30	75	41
3. SNCR with Urea – No FGR	20	0.904	30	75	41
4. SNCR with ammonia – No FGR	10	0.452	30	75	41
5. SCR – No FGR	2	0.0904	30	75	41
6. SNCR with Urea – with FGR	20	0.904	30	75	41
7. SNCR with ammonia – with FGR	10	0.452	30	75	41
8. SCR with FGR	2	0.0904	30	75	41

The H1 impact assessment is shown in Table 4.10 below and it shows that both SNCR and SCR options contribute to nitrous oxide releases from the process, with SNCR producing marginally more nitrous oxide than the SCR options.

Table 4.10: H1 Impact Assessment (Nitrous Oxide)

Option	PC µg/m^3	Long Term			Short Term		
		PC % of EAL	PEC µg/m^3	PEC % of EAL	PC % of EAL	PEC µg/m^3	PEC % of EAL
1. Base Case	0.00	0.0000	41.00	136.67	0.00	82.00	109.33
2. FGR	0.00	0.0000	41.00	136.67	0.00	82.00	109.33
3. SNCR with Urea – No FGR	0.12	0.3978	41.12	137.06	11.81	90.86	121.15
4. SNCR with ammonia – No FGR	0.06	0.1989	41.06	136.87	5.91	86.43	115.24
5. SCR – No FGR	0.01	0.0398	41.01	136.71	1.18	82.89	110.51
6. SNCR with Urea – with FGR	0.12	0.3978	41.12	137.06	11.81	90.86	121.15
7. SNCR with ammonia – with FGR	0.06	0.1989	41.06	136.87	5.91	86.43	115.24
8. SCR with FGR	0.01	0.0398	41.01	136.71	1.18	82.89	110.51

4.4.5 Energy Consumption

The annual energy consumption requirements of each option, on the basis of 7,884 operational hours, are shown in Table 4.11 below. The assessment is undertaken on the basis of primary energy (ie the energy as it is generated at source without transport or transmission losses), which means that impact from all energy sources is considered on the same basis. In order to determine primary energy, a conversion factor from H1 is applied, as follows:

- Electricity from public supply – multiplied by a conversion factor of 2.4 to account for transport and transmission losses;

- Electricity from own supply – multiplied by a conversion factor of 1 as energy is used at source;
- Gas oil (auxiliary fuel) – multiplied by a conversion factor of 1 as there is no associated transport or transmission losses; and
- Waste fuel - multiplied by a conversion factor of 1 as there is no associated transport or transmission losses.

Table 4.11: Energy Consumption Requirements

Option	Annual Delivered MWh				Annual Primary MWh				Total Annual Primary Energy Used (MWh)
	Auxiliary Fuel	Parasitic Power	Waste Fuel	Own Heat	Auxiliary Fuel	Parasitic Power	Waste Fuel	Own Heat	
1. Base Case	19418	19626	647276	0	19418	20116	647276	0	686810
2. FGR	19418	20426	647276	0	19418	20916	647276	0	687610
3. SNCR with Urea – No FGR	19418	19676	647276	2200	19418	20166	647276	2200	689060
4. SNCR with ammonia – No FGR	19418	19676	647276	2200	19418	20166	647276	2200	689060
5. SCR – No FGR	19418	24886	647276	26500	19418	25376	647276	26500	718570
6. SNCR with Urea – with FGR	19418	20476	647276	2200	19418	20966	647276	2200	689860
7. SNCR with ammonia – with FGR	19418	20476	647276	2200	19418	20966	647276	2200	689860
8. SCR with FGR	19418	25686	647276	26500	19418	26176	647276	26500	719370

The annual energy generation potential of each option based on 7,884 operational hours is shown in Table 4.12 below.

Table 4.12: Energy Generation Potential

Option	Annual Energy Exported (MWh)		
	Electricity	Heat	Total Export
1. Base Case	162412	75,429	237841
2. FGR	162012	75,429	237441
3. SNCR with Urea – No FGR	162387	75,429	237816
4. SNCR with ammonia – No FGR	162387	75,429	237816
5. SCR – No FGR	156317	75,429	231746
6. SNCR with Urea – with FGR	161987	75,429	237416
7. SNCR with ammonia – with FGR	161987	75,429	237416
8. SCR with FGR	155917	75,429	231346

From the above assessment it can be seen that

- Options using FGR require approximately 3% more power than the same option without FGR, however, FGR improves the overall thermal efficiency of the process and options using FGR are therefore more favourable overall; and
- SCR options have higher power requirements and are less thermally efficient than the other options.

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4.4.6 Global Warming Potential

Greenhouse gas impacts or global warming potential (GWP) for each option are assessed on the basis of:

- Emissions from the process; and
- Direct and indirect emissions associated with energy consumption.

The main factors that influence GWP are:

a. Debit Side

- Direct CO_2 from the combustion of waste;
- Direct CO_2 from the combustion of auxiliary fuels;
- Indirect CO_2 from the use of electrical power drawn from public supply; and
- N_2O from the control of NOx.

b. Credit Side

- CO_2 saved due to the export of electricity to the public supply associated with the displacement of fossil fuels; and
- CO_2 saved due to the export of heat to the Naval Dockyard associated with the displacement of fossil fuels.

In respect of GWP for the Devonport Facility, this is dominated by emissions of CO_2 from the combustion of waste with a smaller contribution from the combustion of auxiliary fuel; however, this is constant for all options. CO_2 from the use of electrical power will fluctuate, and will depend on the NOx control option that is used.

In relation to this assessment, the factors given in the April 2010 version of H1 have been used and a breakdown of GWP is provided in Table 4.13 below associated with energy consumption, energy recovery and in the amount of N_2O emitted.

Table 4.13: Breakdown of GWP (Tonnes CO_2 per annum)

Source	Electricity & Heat GWP	Waste & Auxiliary Fuels GWP	N_2O GWP	Total GWP
1. Base Case	-75139	233990	0	158851
2. FGR	-74847	233990	0	159143
3. SNCR with Urea – No FGR	-74756	233990	7954	167189
4. SNCR with ammonia – No FGR	-74756	233990	3977	163212
5. SCR – No FGR	-67438	233990	795	167347
6. SNCR with Urea – with FGR	-74463	233990	7954	167481
7. SNCR with ammonia – with FGR	-74463	233990	3977	163504
8. SCR with FGR	-67146	233990	795	167639

Taking the above GWP assessment into account, it can be seen that SCR options have a significantly higher GWP than other options, primarily due to poor energy efficiency performance. SNCR options with ammonia are better than those with urea due to lower amounts of nitrous oxide formation.

4.4.7 Ozone Generation Potential

In respect of ozone generation potential, this is associated with the amount of NOx produced annually and is determined by the application a standard conversion factor (from H1). The output of the assessment is tonnes POCP per annum, and as can be seen, the lowest potential is associated with SCR options.

Table 4.14: Ozone Generation Potential

Option	POCP Tonnes from NOx
1. Base Case	1796.04
2. FGR	1616.43
3. SNCR with Urea – No FGR	646.57
4. SNCR with ammonia – No FGR	646.57
5. SCR – No FGR	395.13
6. SNCR with Urea – with FGR	574.73
7. SNCR with ammonia – with FGR	574.73
8. SCR with FGR	359.21

4.4.8 Raw Material Consumption

The use of SNCR or SCR requires the additional consumption of reagents to facilitate NOx control, and this is shown in Table 4.15 below. Based on the annual tonnage of reagent which would be required by each option, it can be seen that:

- SCR options require less reagent than SNCR options; and
- SNCR with urea uses around 16% less reagent than SNCR with ammonia.

Table 4.15: Raw Material Consumption

Option	Urea Annual Tonnes	Ammonia Annual Tonnes
1. Base Case	0	0
2. FGR	0	0
3. SNCR with Urea – No FGR	215	0
4. SNCR with ammonia – No FGR	0	250
5. SCR – No FGR	0	150
6. SNCR with Urea – with FGR	215	0
7. SNCR with ammonia – with FGR	0	250
8. SCR with FGR	0	150

4.4.9 Waste Generation

There are no additional waste impacts associated with NO_X control techniques, as SCR catalyst is assumed to be regenerated. As such no additional assessment is required.

4.4.10 Environmental Quotient

The environmental quotients for each emission are summed to provide an indication of the total impact from all emissions. The environmental quotient (EQ) is the ratio of each Process Contribution to its respective standard. The environmental quotients for each option are shown in Table 4.16 below and it can be seen that SCR represents the best option.

Table 4.16: Environmental Quotient

Option	Long Term EQ	Short Term EQ
1. Base Case	0.0746	0.5537
2. FGR	0.0671	0.4983
3. SNCR with Urea – No FGR	0.0756	1.4249
4. SNCR with ammonia – No FGR	0.0885	1.7349
5. SCR – No FGR	0.0466	0.8719
6. SNCR with Urea – with FGR	0.0726	1.4027
7. SNCR with ammonia – with FGR	0.0855	1.7128
8. SCR with FGR	0.0451	0.8608

4.4.11 Environmental Assessment Ranking

Based on the environmental assessment, the overall ranking of each option over the baseline is shown in Table 4.17 below

Table 4.17: Environmental Assessment Ranking

Option	Long Term EQ	Short Term EQ	POCP	GWP	Raw Materials	Energy	Total Score
2. FGR	3	5	5	1	1	2	**17**
3. SNCR with Urea – No FGR	5	4	4	4	3	1	**21**
4. SNCR with ammonia – No FGR	7	7	4	2	4	1	**25**
5. SCR – No FGR	2	2	2	5	2	4	**17**
6. SNCR with Urea – with FGR	4	3	3	6	3	3	**22**
7. SNCR with ammonia – with FGR	6	6	3	3	4	3	**25**
8. SCR with FGR	1	1	1	7	2	5	**17**

From the environmental assessment ranking it can be seen that:

- FGR along with SCR options present the best ranking with a total score of 17; however, for FGR NOx emission levels cannot meet defined WID standards without a secondary abatement technique being employed, and it is therefore discounted; while
- The difference between the other options is marginal with:
  a. SCR options offering best ranking, with a score of 17;
  b. SNCR with urea (no FGR) is second best, with a score of 21;
  c. SNCR/FGR with urea is third best, with a score of 22; and
  d. Options using SCNR with ammonia are least favourable, with a score of 25.

4.5 Cost Appraisal

4.5.1 Summary of Costs

Additional costs over those in the baseline associated with the various options are summarised in Table 4.18 below.

Table 4.18: Summary of Costs

Option	Capital (£)	Annual Operating (£)	Equivalent Annual Operating Cost (£)	Increased Cost per Tonne Waste
2. FGR	350,000	26800	62432	0.24
3. SNCR with Urea – No FGR	610,000	119419	181521	0.68
4. SNCR with ammonia – No FGR	730,000	199863	274181	1.03
5. SCR – No FGR	6,000,000	1003947	1614785	6.09
6. SNCR with Urea – with FGR	960,000	146219	243953	0.92
7. SNCR with ammonia – with FGR	1,080,000	226663	336613	1.27
8. SCR with FGR	6,350,000	1030747	1677217	6.33

4.5.2 Cost per Tonne Ranking

The various options are ranked on the basis of cost per tonne of NOx abated and this is shown in Table 4.19 on the following page.

Table 4.19: Cost per Tonne Ranking

Option	NOx Emissions		Ranking Score
	Annual Abated Tonnes	Additional Cost per tonne	
2. FGR	64.14	0	1
3. SNCR with Urea – No FGR	410.52	442	2
4. SNCR with ammonia – No FGR	410.52	668	4
5. SCR – No FGR	500.32	3227	6
6. SNCR with Urea – with FGR	436.18	559	3
7. SNCR with ammonia – with FGR	436.18	772	5
8. SCR with FGR	513.15	3268	7

Although FGR alone represents the best cost option, it is discounted on the basis that to meet WID standards for NOx emissions a secondary abatement technique must also be employed.

Options using SNCR with urea represent the best cost options in terms of achieving WID emission levels, with SCR options requiring significant additional expenditure.

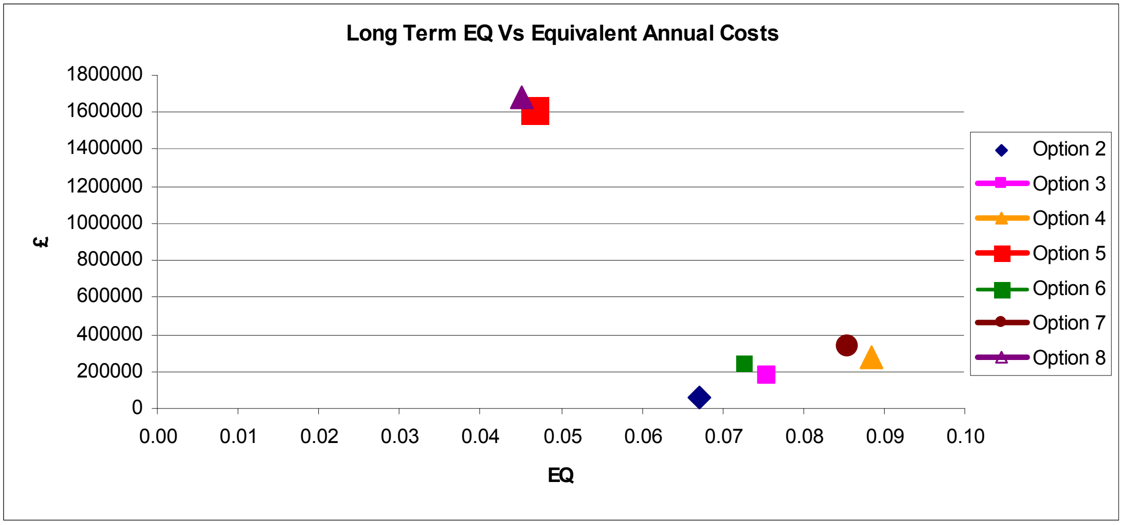
4.6 Conclusion

4.6.1 Comparison Charts

The figures below show the relationship between the costs and the various environmental considerations of implementing each option.

Long Term EQ vs Annual Costs

Figure 4.1: Long Term EQ vs Annual Costs

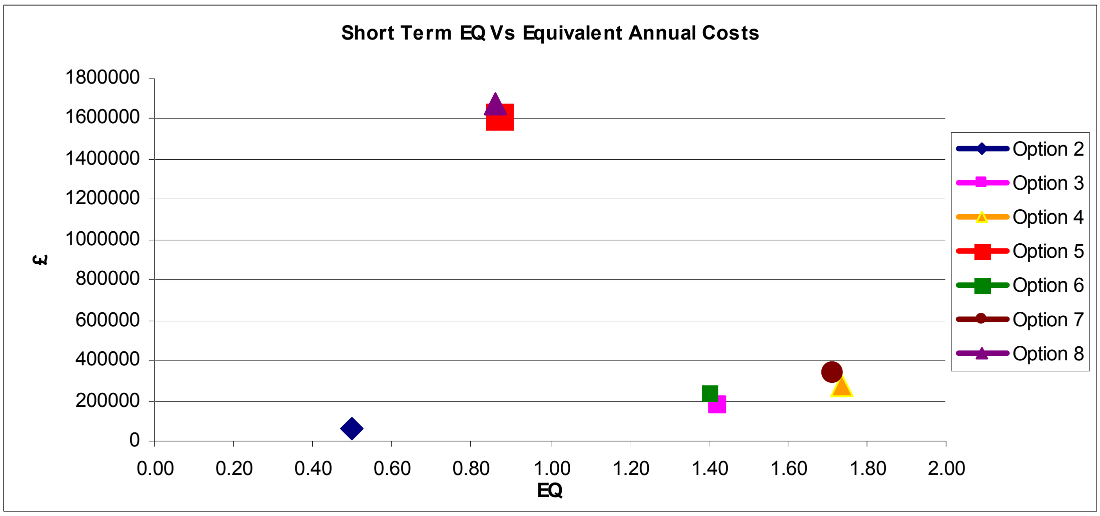


From the above chart it can be seen that:

- SCR options (No 5 and No 8) offer the lowest EQ; however, these options have the highest equivalent annualised costs;
- FGR (option No 2) is the third lowest EQ and lowest equivalent annualised costs; however this option will not deliver the required WID emission standards in isolation; and
- The options involving SNCR using urea represent the next best EQ after SCR, with the lowest equivalent annualised costs.

Short Term EQ vs Annual Costs

Figure 4.2: Short Term EQ vs Annual Costs

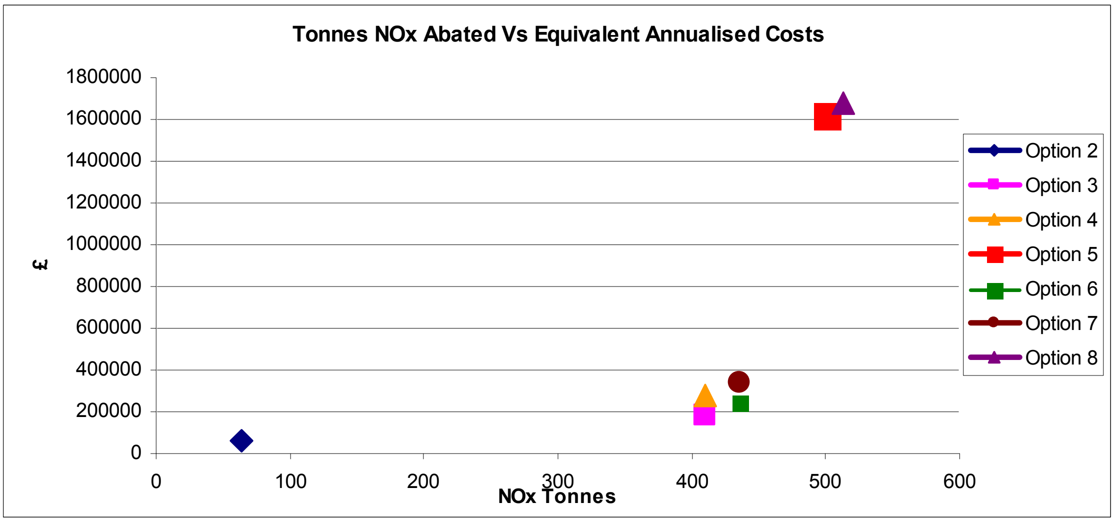


From the above chart it can be seen that:

- FGR (option No 2) is the lowest EQ and lowest equivalent annualised costs; however this option will not deliver the required WID emission standards in isolation
- SCR options (No 5 and No 8) offer the second lowest EQ; however, these options have the highest equivalent annualised costs; and
- The options involving SNCR using urea represent the next best EQ, with the second lowest equivalent annualised costs.

Tonnes NOx Abated vs Annual Costs

Figure 4.3: Tonnes NOx Abated vs Annual Costs

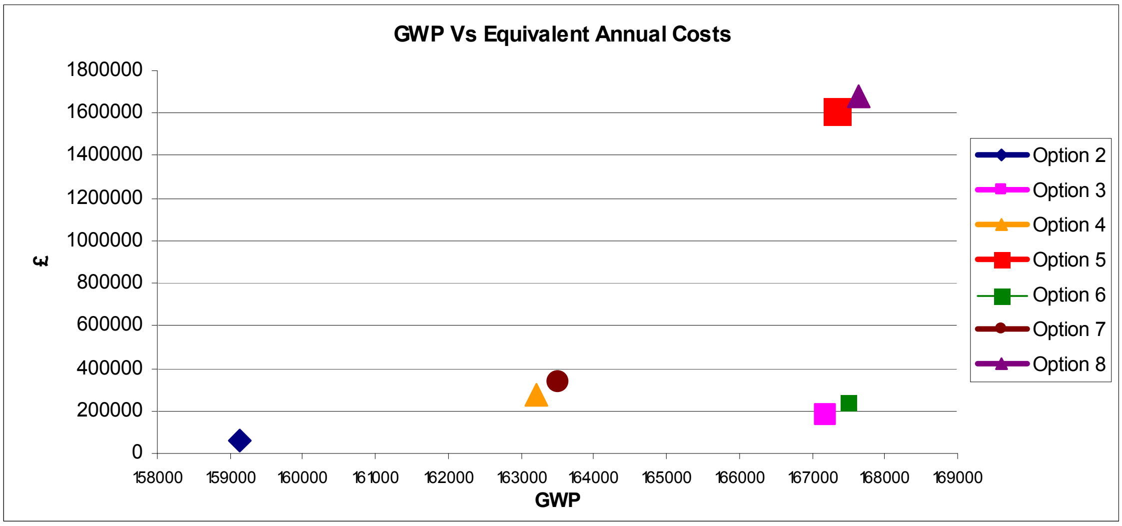


From the above chart it can be seen that:

- SCR options (No 5 and No 8) offer the maximum tonnage of NOx abated, however, these options have the highest equivalent annualised costs;
- The options involving SNCR with FGR (No 6 and 7) represent the next best tonnage of NOx abated, with one of the lowest equivalent annualised costs; and
- FGR (option 2), which represents the lowest equivalent annualised cost, offers the least abatement potential and will not meet the required WID emission standards in isolation.

GWP vs Annual Costs

Figure 4.4: GWP vs Annual Costs

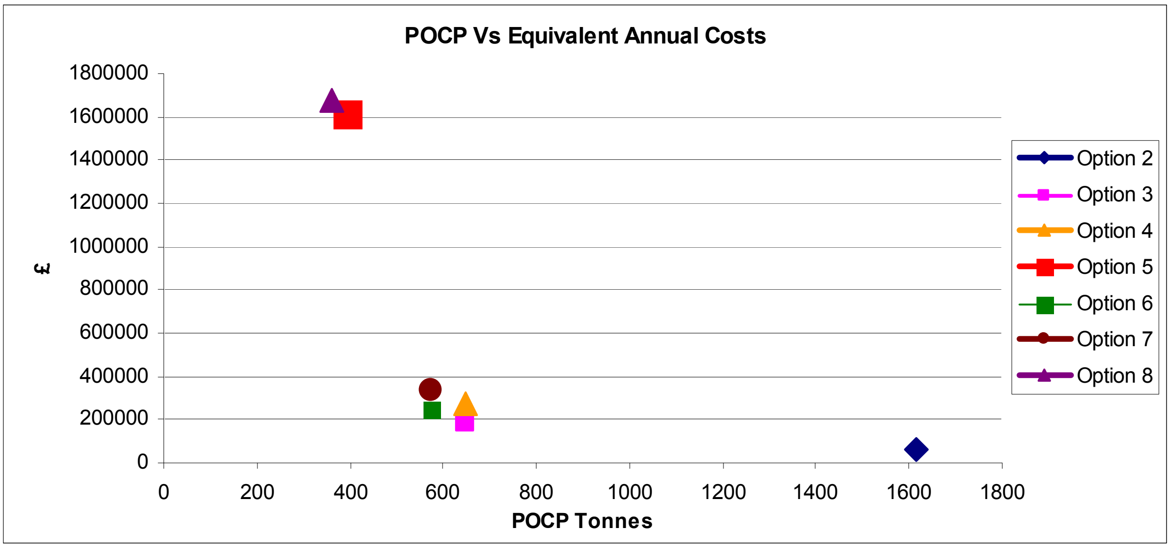


From the above chart it can be seen that:

- SCR options (No 5 and No 8) have the highest GWP and highest equivalent annualised costs;
- The options involving SNCR with ammonia (No 4 and 7) represent the second lowest GWP, with the second lowest equivalent annualised costs; and
- FGR (option 2) represents the lowest equivalent annualised cost and lowest GWP but this option cannot deliver the required WID emission standards in isolation.

POCP vs Annual Costs

Figure 4.5: POCP vs Annual Costs

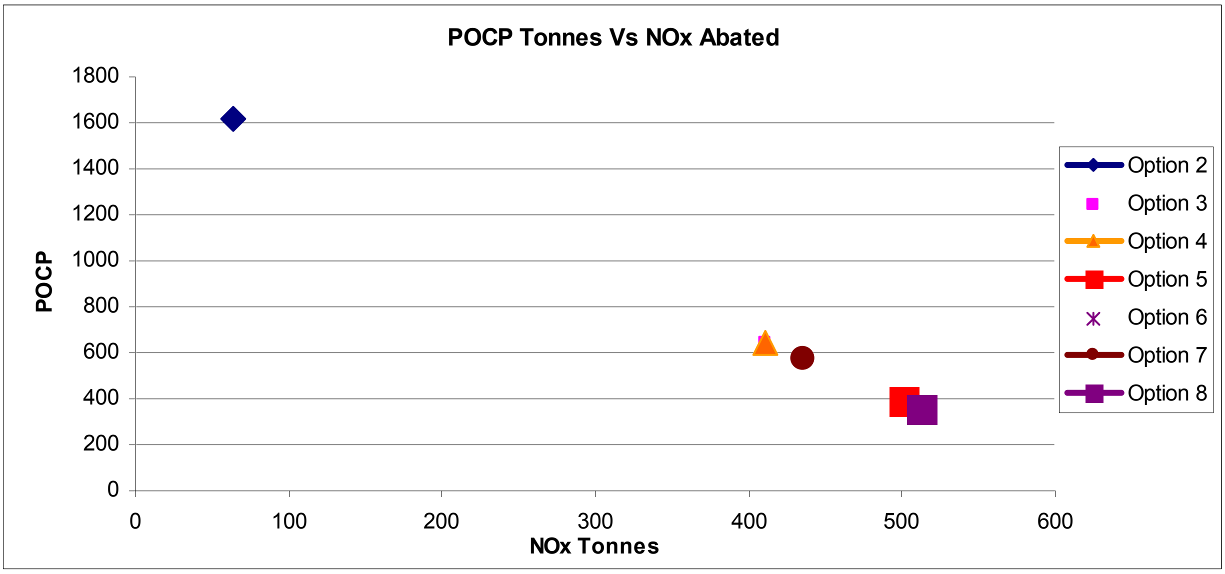


From the above chart it can be seen that:

- SCR options (No 5 and No 8) offer the lowest POCP; however, these options have the highest equivalent annualised costs;
- SNCR with ammonia (No 4 and No 7) offers the second lowest POCP and third lowest equivalent annualised costs; and
- The options involving SNCR using urea (No 3 and No 6) represent the third lowest POCP, with the second lowest equivalent annualised costs

POCP vs NOx Abated

Figure 4.6: POCP vs NOx Abated

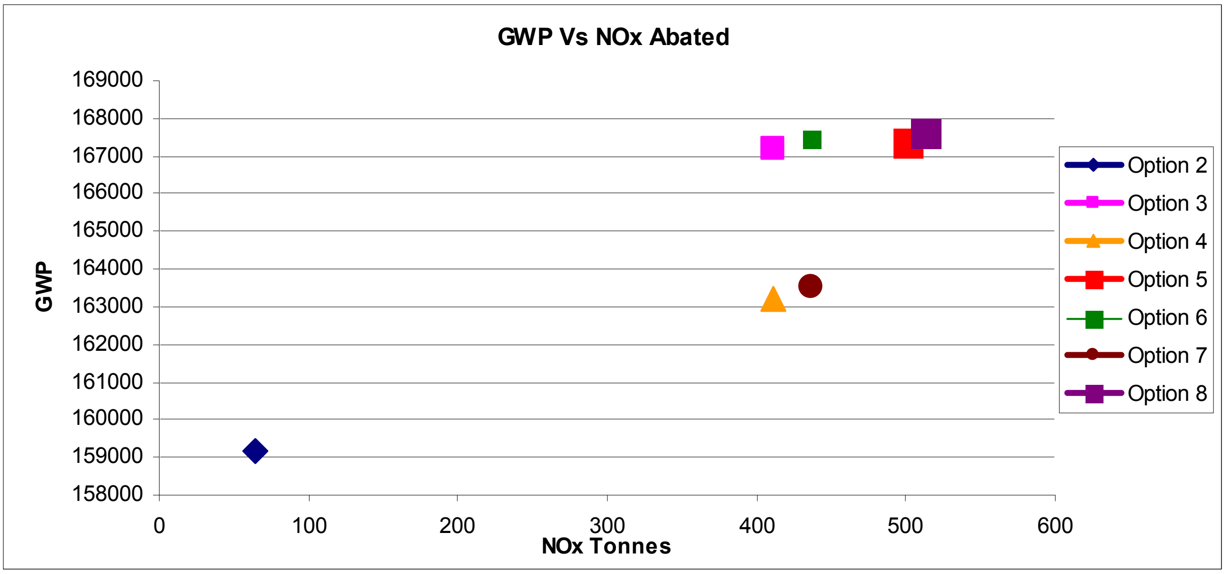


From the above chart it can be seen that:

- SCR options (No 5 and No 8) offer the most tonnes of NOx abated and lowest POCP; and
- SNCR with FGR (No 6 and No 7) offer the second lowest POCP and second best performance in terms of NOx abated.

GWP vs NOx Abated

Figure 4.7: GWP vs NOx Abated

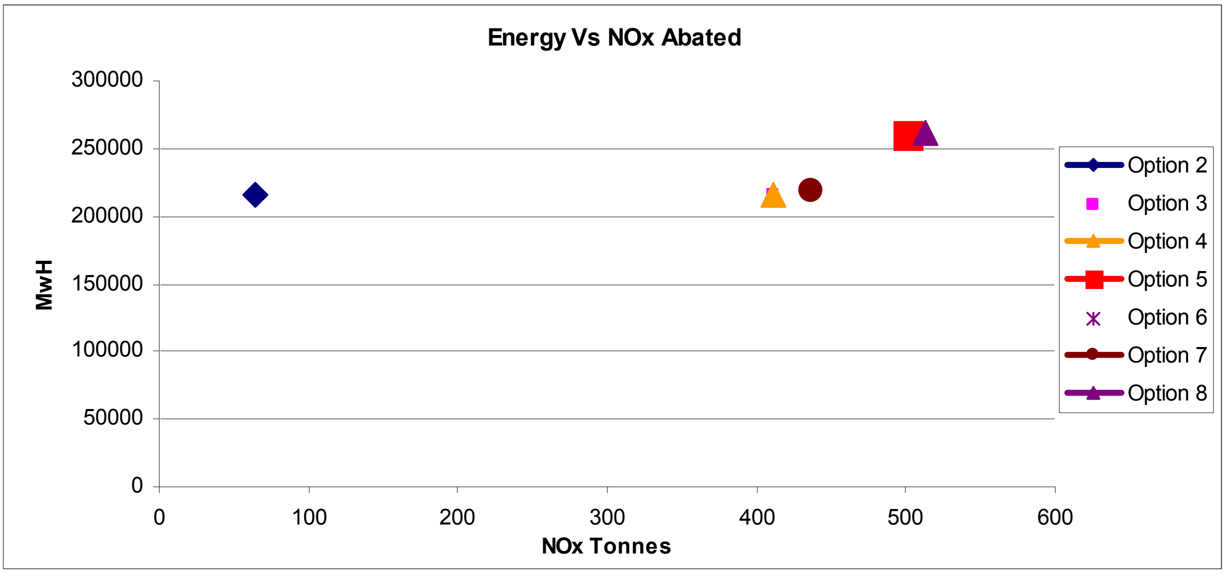


From the above chart it can be seen that:

- SCR options (No 5 and No 8) offer the best NOx abatement; however, these options have the highest GWP;
- SNCR with urea (No 3 and No 6) offers the next best NOx abatement, with the second highest GWP; and
- The options involving SNCR using ammonia (No 4 and No 7) represent the same performance in terms of NOx abated as SNCR with urea, although these options have a lower GWP.

Energy vs NOx Abated

Figure 4.8: Energy vs NOx Abated



From the above chart it can be seen that:

- SCR options (No 5 and No 8) offer the best NOx abatement; however, these options have the highest energy requirements; and
- SNCR options offer the next best NOx abatement potential, with Options No 3 and 4 (without FGR) being marginally better in terms of energy requirement.

4.6.2 Discussion

Following completion of the H1 assessment it is possible to conclude that:

- FGR, although the most cost-effective option, while offering a small NOx reduction potential, will not meet the WID emission standards without the employment of some secondary abatement technique as well;
- SCR options (No 5 and No 8) offer the best environmental option in respect of the air quality impact of NOx emissions and relevant environmental quotients, although this benefit is offset by the GWP of this option, which is around 2.5% higher than that offered by SNCR with ammonia;
- SNCR options provide similar performance in respect of NOx reduction, regardless of reagent choice, although ammonia offers a better performance in terms of GWP, while urea has a better overall environmental quotient;
- Energy recovery in terms of exported power and heat is around 2.6% lower for SCR options than that provided by SNCR options, and energy consumption is around 4.3% higher.
- SCR requires less reagent than SNCR options;
- While SCR options (No 5 and No 8) result in better environmental performance in relation to NOx reduction and environmental quotient, these options represent the two most expensive options, adding up to £6.33/tonne waste treated, alternatively requiring a spend of up to £3,268/tonne of NOx abated; and

- The SNCR option, with urea, provides a better environmental performance to SNCR with ammonia, and is best in terms of annualised costs, requiring an additional £0.92/tonne waste treated or £559/tonne of NOx abated.

MVV has therefore chosen Option No 6, SNCR with urea as the chosen reagent, in combination with FGR, as its preferred secondary abatement technique, on the basis that:

- It offers a 68% reduction in unabated NOx emissions, which is comparable to SNCR using ammonia;
- Expected typical performance is around 20% lower than the WID emission limit;
- Contribution to the local air quality, while indicated as potentially significant by this assessment, assumes that 100% of the long term NOx emissions would be converted to NO_2 which would be worse case; it should be noted however, that no environmental standards are likely to be exceeded;
- The option consumes 2.6% less power than SCR, and produces 4.3% more energy for export, irrespective of reagent selected in the SCR;
- The costs of using SNCR with ammonia are 38% higher than those of SNCR with urea for a comparable level of performance; and
- The annualised equivalent cost of introducing SCR is around 7 times higher than that of SNCR using urea with FGR. Comparing the two options on the basis of tonnes of NOx abated, SCR at £3,268/tonne of abated NOx is nearly 6 times higher than the cost of the equivalent SNCR option, at £558/tonne of abated NOx

Therefore, on the basis this assessment, it is concluded that SNCR using urea, with FGR, represents BAT for this installation.

5 Appraisal of Acid Gas Control Techniques

5.1 BAT Assessment Methodology

5.1.1 Methodology

The assessment of BAT has been undertaken in line with the Environment Agency H1 Guidance “Environmental Risk Assessment for Permits” (April 2010).

This methodology provides an objective approach to establishing the most appropriate technology for the proposed process, taking into account both the environmental consequences and costs associated with various design options. The assessment has been undertaken using a spreadsheet set up in accordance with the H1 Guidance, as there were technical problems with the latest H1 software tool which meant the full options appraisal could not be completed using it.

The assessment basically comprises 6 basic modules:

1. Definition of the objective of the assessment and the options to be considered;
2. Quantification of the emissions from each option;
3. Quantification of the environmental impacts resulting from the emissions;
4. Comparison of the options and ranking in order of best overall environmental performance;
5. Evaluation of the costs to implement each option; and
6. Identification of the option that represents BAT by balancing the environmental benefits against cost.

The spreadsheet calculation (ref. “Devonport H1 BAT Assessment.xls”) has been provided to the Environment Agency, along with this report, to allow the verification of the results.

5.1.2 Objective of the Assessment

The objective of this assessment is to:

- Compare the environmental consequences of the proposed acid gas control measures selected for this project (i.e. the base case) with several alternative options; and
- Evaluate the cost-benefit relationship of the different acid gas control mechanisms.

5.1.3 Data for the Assessment

The data for the assessment is based on typical performance levels for the various options, rather than at the WID emission limit values used in the environmental impact assessment. Data has been obtained from:

- Technology providers; and
- Standard reference materials, such as the Incineration BREF note.

The dispersion factor used for the determination of the process contribution has been determined in line with the H1 methodology.

5.2 Techniques Considered as BAT

The potential options for reduction of acid gases are identified in SGN S5.01 “*Guidance for the Incineration of Waste and Fuel Manufactured From or Including Waste”* and are outlined below.

5.2.1 Primary Techniques

Primary techniques are aimed at minimising the production of acid gases in the combustion system, and include:

Auxiliary Fuel Selection

This technique focuses on the selection of low sulphur fuels (<0.2% w/w) for start-up and process support. In respect of the Devonport facility, gas oil which meets the low sulphur definition will be utilised and as such is considered BAT for the process.

Fuel Selection

This technique focuses on the selection of low sulphur fuels to minimise the generation of acid gases during the combustion process. However, the nature of the sector means that there is little room for selection of different fuels and as such this has been discounted as a feasible primary acid gas control measure.

5.2.2 Secondary Techniques

Where European emission limits cannot be guaranteed to be achieved using primary techniques alone, consideration must be given to employing a relevant secondary technique. Secondary techniques generally employ use of an appropriate reagent to chemically reduce the acid gases that are formed during combustion and are outlined below.

Wet Scrubbing

Wet scrubbing uses pre-formed spray towers in which a liquid is atomised through high pressure spray nozzles. The gas-stream usually enters the bottom of the chamber, and flows concurrent or cross-current to the liquid. The atomised liquid forms droplets and mass transfer occurs at the droplet surface, and therefore the finer the droplets the more gas adsorption is enhanced. Impurities which are soluble in the scrubbing liquid are removed by the gas adsorption process.

The scrubbing medium can be water, or an aqueous suspension of sodium hydroxide or lime can also be used.

Wet scrubbing is recognised as having the following benefits:

- High reaction rates and good performance over a range of loadings;
- Low reagent consumption;
- Low solid residue production and;
- Condensation may assist metal removal.

Although the technique is currently in use in similar processes, it has a number of disadvantages:

- Large effluent disposal and water consumption, where it can’t be fully treated for recycling;

- Effluent treatment plant is likely to be required;
- Wet-plume formation, leading to visual impact;
- Additional energy required to facilitate effluent treatment and plume reheat;
- Higher capital costs;
- The system can experience high corrosion; and
- Pre-scrubbing of particulate material may be needed to achieve particulate emission levels.

Dry Scrubbing

Dry scrubbing utilises the pneumatic injection of the reagent (hydrated lime or sodium bicarbonate and activated carbon) into the flue-gas stream in order to treat it. Dry scrubbing systems are relatively simple, and, unlike other systems, minimise visible plume and have no liquid release.

Their benefits are:

- Relatively good performance and good reliability;
- Low or zero water use;
- Possible to reduce reagent consumption by recirculation of residues;
- Relatively low capital costs; and
- As no flue-gas reheat is needed, a greater proportion of the flue-gas energy can be recovered.

Disadvantages of the dry scrubbing system are:

- Low reaction rate, resulting in longer residence time to achieve desired emission control;
- There is higher solid residue production with lime based systems than bicarbonate based systems.

Semi-Dry Scrubbing

Semi-dry scrubbing systems utilise the injection of the reagent (lime) with water into the flue-gas as a concentrated solution (lime milk), which results in gas cooling and treatment. The benefits of the semi-dry scrubbing system include:

- Relatively good performance and good reliability; and
- Lower water consumption than wet systems.

Disadvantages of the semi-dry scrubbing system include:

- Higher solid waste residues; and than wet systems;
- Recycling of the reagent in the process is not proven;
- Higher water consumption than dry systems; and
- High flue-gas inlet temperature requirement limits the amount of flue gas heat recovery.

5.3 Identification of Options

5.3.1 Introduction

The principal feature of a quantitative BAT assessment is the comparison of a base case with alternative options. Consideration should be given to the practicability of the option and the use of the ‘cleanest’, feasible technique when selecting options.

Theoretically, this can generate a large number of permutations and to avoid unnecessary evaluation of a large number of process options, the number of techniques is reduced by the ‘application of technical assessment and professional judgement’ such as ‘technical viability’, ‘excessive cost’ and ‘availability of particular techniques’.

This section sets out the identification of appraisal options associated with the selection.

5.3.2 Appraisal Options

The alternative options have been selected to represent a realistic range of plausible alternatives to the base case, as agreed with the Environment Agency. The range of options cannot include all possible alternatives and permutations because these would be too numerous to assess, but it does include enough alternatives to enable a comprehensive assessment of the plausible best available techniques.

The options considered for Devonport are presented in Table 5.1 below – the base case is option No 1 and MVV’s preferred option is No 3:

Table 5.1: Appraisal Options

Acid Gas Control Option	Option Number				
	1	2	3	4	5
No Abatement	✓				
Dry Scrubber – Lime		✓			
Dry Scrubber – Sodium Bicarbonate			✓		
Wet Scrubber				✓	
Semi-Dry Scrubber					✓

In terms of this assessment, the base case is assumed to be operation of the process without specific acid gas controls in place; that is acid gas emissions are unabated.

5.3.3 Identification of Factors to be considered

The factors to be considered during the assessment are summarised in the table below and justification is provided where the factor is not considered relevant.

Table 5.2: Factors to be considered during Assessment

Factor	Relevant	Comment
Emissions to Air	✓	Techniques being considered give rise to different acid gas emission levels; therefore this is a key factor in BAT determination.
Emissions to Water	✓	Potential significant difference between options relating to the volume of effluent discharged; therefore relevant to the BAT determination.
Global Warming Potential	✓	Potentially significant differences between options due to energy efficiency differences; therefore relevant to BAT determination.

Ozone Generation	✓	Potentially significant differences between options due to secondary emissions of SO_3; therefore relevant to BAT determination.
Odour	×	No significant difference between options.
Noise and Vibration	×	No significant difference between options.
Water Use	✓	Potentially significant differences between options. Therefore relevant to BAT determination.
Visual Impact	✓	Potentially significant differences between options. Therefore relevant to BAT determination.
Waste	✓	Potentially significant differences between options. Therefore relevant to BAT determination.

5.4 Environmental Assessment

5.4.1 Abated Acid Gas Emissions for Each Option

In terms of the long term emissions from the process in comparison with the baseline condition (i.e. no acid gas abatement):

- The baseline level, where no primary or secondary control is employed, is 400 mg/Nm^3 for SO_2, 900 mg/Nm^3 for HCl and is 30 mg/Nm^3 for HF;
- Dry scrubbing with lime offers up to a 87.5% reduction for SO_2 at 50 mg/Nm^3, 98.8% for HCl at 10 mg/Nm^{3}and 96.7% for HF at 1 mg/Nm^3;
- Dry scrubbing with sodium bicarbonate offers up to a 90% reduction for SO_2 at 40 mg/Nm^3, 99% for HCl at 9 mg/Nm^3 and 97.3% for HF at 0.8 mg/Nm^3;
- Wet scrubbing offers up to a 95% reduction for SO_2 at 20 mg/Nm^3, 99.4% for HCl at 5 mg/Nm^3 and 98.3% for HF at 0.5 mg/Nm^3; and
- Semi-dry scrubbing offers up to a 87.5% reduction for SO_2 at 50 mg/Nm^3, 98.8% for HCl at 10 mg/Nm^3 at 50 mg/Nm^3 and 96.7% for HF at 1 mg/Nm^3.

Performance of the different options is shown in Table 5.3 below.

Table 5.3: Performance of Different Options

Option	mg/Nm^3	g/s	Annual Tonnes Generated	Annual Tonnes Abated
Sulphur Dioxide				
1. No Abatement	400	18.08	513.15	0
2. Dry Scrubber - Lime	50	2.26	64.14	449.01
3. Dry Scrubber – Sodium Bicarbonate	40	1.808	51.32	461.84
4. Wet Scrubber	20	0.904	25.66	487.50
5. Semi-Dry Scrubber	50	2.26	64.14	449.01
Hydrogen Chloride				
1. No Abatement	900	40.68	1154.60	0
2. Dry Scrubber - Lime	10	0.452	12.83	1141.77
3. Dry Scrubber – Sodium Bicarbonate	9	0.4068	11.55	1143.05
4. Wet Scrubber	5	0.226	6.41	1148.18
5. Semi-Dry Scrubber	10	0.452	12.83	1141.77
Hydrogen Fluoride				
1. No Abatement	30	1.356	38.49	0
2. Dry Scrubber - Lime	1	0.0452	1.28	37.20
3. Dry Scrubber – Sodium Bicarbonate	0.8	0.03616	1.03	37.46
4. Wet Scrubber	0.5	0.0226	0.64	37.85
5. Semi-Dry Scrubber	1	0.0452	1.28	37.20

5.4.2 Emissions to Air – Long Term Impact

In respect of the H1 assessment, the results for each option in respect of long term impact are presented in Table 5.4 below. As can be seen, on the basis of this assessment, all of the options would be identified as insignificant against the 1% process contribution (%PC) H1 criteria.

Table 5.4: Emissions to Air - Long Term Impact

Option	EAL µg/m^3	PC µg/m^3	PC % of EAL	Background µg/m^3	PEC µg/m^3	PEC % of EAL
Sulphur Dioxide						
1. No Abatement	125	2.39	1.91	7.1	9.49	7.59
2. Dry Scrubber - Lime	125	0.30	0.24	7.1	7.40	5.92
3. Dry Scrubber – Sodium Bicarbonate	125	0.24	0.19	7.1	7.34	5.87
4. Wet Scrubber	125	0.12	0.10	7.1	7.22	5.78
5. Semi-Dry Scrubber	125	0.30	0.24	7.1	7.40	5.92
Hydrogen Chloride						
1. No Abatement	30	5.37	17.8992	0.004	5.78	19.27
2. Dry Scrubber - Lime	30	0.06	0.1989	0.004	0.47	1.57
3. Dry Scrubber – Sodium Bicarbonate	30	0.05	0.1790	0.004	0.46	1.55
4. Wet Scrubber	30	0.03	0.0994	0.004	0.44	1.47
5. Semi-Dry Scrubber	30	0.06	0.1989	0.004	0.47	1.57
Hydrogen Fluoride						
1. No Abatement	1	0.1790	17.90	0.003	0.18	18.20
2. Dry Scrubber - Lime	1	0.0060	0.60	0.003	0.01	0.90
3. Dry Scrubber – Sodium Bicarbonate	1	0.0048	0.48	0.003	0.01	0.78
4. Wet Scrubber	1	0.0030	0.30	0.003	0.006	0.60
5. Semi-Dry Scrubber	1	0.0060	0.60	0.003	0.01	0.90

A wet scrubber represents the best option for the reduction of emission levels, with sodium bicarbonate dry scrubbing representing the second best option.

5.4.3 Emissions to Air – Short Term Impact

Emissions rates used for the short term impact are shown in Table 5.5 below.

Table 5.5: Emissions Rates

Option	mg/Nm^3	g/s
Sulphur Dioxide		
1. No Abatement	800	36.16
2. Dry Scrubber - Lime	50	2.26
3. Dry Scrubber – Sodium Bicarbonate	40	1.808
4. Wet Scrubber	20	0.904
5. Semi-Dry Scrubber	50	2.26
Hydrogen Chloride		
1. No Abatement	1,800	81.36
2. Dry Scrubber - Lime	10	0.452
3. Dry Scrubber – Sodium Bicarbonate	9	0.4068
4. Wet Scrubber	5	0.226
5. Semi-Dry Scrubber	10	0.452
Hydrogen Fluoride		
1. No Abatement	60	2.712
2. Dry Scrubber - Lime	1.00	0.0452
3. Dry Scrubber – Sodium Bicarbonate	0.80	0.03616
4. Wet Scrubber	0.50	0.0226
5. Semi-Dry Scrubber	1.00	0.0452

In respect of the H1 assessment, the results for each option in respect of short term impact are presented in Table 5.6 below, and, as can be seen, on the basis of this assessment all of the options would be identified as insignificant against the 10% process contribution (%PC) H1 criteria.

Table 5.6: Emissions to Air - Short Term Impact

Option	EAL µg/m^3	PC µg/m^3	PC % of EAL	Background µg/m^3	PEC µg/m^3	PEC % of EAL
Sulphur Dioxide						
1. No Abatement	350	354.37	101.25	11.3	365.67	104.48
2. Dry Scrubber - Lime	350	22.15	6.33	11.3	33.45	9.56
3. Dry Scrubber – Sodium Bicarbonate	350	17.72	5.06	11.3	29.02	8.29
4. Wet Scrubber	350	8.86	2.53	11.3	20.16	5.76
5. Semi-Dry Scrubber	350	22.15	6.33	11.3	33.45	9.56
Hydrogen Chloride						
1. No Abatement	75	797.33	1063.10	0.82	798.15	1064.20
2. Dry Scrubber - Lime	75	4.43	5.91	0.82	5.25	7.00
3. Dry Scrubber – Sodium Bicarbonate	75	3.99	5.32	0.82	4.81	6.41
4. Wet Scrubber	75	2.21	2.95	0.82	3.03	4.05
5. Semi-Dry Scrubber	75	4.43	5.91	0.82	5.25	7.00
Hydrogen Fluoride						
1. No Abatement	3	26.58	885.92	0.006	26.58	886.12
2. Dry Scrubber - Lime	3	0.44	14.77	0.006	0.45	14.97
3. Dry Scrubber – Sodium Bicarbonate	3	0.35	11.81	0.006	0.36	12.01
4. Wet Scrubber	3	0.22	7.38	0.006	0.23	7.58
5. Semi-Dry Scrubber	3	0.44	14.77	0.006	0.45	14.97

A wet scrubber represents the best option for reduction of emission levels with sodium, with bicarbonate dry scrubbing representing the second best option.

5.4.4 Water Consumption

In relation to acid gas control techniques the annual water consumption associated with each option is shown in Table 5.7 below.

Table 5.7: Water Impact – Water Consumption

Option	Water Consumption (tpa)
1. No Abatement	0
2. Dry Scrubber - Lime	13,940
3. Dry Scrubber – Sodium Bicarbonate	0
4. Wet Scrubber	72,730
5. Semi-Dry Scrubber	13,940

The dry scrubber system using sodium bicarbonate is the best option in relation to annual water consumption.

5.4.5 Effluent

In respect of acid gas control, the annual discharge of effluent was assessed for each option and the results are summarised in Table 5.8 to follow. The wet scrubber system is the only option anticipated to require discharge of effluent from the site that could not be reused on site.

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Table 5.8: Water Impact – Acid Gas Control

Option	Effluent Discharged (tpa)
1. No Abatement	0
2. Dry Scrubber - Lime	0
3. Dry Scrubber – Sodium Bicarbonate	0
4. Wet Scrubber	73,500
5. Semi-Dry Scrubber	0

5.4.6 Energy Consumption

The annual energy consumption requirements of each option, on the basis of 7,884 operational hours, are shown in Table 5.9 below. The assessment is undertaken on the basis of primary energy (ie the energy as it is generated at source without transport or transmission losses) which means that impact from all energy sources is considered on the same basis. In order to determine primary energy a conversion factor from H1 is applied as follows:

- Electricity from public supply – multiplied by a conversion factor of 2.4 to account for transport and transmission losses;
- Electricity from own supply – multiplied by a conversion factor of 1 as energy is used at source;
- Gas oil (auxiliary fuel) – multiplied by a conversion factor of 1 as there is no associated transport or transmission losses; and
- Waste fuel - multiplied by a conversion factor of 1 as there is no associated transport or transmission losses.

Table 5.9: Energy Consumption

Option	Annual Delivered MWh				Annual Primary MWh				Total Annual Primary Energy Used (MWh)
	Auxiliary Fuel	Parasitic Power	Waste Fuel	Own Heat	Auxiliary Fuel	Parasitic Power	Waste Fuel	Own Heat	
1. No Abatement	19418	14291	647276	0	19418	14781	647276	0	681475
2. Dry Scrubber - Lime	19418	26011	647276	0	19418	26501	647276	0	693195
3. Dry Scrubber – Sodium Bicarbonate	19418	25811	647276	0	19418	26301	647276	0	692995
4. Wet Scrubber	19418	32271	647276	0	19418	32761	647276	0	699455
5. Semi-Dry Scrubber	19418	27151	647276	0	19418	27641	647276	0	694335

The energy generation potential of each option is shown in Table 5.10 below.

Table 5.10: Energy Generation Potential

Option	Annual Energy Exported (MWh)		
	Electricity	Heat	Total Export
1. No Abatement	167747	75429	243176
2. Dry Scrubber - Lime	161887	75429	237316
3. Dry Scrubber – Sodium Bicarbonate	161987	75429	237416
4. Wet Scrubber	149309	75429	224738
5. Semi-Dry Scrubber	151869	75429	227298

From the above assessment, it can be seen that dry scrubbing with sodium bicarbonate is the best option in terms of energy consumption and export efficiency.

5.4.7 Global Warming Potential

Greenhouse gas impacts or global warming potential (GWP) for each option are assessed on the basis of:

- Emissions from the process; and
- Direct and indirect emissions associated with energy consumption.

The main factors that influence GWP are:

a. Debit Side

- Direct CO_2 from the combustion of waste;
- Direct CO_2 from the combustion of auxiliary fuels;
- Indirect CO_2 from the use of electrical power drawn from public supply; and

b. Credit Side

- CO_2 saved due to the export of electricity to the public supply associated with the displacement of fossil fuels; and
- CO_2 saved due to the export of heat to the Naval Dockyard associated with the displacement of fossil fuels.

In respect of GWP for the Devonport Facility, this is dominated by emissions of CO_2 from the combustion of waste with a smaller contribution from the combustion of auxiliary fuel; however, this is constant for all options. CO_2 from the use of electrical power will fluctuate, and will depend on the acid gas control option that is used.

In relation to this assessment, the factors given in the April 2010 version of H1 have been used and a breakdown of GWP is provided in Table 5.11 below associated with energy consumption, energy recovery.

Table 5.11: Breakdown of GWP (Tonnes CO_2 per annum)

Source	Electricity & Heat GWP	Waste & Auxiliary Fuels GWP	Total GWP
1. No Abatement	-78150	233990	155840
2. Dry Scrubber - Lime	-73870	233990	160120
3. Dry Scrubber – Sodium Bicarbonate	-73943	233990	160047
4. Wet Scrubber	-67820	233990	166170
5. Semi-Dry Scrubber	-69690	233990	164301

Taking the above GWP assessment into account, it can be seen that dry scrubbing with sodium bicarbonate offers the best solution, and would represent BAT in respect of GWP.

5.4.8 Ozone Generation Potential

In respect of ozone generation potential, this is associated with the amount of sulphur dioxide produced annually and as can be seen the lowest potential is associated with wet scrubbing.

Table 5.12: Ozone Generation Potential

Option	POCP Tonnes from SO_2
1. No Abatement	2463.14
2. Dry Scrubber – Lime	307.89
3. Dry Scrubber – Sodium Bicarbonate	246.31
4. Wet Scrubber	123.16
5. Semi-Dry Scrubber	307.89

5.4.9 Raw Material Consumption

The use of scrubbing systems requires the consumption of reagents to facilitate acid gas control, and the annual reagent consumption is shown in Table 5.13 below – the best solution is the wet scrubber..

Table 5.13: Annual Raw Material Consumption

Option	Sodium Bicarbonate Annual Tonnes	Lime Annual Tonnes
1. No Abatement	0	0
2. Dry Scrubber - Lime	0	3870
3. Dry Scrubber – Sodium Bicarbonate	4220	0
4. Wet Scrubber	0	1820
5. Semi-Dry Scrubber	0	3290

5.4.10 Waste Generation

Annual waste impacts associated with acid gas control systems are shown in Table 5.14 below, sodium bicarbonate scrubbing offers the best solution.

Table 5.14: Waste Impact Options

Option	Bottom Ash Annual Tonnes	APC Residue Annual Tonnes (without fly ash)
1. No Abatement	62,275	0
2. Dry Scrubber - Lime	62,275	5,510
3. Dry Scrubber – Sodium Bicarbonate	62,275	2,560
4. Wet Scrubber	62,275	3,420
5. Semi-Dry Scrubber	62,275	6,060

5.4.11 Environmental Quotient

The environmental quotients for each emission are summed to provide an indication of the total impact from emissions. The environmental quotient (EQ) is the ratio of each Process Contribution to its respective standard. The environmental quotients for each option are shown in Table 5.15 below and it can be seen that wet scrubbing represents the best option and MVV preferred option using sodium bicarbonate is the second best option.

Table 5.15: Environmental Quotient for each Option

Option	Long Term EQ	Short Term EQ
1. No Abatement	0.377	20.503
2. Dry Scrubber - Lime	0.010	0.270
3. Dry Scrubber – Sodium Bicarbonate	0.008	0.222
4. Wet Scrubber	0.005	0.129
5. Semi-Dry Scrubber	0.010	0.270

5.4.12 Environmental Assessment Ranking

Based on the environmental assessment, the overall ranking of each option over the baseline is shown in Table 5.16 below.

Table 5.16: Environmental Assessment Ranking

Option	Long Term EQ	Short Term EQ	POCP	GWP	Raw Materials	Energy	Waste	Water	Effluent	Total Score
2. Dry Scrubber - Lime	3	3	3	2	2	2	3	4	1	23
3. Dry Scrubber – Sodium Bicarbonate	2	2	2	1	3	1	1	1	1	14
4. Wet Scrubber	1	1	1	4	1	4	2	2	2	18
5. Semi-Dry Scrubber	3	3	3	3	2	3	4	4	1	26

From the above ranking table it can be seen that Option 3, using sodium bicarbonate, presents the best overall performance, with a score of 14.

5.5 Cost Appraisal

5.5.1 Summary of Costs

Additional costs over those in the baseline associated with the various options are summarised in Table 5.17 below.

Table 5.17: Additional Costs

Option	Capital (£)	Annual Operating (£)	Equivalent Annual Operating Cost (£)	Increased Cost per Tonne Waste
2. Dry Scrubber - Lime	14,200,000	1,720,400	3,166,049	11.95
3. Dry Scrubber – Sodium Bicarbonate	13,000,000	1,635,600	2,959,081	11.17
4. Wet Scrubber	21,670,000	2,992,428	5,198,569	19.62
5. Semi-Dry Scrubber	15,600,000	2,788,930	4,377,107	16.52

5.5.2 Cost per Tonne Ranking

The various options are ranked on the basis of cost per tonne of Acid Gas abated.

Table 5.18: Cost per Tonne Ranking

Option	Pollutant Emissions		Ranking Score
	Abated Tonnes	Additional Cost per tonne	
2. Dry Scrubber - Lime	1628	1945	2
3. Dry Scrubber – Sodium Bicarbonate	1642	1802	1
4. Wet Scrubber	1674	3106	4
5. Semi-Dry Scrubber	1628	2689	3

Option 3, using a dry scrubber with sodium bicarbonate, represents the best cost option.

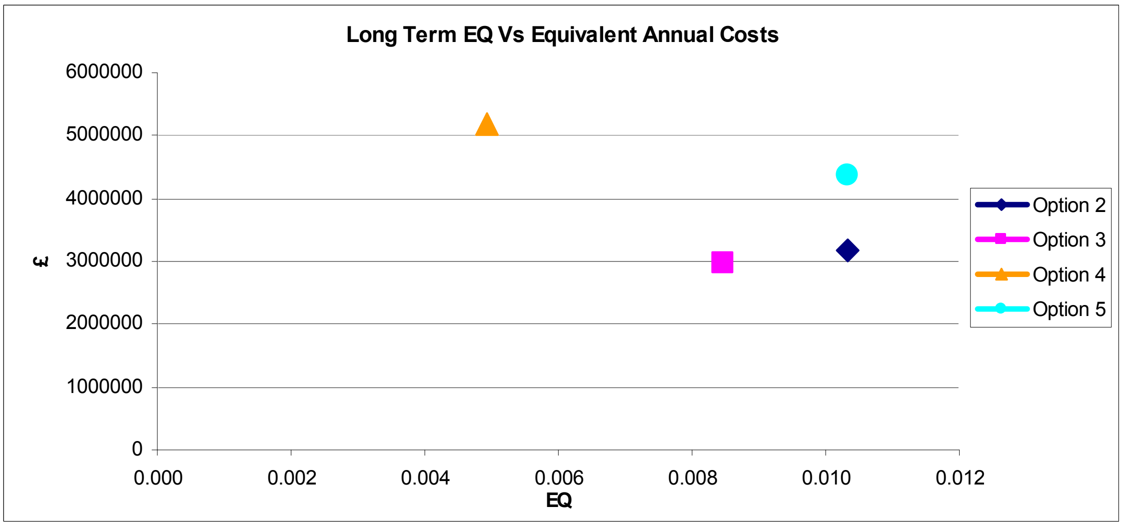
5.6 Conclusion

5.6.1 Comparison Charts

The figures below show the relationship between the costs and the various environmental considerations if implementing each option.

Long Term EQ vs Annual Costs

Figure 5.1: Long Term EQ vs Annual Costs

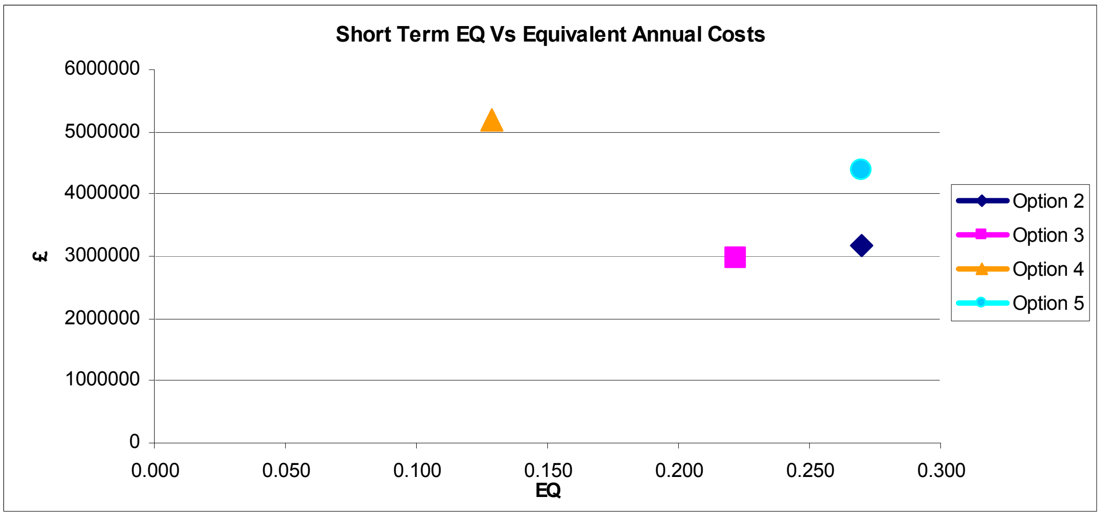


From the above chart it can be seen that:

- Wet scrubbing (Option No 4) offers the lowest EQ; however, this has the highest equivalent annualised costs; and
- Dry scrubbing with sodium bicarbonate (Option 3) offers the second best performance in respect of EQ, and the best overall annualised cost performance.

Short Term EQ vs Annual Costs

Figure 5.2: Short Term EQ vs Annual Costs

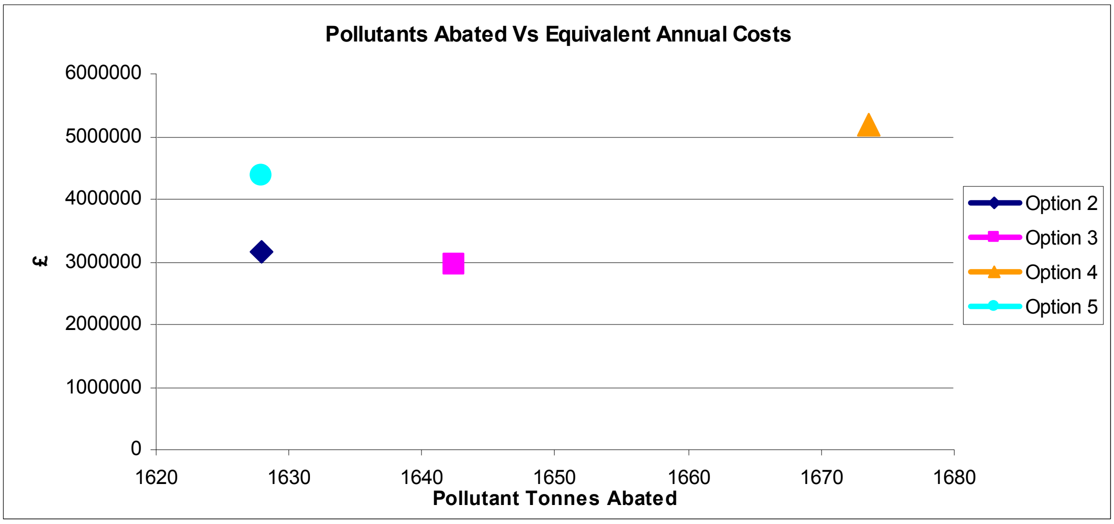


From the above chart it can be seen that:

- Wet scrubbing (Option No 4) offers the lowest EQ; however, this has the highest equivalent annualised costs; and
- Dry scrubbing with sodium bicarbonate (Option 3) offers the second best performance in respect of EQ, and the best overall annualised cost performance.

Tonnes Pollutant Abated vs Annual Costs

Figure 5.3: Tonnes Pollutant Abated vs Annual Costs



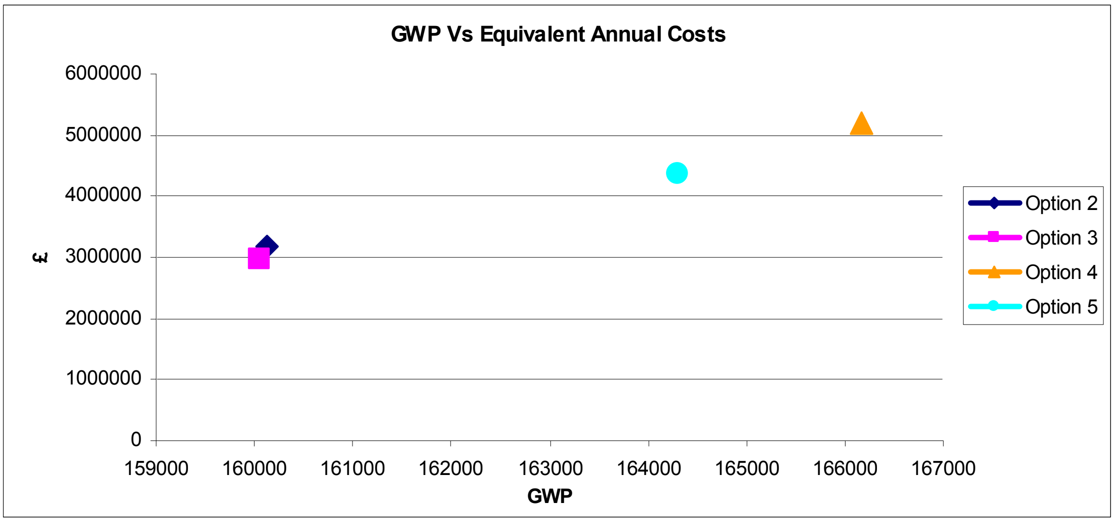
From the above chart it can be seen that:

- Semi-dry scrubbing (Option No 5) offers the lowest performance in terms of pollutants abated and has the second highest equivalent annualised costs;

- Dry scrubbing with sodium bicarbonate (Option 3) offers the second best performance in respect of pollutants abated, and the best overall annualised cost performance.

GWP vs Annual Costs

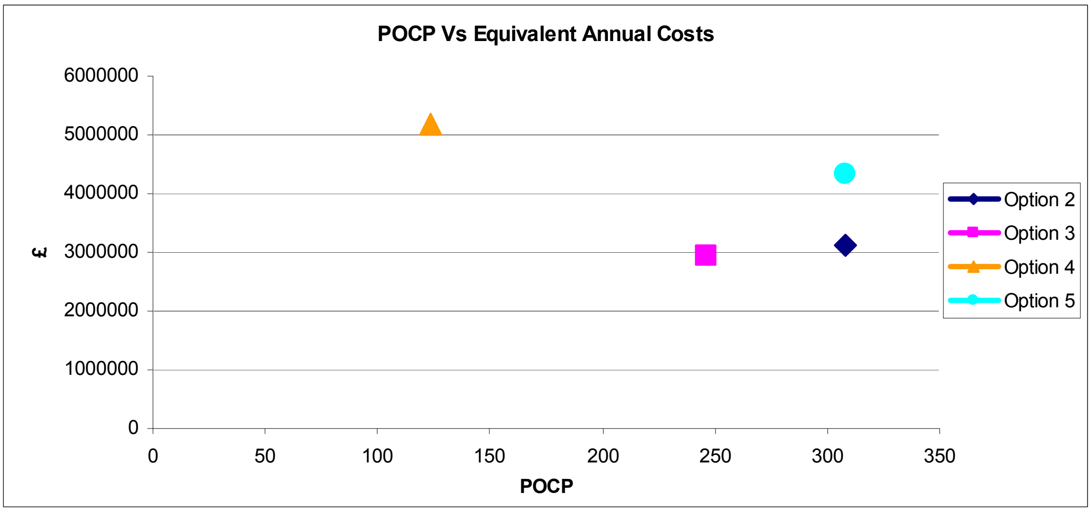
Figure 5.4: GWP vs Annual Costs



From the above chart it can be seen dry scrubbing with sodium bicarbonate (Option 3) offers the best performance in respect of GWP, and the best overall annualised cost performance.

POCP vs Annual Costs

Figure 5.5: POCP vs Annual Costs

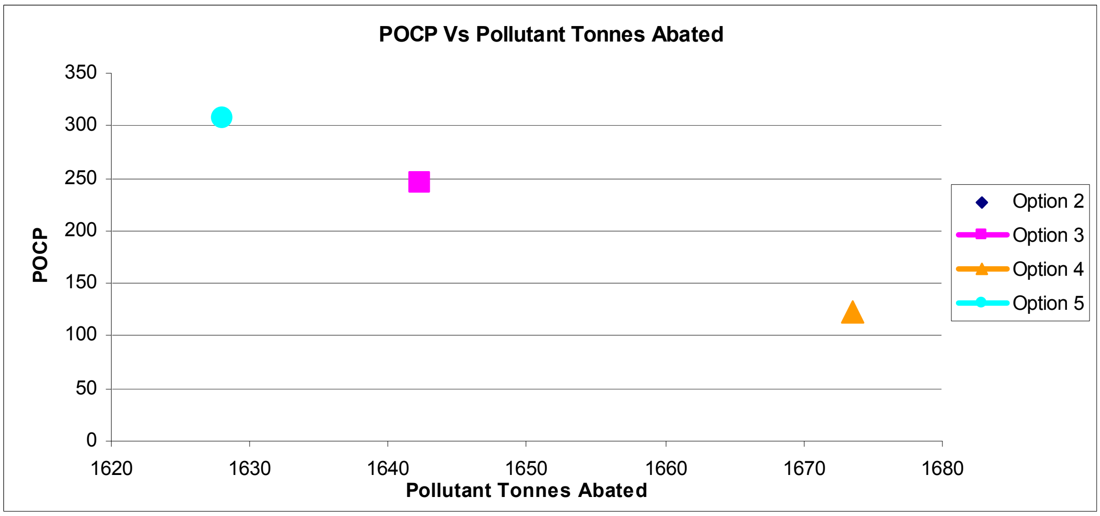


From the above chart it can be seen that:

- Wet scrubbing (Option No 4) offers the lowest POCP; however, this has the highest equivalent annualised costs; and
- Dry scrubbing with sodium bicarbonate (Option 3) offers the second best performance in respect of POCP, and the best overall annualised cost performance.

POCP vs Pollutant Abated

Figure 5.6: POCP vs Pollutant Abated

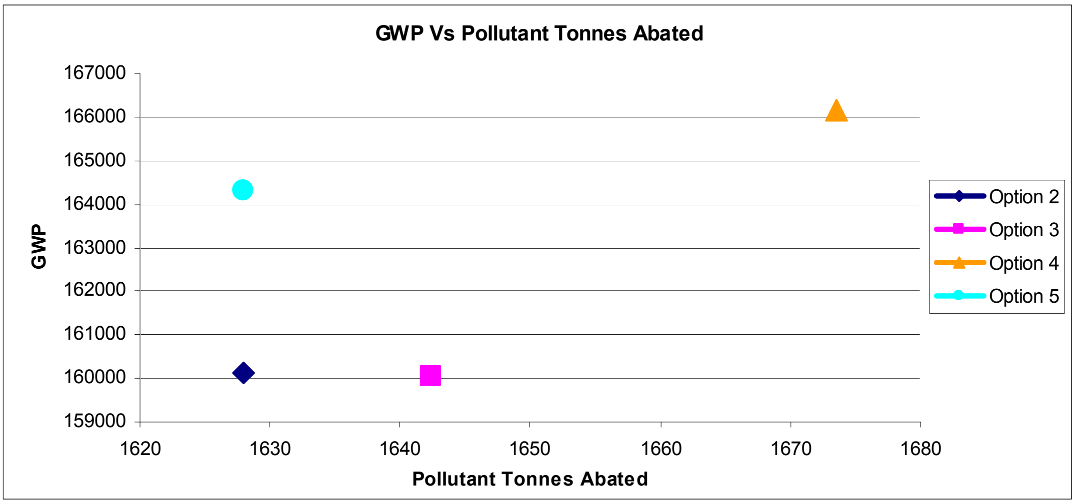


From the above chart it can be seen that:

- Wet scrubbing (Option No 4) offers the best performance in terms of pollutants abated, with the lowest POCP; and
- Dry scrubbing with sodium bicarbonate (Option 3) offers the second best performance in respect of pollutants abated and POCP.

GWP vs Pollutants Abated

Figure 5.7: GWP vs Pollutants Abated



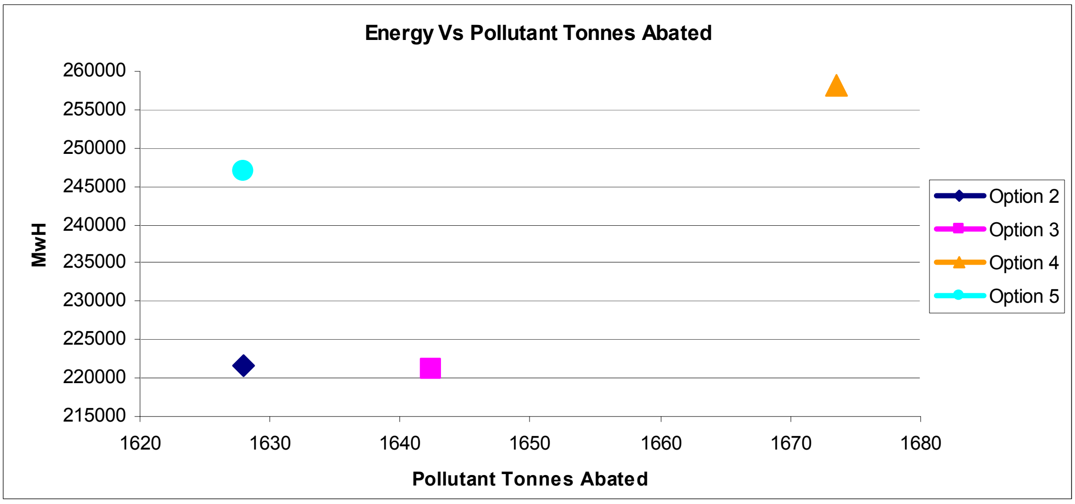
From the above chart it can be seen that:

- Wet scrubbing (Option No 4) offers the best performance in terms of pollutants tonnes abated; however, this has the highest annual GWP tonnes; and

- Dry scrubbing with sodium bicarbonate (Option 3) offers the second best performance in respect of pollutants abated, and the lowest annual GWP tonnes..

Energy vs Pollutants Abated

Figure 5.8: Energy vs Pollutants Abated

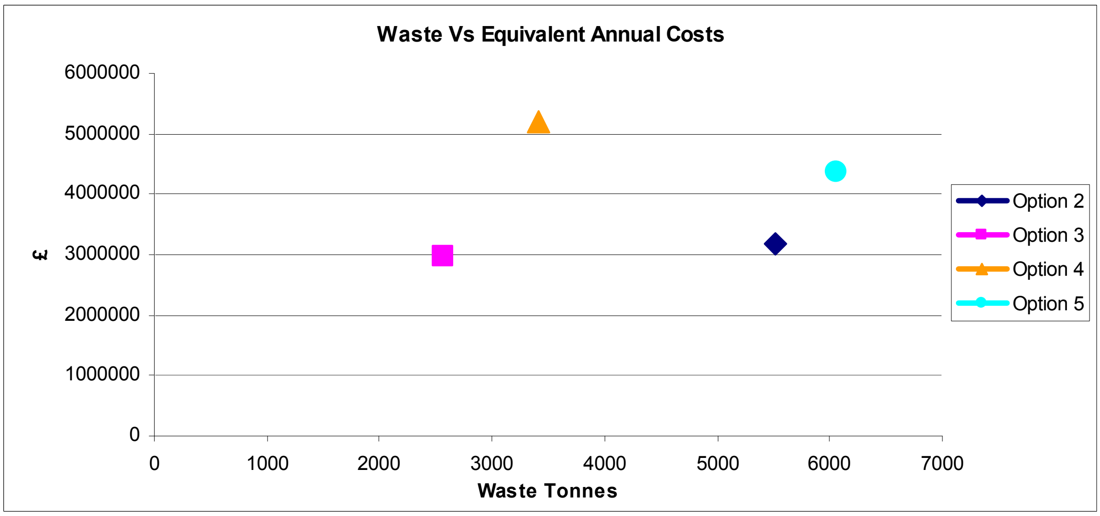


From the above chart it can be seen that:

- Wet scrubbing (Option No 4) offers the best performance in terms of pollutants abated; however, this has the highest energy consumption and lowest energy export potential; and
- Dry scrubbing using sodium bicarbonate (Option 3) offers the second best performance in respect of pollutants abated, and the best overall energy performance.

Waste vs Equivalent Annual Costs

Figure 5.9: Waste vs Equivalent Annual Costs



From the above chart it can be seen dry scrubbing with sodium bicarbonate (Option 3) offers the best performance in respect of overall annualised cost performance with the lowest waste tonnage produced.

5.6.2 Discussion

Following completion of the H1 assessment it is possible to conclude that:

- Dry scrubbing with lime (Option 2) ranks third in terms of environmental performance and second in terms of costs;
- Dry scrubbing with sodium bicarbonate (Option No 3) offers the best environmental and cost performance. This option provides for the second lowest EQ based on pollutant emission levels and POCP, however, GWP, energy, waste, water use and effluent discharge provide the best level of performance;
- Wet scrubbing is ranked second overall in terms of environmental performance; however, the benefit offered in terms of pollutant emission levels, is offset by the GWP of this option which is around 3.8% higher than that offered by dry scrubbing with sodium bicarbonate. Additionally this option provides the worst performance in terms of water use, effluent discharge and overall costs;
- Semi-dry scrubbing offers the worst performance in terms of environmental ranking, and the third worst ranking for cost. Performance ranking is affected by pollutant levels achieved, GWP and the highest waste production; and
- Energy recovery in terms of exported power and heat is around 5.3% lower for wet scrubbing, and 4.3% lower for semi-dry scrubbing, than that provided by dry scrubbing options.

MVV has therefore chosen Option No 3, dry scrubbing using sodium bicarbonate, on the basis that:

- It offers up to 90% reduction in unabated SO_2 emissions, up to 99% reduction in unabated HCL emissions and up to 97.3% reduction in unabated HF emissions;
- Expected typical performance is around 20% lower than the WID emission limit;
- Contribution to the local air quality is indicated as insignificant by this H1 assessment, and no environmental standards are likely to be exceeded;
- GWP is 3.8% lower than wet scrubbing, 2.7% lower than semi-dry scrubbing and 0.05% lower than dry scrubbing using lime;
- Option 3 produces 5.3% more energy for export than wet scrubbing, 4.3% more than semi-dry scrubbing, and is comparable to dry scrubbing using lime; and
- The equivalent annual costs are 5.8% lower than dry scrubbing with lime, 7% lower than wet scrubbing and 47.9% lower that semi-dry scrubbing.

Therefore on the basis this assessment, it is concluded that dry scrubbing with sodium bicarbonate represents BAT for this installation.

6 Assessment of Particulate Control Techniques

6.1 Introduction

The assessment of BAT has been undertaken in line with the Environment Agency H1 Guidance “Environmental Risk Assessment for Permits” (April 2010).

6.2 Techniques Considered As BAT

The potential options for reduction of particulates are identified in SGN S5.01 “*Guidance for the Incineration of Waste and Fuel Manufactured From or Including Waste”* and are outlined below.

6.2.1 Bag Filter

Bag filters or fabric filters are proven technology for waste incineration processes, and comprise a filter chamber in which fabric filters are suspended.

As the flue gas is drawn through the filter bag, a cake of particulate matter will form on the outer surface of the bag, and this assists with the filtration and scrubbing processes. Cleaned gases which have passed through the bag filter will be drawn upward into an outlet plenum chamber, and are ducted to the flue gas fan for discharge via the chimney.

The filter bags will be cleaned by a standard ‘reverse-jet’ technique, whereby a pulse of compressed air will be introduced down each filter bag. This pulse of compressed air causes the collected dust cake on the outer surface of the bag to break loose and fall into the basin of the filter chamber. The solid material, known as air pollution control residue (APC residue), which collects in the filter hoppers, is transferred using mechanical conveying to one of two storage silos. A proportion of the APC residue is recirculated and re-injected into the flue gas to optimise the use of fresh reagent.

Fabric filters will comprise multiple compartments which can be individually isolated in the event of bag failure. Fabric filters tend to be less susceptible to “blinding” than ceramic filters and are therefore generally considered BAT.

6.2.2 ‘Candles’ Ceramic Filter

Ceramic filters are a possible alternative to fabric filters and can be used in high temperature applications. Filtration works in a similar manner to the fabric filter, however, the filtration elements are manufactured in ceramic elements (“candles”) rather than a fabric bag. This is shown below:

According to EPR 5.01 the use of ceramic filters has been generally limited to smaller plant due to larger gas volumes at higher temperatures.

6.2.3 Other Particulate Control Measures

SGN EPR5.01 identifies two other potential systems for particulate control:

- Electrostatic precipitators, which utilise the application of a high voltage electrical field across the flue gas stream to ‘attract’ particulate materials and cause their removal from the gas stream; the technique relies on the electrical resistivity of the dust in the gas stream; and

- Wet scrubbers can assist with particulate control, although their main application is acid gas control.

Neither of these techniques is considered BAT on its own, and as such is not considered further for the Devonport Facility.

6.3 Comparison of Ceramic and Bag Filters

A comparison of the two filtration systems is summarised in Table 6.1 below:

Table 6.1: Comparison of Ceramic and Bag Filters

Criterion	Ceramic Filter	Fabric Filter	Comment
Emission Level Achieved	ca. 10 mg/m^3 1)	< 2 mg/m^3	1) seals in the cover plate
Maximum Temperature	> 400 °C	250 °C	
Cleaning Performance	poor 2)	very good	2) only flow reversal
Air Quantity for Cleaning	high	low	
Risk of Obstruction	high	very low	
Fire Hazard	none	very low	
Pressure Loss	high	low	
Area Required	high 3)	low	3) Filter element max. 3 m
State of Development	experimental 4)	many references	4) for use in MVA
Number of Suppliers	low	high	
Cost	high	low to medium	

In addition to the above, it is noted that ceramic filters are subject to:

- Mechanical shock due to filter vessel residue filling or bridging;
- Thermal shock due to high gas temperature excursion; and
- Chemical shock due to formation of a low permeability coating during abnormal conditions.

6.4 Conclusion

MVV has chosen a fabric bag filtration system for the Devonport Facility, as:

- Output performance is better than that achieved with ceramic filters, for a lower filter bag area;
- The location of the filter after the other pollution control measures means that operating temperature is not an issue
- The filter is less prone to damage from mechanical, thermal and chemical shock;
- Filter cleaning is achieved with lower air volumes than with the ceramic filter and cleaning performance is better, therefore efficiency is easier to maintain;
- Bag filters are a well proven abatement technique while ceramic filters are not proven for facilities of similar capacity to the Devonport plant; and
- Capital and operating costs for the bag filters are lower than the equivalent ceramic filter.

7 Comparison against Indicative BAT Standards

7.1 Introduction

As outlined above, the current regulatory regime requires that activities identified under Schedule 1 should be subject to an assessment to demonstrate that the technology/technique proposed can be considered to be the 'Best Available' at the time the application is being made by making reference to appropriate standards.

7.2 BAT Standards

In respect of this application, reference has been made to the following standards:

- EPR 5.01 *"Guidance for the Incineration of Waste and Fuel Manufactured From or Including Waste*; and
- EU Reference Document on the Best Available Techniques for Waste Incineration.

7.3 Conclusion

In preparing the individual aspects of the application, an assessment was undertaken in respect of the relevant part of the BAT guidance documents, and the detailed conclusion of this assessment is presented in Appendix B and is summarised in Table 7.1:

Table 7.1: Summary of Assessment against BAT Standards

Area	Comment
1. In-process Controls	The chosen technology was found to meet the necessary requirements for: ▪ Waste handling, reception and storage; ▪ Furnace system type and design; ▪ Cooling system; and ▪ Boiler design. In addition the requirements specified under WID were found to have been met including the requirements pertaining to process control, monitoring and interlocks.
2. Emissions Control	Emissions control include a range of recognised primary and secondary control techniques for control of: ▪ Oxides of nitrogen; ▪ Acid gases; ▪ Halogens; ▪ Metals; ▪ Dioxins and furans; and ▪ Odour; and fugitive releases.
3. Management	MVV will introduce an integrated business management system designed to meet the requirements of: ▪ BS EN ISO9001 – Quality Management; ▪ BS EN ISO14001 – Environmental Management ▪ OHSAS 18001 – Health and Safety Management. The integrated system will be certified against the relevant standards during the first year of operation.

4. Raw Materials	Raw materials have been selected in accordance with relevant guidance standards and their ongoing use will continue to be monitored during the lifetime of the plant. Water use includes use of mains water, and the reuse of process water where possible. Water use across the process will be established at the time of commissioning and a water audit will be completed at least every 2 years in accordance with SGN S5.01.
5. Waste Handling, Recovery and Disposal	The design of the process optimises the recovery and recycling of materials including bottom ash. Disposal to landfill will be minimised where possible. A waste minimisation audit will be completed at least once every 2 years in line with SGN S5.01.
6. Energy	The process facilitates the generation of electricity and heat from the EfW plant and comparison of the process in line with the BREF Note for the sector indicates that the proposed EfW/CHP operates above the range for the sector in terms of: ▪ Energy consumption; ▪ Energy production; and ▪ Energy export.
7. Accident Management	The site does not satisfy the criteria for either a lower or upper tier COMAH site. However, the general principles of accident management as required by COMAH have been adopted in the development of the Accident Plan for the site.
8. Noise	The design of the process has considered the relevant noise levels produced by individual items of plant and provision has been made for: ▪ Acoustic enclosures where necessary (eg turbines); ▪ Cladding of the appropriate attenuation specification; ▪ Appropriate levels of plant maintenance; and ▪ Operation of the plant with enclosed buildings.
9. Monitoring	Monitoring for the process includes both process monitoring and emissions monitoring. Techniques to be employed include: ▪ Continuous monitoring; and ▪ Extractive monitoring. Techniques and equipment to be employed will be in accordance with MCERTs and recognised standards as specified in SGN S5.01.
10. Emissions Benchmarks	Emissions from the process have been evaluated by a combination of techniques including H1 assessment and dispersion modelling. Evaluation of the typical emission levels associated with the process has confirmed that plant performance is anticipated to be better than WID emission limits. Modelling at WID emission levels as a worse case scenario has confirmed that there should be no significant impact from plant emissions to either the environment or to human health.

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

Appendix A Detailed Technology Assessment

Appendix B BAT Appraisal against Standards