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1 Selection of Thermal Treatment Technology

Introduction

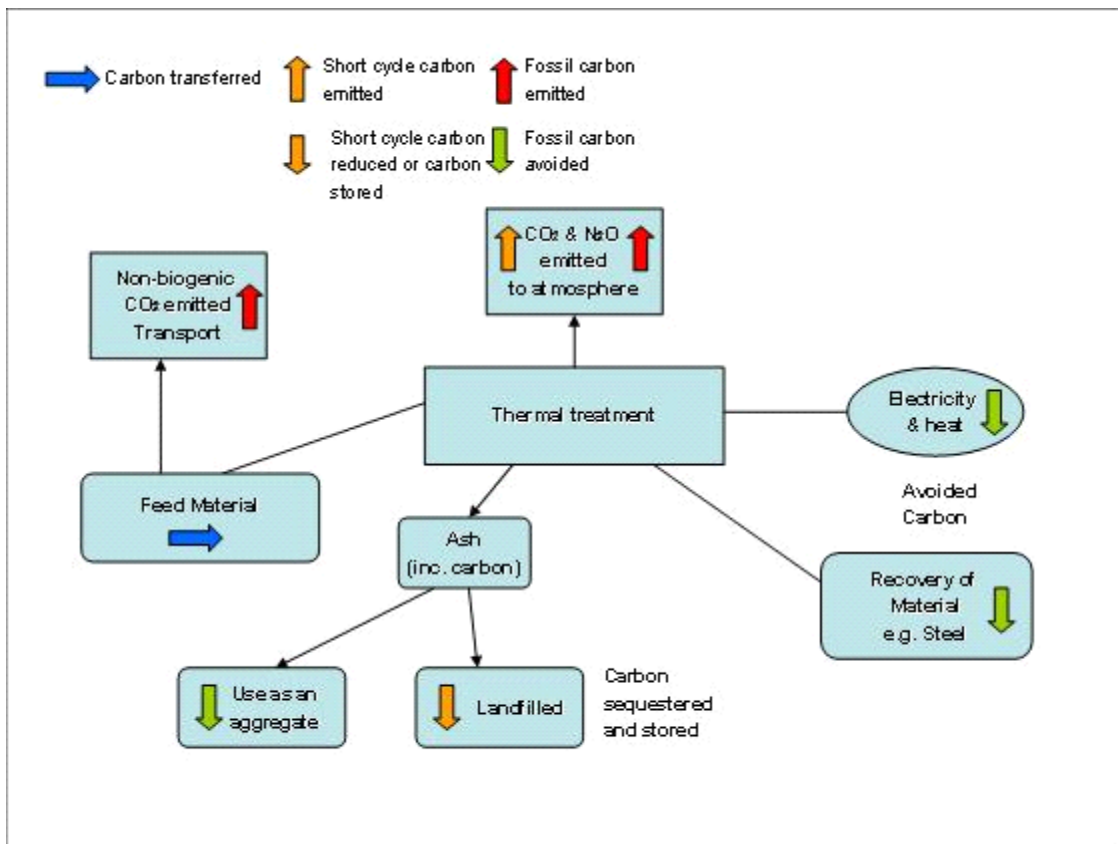
- 1.1 A brief review of available technologies for thermal treatment of waste is provided in section 2.1.3. The review considered a wide range of technologies, but concluded that moving grate and fluidised bed systems are the only proven systems for MSW applications within the UK. Gasification and pyrolysis systems are recognised as emerging techniques; however, they are still yet to be proven technologies at the scale proposed for this facility within the UK.
- 1.2 This section provides further discussion on the following alternatives:
- Option 1: Moving Grate;
 - Option 2: Fluidised Bed;
 - Option 3: Gasification; and
 - Option 4: Pyrolysis.
- 1.3 The above alternatives can be categorised as either traditional thermal treatment technologies or advanced thermal treatment technologies.

Traditional Thermal Treatment Technologies

- 1.4 Traditional thermal treatment technologies are based upon the complete combustion of the residual waste feedstock. The application of traditional thermal treatment technologies to the burning of MSW requires the facility to comply with the WID. Fundamental requirements of the WID include the requirement to achieve a combustion temperature of $>850^{\circ}\text{C}$ with a residence time after the last injection of combustion air of at least 2 seconds. A number of variations exist based on the type of combustion plant. Options 1 and 2 in this assessment represent alternative types of traditional thermal treatment.
- 1.5 Traditional thermal treatment processes require flue gas treatment to control NO_x emissions, which may give rise to emissions of nitrous oxide, a powerful global warming agent, as a by-product of the SNCR reaction. The nitrous oxide emissions are not a function of the thermal treatment option itself, being related to the selected abatement for NO_x and are consequently not included within this section. A separate assessment of the selected NO_x abatement is provided later in this section and includes consideration of the global warming impacts associated with the available abatement techniques.
- 1.6 Traditional thermal treatment processes offer a proven technique, able to operate flexibly, to cater for a wide range of waste inputs and in many cases, such as with moving grate systems, with little pre-treatment.

1.7 Figure 1-1 shows a typical waste flow for traditional thermal treatment process.

Figure 1-1: Traditional Thermal Treatment Process



Option 1: Moving Grate

- 1.8 Moving grate technologies are the most widely adopted system for MSW applications and as such are well proven and reliable. The moving grate system is capable of burning MSW as received, thereby avoiding the need for upfront pre-treatment. A variety of designs are available, but typically the grate system will include a mechanism for distributing the waste feed across the grate and for transporting the waste forward, providing mixing as it traverses the length of the grate.
- 1.9 The waste is burned with an excess of air that is frequently drawn from above the waste bunker, providing a source of odour control, should this be an issue. Primary air is normally fed through the grate with a secondary air supply above the grate to create turbulence.
- 1.10 Exhaust gases from the furnace will require treatment to achieve compliance with the emission limit requirements of the Waste Incineration Directive (WID).
- 1.11 Moving grate systems will produce two waste streams, bottom ash and Air Pollution Control (APC) residues (including flyash).

Option 2: Fluidised Bed Furnace

- 1.12 Fluidised Bed (FB) technology operates by feeding waste onto a bed of 'fluidised' sand particles where combustion is thermally more efficient than traditional technologies such as moving grate. However, fluidised bed technology requires a homogenous feedstock with high calorific value. For MSW applications the feedstock will require full pre-treatment (sorting, crushing, shredding) prior to combustion taking place. These pre-treatment stages are resource intensive and typically outweigh the combustion thermal efficiency advantages. 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 make use of pre-heating of air to reach the required operating temperatures (both of which are energy intensive).
- 1.13 This technology is capable of achieving lower NO_x emissions in the raw gas than are typically achievable in moving grate systems. This is achieved through lower bed temperatures thus reducing thermal NO_x formation. However, additional abatement using either SCR or SNCR will still be required to guarantee WID compliance.
- 1.14 Additional raw materials are required in the form of sand within the fluidised bed system.
- 1.15 Solid waste streams from the process typically include bottom ash, cyclone ash (usually mixed with the bottom ash), and APC residues (including fly ash). Due to the addition of sand for fluidisation waste residues are generally higher for FB systems.

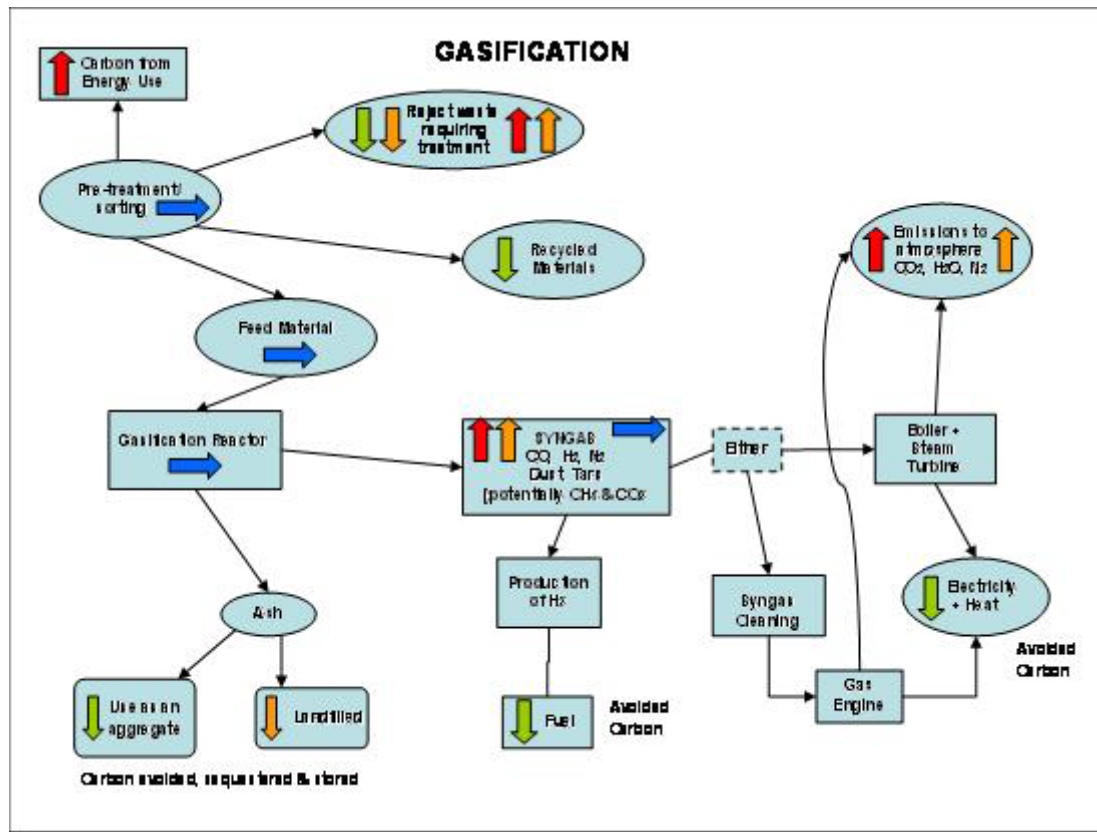
Advanced Thermal Treatment

- 1.16 Gasification and pyrolysis treatment (Options 3 and 4) processes have a long history of application to fossil fuels and certain homogeneous waste streams (although these were not historically governed by the requirements of the Waste Incineration Directive), but their application to MSW is relatively new in the UK.

Option 3: Gasification

- 1.17 Gasification is the partial thermal degradation of a substance in the presence of oxygen but with insufficient oxygen to oxidise the fuel completely. A typical process flow for a gasification process is shown in Figure 1-2.

Figure 1-2: Process flow for Gasification

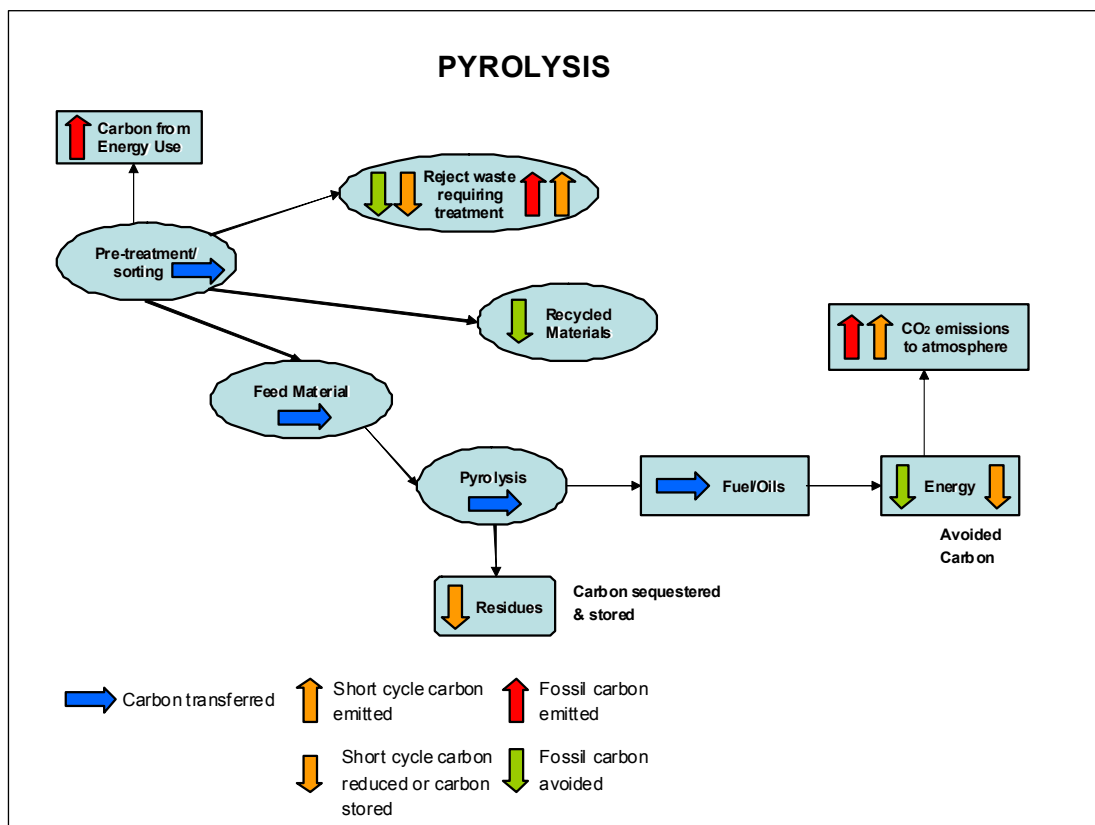


- 1.18 This process produces gaseous fractions known as 'synthesis gas' or 'syngas', primarily a combination of carbon monoxide, hydrogen and methane. The syngas offers the potential to be utilised in a number of ways, including combustion in engines, steam raising boilers or other energy conversion processes, subject to gas quality and legislative requirements. In applications where the syngas is not used as a fuel in a combustion process, it is uncertain that this would be subject to WID and therefore may lie outside the scope of an application under Section 5.1 of Schedule 5 of the Regulations. Where syngas is combusted in a steam raising boiler to generate electricity, slight efficiency improvements might be obtained owing to a potentially higher temperature of steam generation.
- 1.19 Operationally to obtain consistent gas quality a less heterogeneous incoming waste stream is required and some pre-treatment of MSW is therefore necessary. Typical temperatures for gasification would be above 750°C.
- 1.20 Ash and char are also produced from the gasification process.

Option 4: Pyrolysis

1.21 Pyrolysis is the thermal degradation of a substance in the absence of added oxygen. Pyrolysis also offers the potential option of more innovative use of the pyrolysis syngas other than immediate combustion to produce heat. Unlike gasification or traditional combustion technologies, pyrolysis requires energy input from a combination of waste heat from the process and supplementary combustion, likely to be using either natural gas or low sulphur oil, to achieve the temperature required for thermal treatment. A typical flow chart for a pyrolysis process is shown in Figure 1-3 below.

Figure 1-3 : Pyrolysis Process Flow



1.22 Typical temperatures for pyrolysis are between 300-800°C.

Option 5: Plasma Arc

1.23 Plasma Arc technology produces very high temperatures to destroy wastes, and produce energy. Plasma Arc technology for MSW has only been carried out at the research and development or demonstration stage. There is a commercial plant in Canada which has a design capacity to process approximately 60,000 tonnes per annum.

- 1.24 Plasma is a mixture of electrons, ions and neutral particles (atoms and molecules). This temperature, ionised, conductive gas can be created by the interaction of a gas with an electrical magnetic field. Plasma is a source of reactive species, and the high temperatures promote rapid chemical reactions.
- 1.25 Plasma processes utilise high temperatures (5,000°C - 15,000°C) resulting from the conversion of electrical energy to heat, to produce plasma. It involves passing a large electrical current through an inert gas stream. Under these conditions, hazardous contaminants such as PCBs, dioxins, furans, pesticides etc are broken into their atomic constituents by injection into the plasma.
- 1.26 Given the growing interest in ATT technologies, plasma arc could have a larger part to play in future developments. The process can be very complex, expensive and operator intensive. However, Plasma Arc technology is not considered to be at a stage suitable for use in a project such as the Dunbar facility.

Assessment of Technology Options

- 1.27 The discussions above provide an overview of the moving grate, fluidised bed, pyrolysis and gasification systems.
- 1.28 The following paragraphs provide further discussion of the issues and impacts associated with each technology option and conclude that moving grate represents BAT for the Dunbar EfW Facility.
- 1.29 Given that this application is being made under Section 5.1, Schedule 1, Part 2 of the 2007 Regulations, it has been assumed that all options will involve onsite combustion of any secondary fuels and that all facilities will be required to operate in accordance with the requirement of the WID.

Emissions

- 1.30 All waste treatment plants based on combustion, gasification or pyrolysis technologies are classified as incineration plants under WID and are therefore required to meet the same emissions limits. Although there is the potential for differences in emissions e.g. fluidised bed is capable of achieving lower NO_x emissions, technology providers will provide WID limit guarantees and include abatement to ensure that these levels are met.

Global Warming Potential (GWP) and Energy Efficiency

- 1.31 The GWP of a facility is calculated through assessing all direct releases of greenhouse gases from the process (including the main process, associated abatement and energy related

emissions) and indirect emissions of greenhouse gases from the primary source of heat or power imported for use in the process.

- 1.32 The purpose of all combustion processes is to fully oxidise a fuel (in this case MSW) and in the process use the heat energy released through the exothermic reaction of carbon with oxygen within a down stream energy conversion stage. For pyrolysis/gasification applications, the process incorporates physico/chemical treatment of MSW, prior to combustion of the produced syngas, bio-oil and char, in accordance with WID, although noting that this combustion stage does not necessarily form part of the process and can be undertaken at an offsite facility.
- 1.33 For any given thermal treatment facility, the waste stream to be accepted will have been fixed during the planning and contract definition process. There will subsequently be a reasonably well defined composition in terms of carbon content and consequently the quantity of CO₂ released from the combustion of the waste material will be fixed. For gasification and pyrolysis processes subject to WID, the same carbon in ash requirement applies. The products of gasification/pyrolysis processes (a combination of syngas, liquid fuel and solid residue) will contain the chemical energy associated with the same carbon input stream. Where this material is combusted on site, within the scope of the Environmental Permit, this is likely to be subject to the requirements of WID and will be converted by oxidation to CO₂.
- 1.34 It can be noted from the above that the chemistry of the combustion process would be identical for each of the thermal treatment options considered, giving rise to the same emission of CO₂ associated with the MSW fuel itself.
- 1.35 In this context, it is necessary to consider the efficiencies related to converting combusted/combustible gases resulting from a process to heat and power, requirement for supplementary combustion of fuel to maintain the thermal treatment process and those measures to maximise internal energy efficiency of the plant itself (i.e. the 'parasitic' load required to drive supporting equipment and plant).

Energy Conversion Efficiencies

- 1.36 The post combustion energy conversion technology for Options 1 and 2 will consist of recovering the energy from the hot combustion gases using a heat recovery unit or boiler. Steam produced would drive a steam turbine to generate electricity/power. Where suitable, a combined heat and power (CHP) unit can generate heat and power simultaneously. In principle, this is independent of the primary combustion process and so the efficiency of this aspect of the installation should not give rise to any difference between the technologies with respect to overall energy efficiency.
- 1.37 Syngas produced from gasification and pyrolysis (Options 3 and 4) is a combustible gas. The use of this gas does provide a more flexible option i.e. it can be used on site or

piped/transported off site. The gas is typically either burned in a boiler to raise steam and electricity, or used as a fuel in an engine or turbine¹. A summary of energy transfers from each process is given in Table 1-1.

Table 1-1: Summary of Technologies and Potential Energy Transfers

Waste Treatment Process	Output	Transfer of Energy
Traditional thermal treatment (moving grate and fluidised bed)	<ul style="list-style-type: none"> • Hot exhaust gases 	<ul style="list-style-type: none"> • Pass hot gases through waste heat boiler to produce hot water or steam. • Steam is used in a turbo-generator to generate electricity at up to approximately 27% electrical energy conversion efficiency. • Hot water can be used in a district heating system. • Where steam or hot water are raised for use in an industrial process, efficiency of electrical power generation is reduced but overall energy efficiency is significantly improved.
Pyrolysis	<ul style="list-style-type: none"> • Syngas • Char • Bio-oil 	<ul style="list-style-type: none"> • Use in steam boiler to drive a steam turbo-generator. • Offers the potential to recover and use H₂ in a fuel cell to generate power and heat, although the market for this outlet is in its infancy. • Offers the potential to recover H₂ to use as a vehicle fuel, although no infrastructure or market currently exists for this output. • Use pyrolysis oil as an engine fuel.
Gasification	<ul style="list-style-type: none"> • Syngas • Char 	<ul style="list-style-type: none"> • Use in steam boiler to generate process steam only • Use as a fuel in a steam turbo-generator • Use in a stationary gas engine/turbine to generate electricity at approximately 40% electrical energy conversion efficiency. • Offers the potential to recover and use H₂ in a fuel cell to generate power and heat, although the market for this outlet is in its infancy.

¹ SLR Consulting Limited (2008) Costs of incineration and non-incineration energy from waste technologies

Waste Treatment Process	Output	Transfer of Energy
		<ul style="list-style-type: none"> Offers the potential to recover H₂ to use a vehicle fuel, although no infrastructure or market currently exists for this output.

Note: Modified from SLR report (2008).

- 1.38 As noted previously, for the purposes of the current application, energy conversion is proposed within a steam turbine and other potential outlets for steam, hot water, syngas, bio-oil and char are outside the scope of the application.
- 1.39 Data for the gross efficiency of ATT technologies using MSW are not available on a comparable basis with traditional incineration techniques due to the limited number of operational plants. Differences in the quoted gross efficiencies of ATT technologies and incineration can arise due to a number of factors which include:
- differences in the assumed CV of the MSW feedstock (which does not apply in this case);
 - net power or gross power output (depending on technique used for conversion);
 - whether the parasitic load includes any power consumed in the preparation of the feedstock; and
 - size of the steam/gas turbine which influences conversion efficiencies.
- 1.40 A desire to maximise the efficiency of the conversion process is recognised for any thermal treatment technology, although it is noted that the primary purpose of the technology is the treatment of waste within the constraints imposed by the WID and in the context of the relevant technology guidance. The overall efficiency will be dependent on the efficiencies of the steam turbine and heat exchange. The principal difference between the overall energy efficiency of each traditional thermal treatment technology option is likely to arise from the parasitic load, although there would be only minor variation in parasitic load (relating to internal material flow transfer and flue gas treatment).
- 1.41 Each stage of the conversion process from waste to combustion/gasification/pyrolysis product, energy recovery and secondary energy conversion technologies will reduce the overall conversion efficiency and will have space and layout implications.
- 1.42 Efficiency of the process can be increased through the use of CHP, although this is site specific as it depends on the potential heat users available in the local area. However, this is again largely independent of the technologies being investigated.

Indirect Energy

- 1.43 Energy requirements related to the indirect energy input (i.e. fuel for auxiliary/support burners) would be similar for traditional thermal treatment options and therefore a similar quantity of CO₂ would be produced from each option. Unlike gasification or traditional combustion technologies, pyrolysis also requires supplementary combustion, likely to be using either natural gas or low sulphur oil, to achieve the temperature required for thermal treatment.

Plant Energy Requirements

- 1.44 General energy efficiency techniques for the proposed facility were considered earlier in Section 2.7 of the main application document. This section includes operational, maintenance and housekeeping energy efficiency measures. There is nothing to prevent similar techniques for energy efficiency being applied to any of the 4 options.
- 1.45 Only Option 1 is capable of handling MSW as received, Options 2, 3 and 4 all require some pre-processing of the waste. These pre-processing options introduce additional energy requirements, typically electricity to operate pre-processing equipment and therefore the overall energy demand of the facility will increase.

Residue Generation

- 1.46 The residues generated by moving grate systems are either similar or lower in quantity compared to the alternatives, and compared to those for ATT there is the potential for lower hazards associated with the residues.

Odour

- 1.47 For all options odour management is capable of ensuring that odour nuisance is not an issue. On the assumption that pre-treatment of the waste takes place on site, which is required for all of the of the alternatives to moving grate considered, Options 2, 3 and 4 all have an increased potential for odour associated with these activities due to increased handling and processing of the raw waste.

Raw Materials

- 1.48 Raw material usage of moving grate systems is less than that required for fluidised bed systems primarily as a result that there is no requirement for fluidisation sand. ATT options require similar air pollution abatement systems and therefore similar raw materials.
- 1.49 There is the potential for variable usage of raw materials dependant on the raw gas concentrations of pollutants. Given that moving grate systems can present higher raw gas concentrations, the alternatives offer lower reagent usage.
- 1.50 Pyrolysis systems require the addition of supplementary fuel to maintain the treatment process. Whilst all systems will require the use of supplementary fuels during certain operational conditions e.g. start-up/shutdown or occasionally to maintain minimum WID temperatures, their consumption would be much lower than that for pyrolysis.

Noise

- 1.51 Noise emissions from all options are considered similar, although noting that the alternatives to moving grate all require pre-treatment of the waste, which introduce mechanical systems with associated additional noise sources.

Accidents

- 1.52 All options will handle similar raw materials and reagents and therefore each present similar chemical hazards. ATT systems producing gaseous fuels introduce additional potential fuel handling hazards.
- 1.53 Historically systems requiring pre-treatment of wastes have introduced operational hazards, such as fires and overall have impacted on the reliability of these facilities.

Other

- 1.54 This application is being made to operate a facility to handle 300,000 tonnes per annum of MSW, at the design CV. Moving grate technology has been proven at this scale in the UK, at a number of facilities.
- 1.55 Only two UK facilities are operating fluidised bed technologies (Allington, Kent and Baldovie, Dundee) with moving grate systems clearly being the most common thermal treatment solutions applied to date in the UK. It can be cost competitive within a typical size range of 100,000 to 500,000 tonnes per annum, subject to the pre-treatment and transfer infrastructure capital and operating cost.
- 1.56 Currently there is limited experience of gasification technology employed for the treatment of MSW, with no plants in the UK and only a few applications in Europe, where experience has proven mixed. Gasification technology is being developed in a size range of up to 90,000 tonnes per annum, with pre-prepared fuel. Proven availability is an issue for the technology and it cannot be considered to be generally proven at the current time, although certain technology applications are in the post demonstration phase. There is limited alternative for the proposed catchment waste stream, when the technology is unavailable and it can be assumed that waste would be diverted to landfill, or an alternative thermal treatment process, in the absence of any additional infrastructure (subject to storage capacity).
- 1.57 There is limited experience of the application of pyrolysis technology for the treatment of MSW, its presence in the market is not well established and its commercial application is limited. To obtain consistent gas quality a less heterogeneous incoming waste stream is required and some pre-treatment is therefore necessary. It is being tested in a size range of up to 30,000 tonnes per annum, with pre-prepared fuel. Proven availability is an issue for the technology and it cannot be considered to be fully proven at the current time. As for gasification, there is limited alternative for the proposed catchment waste stream, when the technology is unavailable and it can be assumed that waste would be diverted to landfill, in the absence of any additional infrastructure, (subject to storage capacity).
- 1.58 Pyrolysis/gasification plants could scale to the anticipated throughput of the proposed facility but these are not fully proven at the commercial scale in the UK, although post demonstration plants now exist.

Pre-treatment

- 1.59 As already indicated, Option 1 is the only option which can accept the MSW without some form of pre-treatment. Fluidised bed technologies require pre-treatment to remove those materials which form large amounts of slag and disrupt the fluidisation process. Refuse derived fuels (RDF) are typically used for fluidised bed technology. Within the UK there are currently a limited number of facilities generating RDF, the nearest being the Byker facility in

Newcastle which has a capacity of 50,000 tpa and already has a current incineration outlet for this material. Other facilities are located in Kent, Newport on the Isle of Wight and Slough. To enable the facility to operate, an RDF treatment facility would need to be included into the proposal for the Project.

- 1.60 Gasification and pyrolysis processes have specific limitations on the type of feedstock that can be processed. Pre-treated waste systems would therefore need to be included within the proposals on-site.
- 1.61 Any option which requires a pre-treatment stage (i.e. Options 2, 3 and 4) would introduce additional activities onsite beyond those of thermal treatment of waste and the generation of energy which are currently proposed on the site. In addition these activities come with additional energy demands and also require further land take. Based upon these considerations and a review of the market for products, there is no benefit anticipated for alternative thermal treatment solutions over the next 5-10 years under current market conditions.

Use of Combustion Products

- 1.62 As noted previously, gasification and pyrolysis technologies produce syngas which have the potential to produce electricity using steam turbines, gas engines/turbines or CCGT. Syngas provides the possibility of using the gas either on-site or transported off site and used in other processes, although this would lie outside the scope of the current application.
- 1.63 If gasification or pyrolysis technologies were to be used at the facility, it would be important to establish a market for export for hydrogen and syngas, or as previously assumed for the purpose of the GWP assessment, include these facilities onsite.
- 1.64 Although it is reported in some studies that the efficiency of ATT technologies is greater than traditional thermal treatment technologies, this frequently ignores the full waste cycle and necessary intermediate steps. As an example, the syngas produced from ATT requires cooling and cleaning prior to use in gas engines/turbines, with the potential loss of additional energy that may account for up to 20% of the total energy content of the waste.
- 1.65 The dry solid intermediate residue (char) produced from pyrolysis has a high carbon content of up to 40%². Recovery of energy from char is therefore necessary for energy efficiency. Char combustion or gasification in a further step represents additional equipment and costs, with concomitant space implications.

² Fichtner (2004) The viability of advanced thermal treatment of MSW in the UK

- 1.66 Article 6.1 of the Waste Incineration Directive requires that all incineration processes must be operated in such a way that Total Organic Carbon (TOC) or Loss on Ignition (LOI) content of the slag and bottom ashes will not be higher than 3% or 5% respectively. Several studies have commented that residues from the pyrolysis process would not achieve this requirement without further treatment.^{3,4}
- 1.67 Bottom ash arising from thermal incineration processes can all achieve a TOC of less than 3%. Any differences in the carbon in bottom ash will therefore be very small for the proven thermal treatment technologies considered.

Conclusions

- 1.68 The various options for thermal treatment of MSW have relative benefits and disadvantages. All four options are capable, subject to appropriate abatement measures being taken, of performing within WID emissions limits (albeit limited emissions performance data are reported in respect of gasification and pyrolysis). Whilst moving grate systems generate higher raw gas pollutant concentrations, the application of abatement, which is still required for all options, enables compliance with WID limits and in many instances performance well below these levels.
- 1.69 The performance of the various options in terms of carbon dioxide releases is recognised as being dependant on the carbon within the fuel and not a direct function of the thermal treatment technology. For the waste stream to be accepted at the facility carbon dioxide releases from the facility associated with treatment of the waste will therefore be limited by the plant capacity of 300,000tpa.
- 1.70 Whilst this addresses the potential for carbon dioxide releases directly associated with the fuel, the potential releases of carbon dioxide associated with the following are also considered relevant:
1. the efficiencies of techniques for converting combusted/combustible gases resulting from the process to heat and power;
 2. the requirement for supplementary combustion of fuel to maintain the thermal treatment process; and
 3. measures to maximise internal energy efficiency of the plant itself (i.e. the 'parasitic' load required to drive supporting equipment and plant).

³ Fichtner (2004) The viability of advanced thermal treatment of MSW in the UK

⁴ SLR Consulting (2008)

- 1.71 The discussions above have demonstrated that, compared with the other options considered, moving grate systems have similar or improved performance in all three areas.
- 1.72 Moving grate has either a similar or improved performance compared to the other options in relation to electrical efficiency, residue generation, odour, raw material consumption, noise and potential for accidents.
- 1.73 In this context and alongside in particular the facts that its reliability at a commercial scale is proven and that it provides a cost effective option, moving grate has been selected and is considered BAT for the proposed facility.
- 1.74 Table 1-2 below provides a summary comparison of the alternatives against moving grate for key BAT requirements.

Table 1-2: BAT Comparison of Alternatives versus Moving Grate

BAT Criteria	Option 1 Moving Grate	Option 2 Fluidised Bed	Option 3 Gasification	Option 4 Pyrolysis
Emissions	Abated emissions meet WID, lower levels are achieved at many plant.	Lower NO _x levels than moving grate are achievable, but abatement will still be required to guarantee WID.	Lower emissions of metals as these are transferred to solid residues (see below). Emissions performance is still reported as limited ⁽¹⁾ , although it is reported that lower emissions are achievable ⁽²⁾ .	Lower emissions of metals as these are transferred to solid residues (see below). Emissions performance is still reported as limited ⁽¹⁾ , although it is reported that lower emissions are achievable ⁽²⁾ .
Global Warming Potential (GWP) ⁽⁴⁾	GWP arises as a result of carbon within the waste combusting to release CO ₂ and release of nitrous oxides associated with the NO _x abatement (although this is not directly associated with the main technology).	Higher due to pre-treatment of incoming wastes.	Higher due to pre-treatment of incoming wastes.	Higher due to pre-treatment of incoming wastes and additional burning of support fuel to maintain process temperatures.
Net electrical efficiency	22-26%.	21%	Lower (14-20%) ⁽³⁾ .	Lower (14-20%) ⁽³⁾ .
Residue Generation	Produces bottom ash (<3% carbon) and APC residues.	Produces larger volumes of residues for disposal.	Similar to MG, although residues contain higher levels of metals.	Similar to MG, although residues contain higher levels of metals.
Odour	Odour management typically avoids nuisance.	Pre-treatment can cause additional odours.	Pre-treatment can cause additional odours.	Pre-treatment can cause additional odours.
Raw Materials	See Figure 7	Higher due to fluidisation sand requirements.	Variable, depends on flue gas treatment selected	Variable, depends on flue gas treatment selected
Noise	With appropriate abatement noise can be successfully be controlled.	Similar to MG, although pre-treatment plant may cause additional noise requiring abatement.	Similar to MG, although pre-treatment plant may cause additional noise requiring abatement.	Similar to MG, although pre-treatment plant may cause additional noise requiring abatement.
Accidents	See section 2.8	Similar to MG, although some plants have experienced problems	Fuel-gas handling present additional risks.	Fuel-gas handling and spillages from liquid fuel present additional risks.

BAT Criteria	Option 1 Moving Grate	Option 2 Fluidised Bed	Option 3 Gasification	Option 4 Pyrolysis
		with waste pre-treatment stages.		
Costs	Lowest cost per tonne.	Capital significantly higher as requires pre-treatment plant and additional residue collection (typically cyclone and bagfilters).	Widely variable, but generally higher ⁽¹⁾ .	Widely variable, but generally higher ⁽¹⁾ .
Other	Proven technology with a large number of operational facilities.	Some operational experience, with mixed performance.	No large scale UK operational plants. Largest capacity plant treating MSW is 80,000 tpa (Sweden).	No large scale UK operational plants. Large commercial scale plant operational in Europe, Japan and North America – up to 150,000tpa.

- (1) Review of BAT for New Incineration Issues; Part 1 Waste Pyrolysis and Gasification Activities. P4-100/TR, Environment Agency, 2001.
- (2) Advanced Thermal Treatment of Municipal Solid Waste, DEFRA, 2005.
- (3) The Viability of Advanced Thermal Treatment of MSW in the UK, Fichtner Consulting Engineers Limited, 2004.
- (4) Comparison assumes all facilities operate to WID and any intermediate fuels generated are combusted onsite.