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Incineration of Municipal Solid Waste

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Cover image courtesy of Viridor (Lakeside Energy from Waste plant).

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Contents

Preamble

This Waste Management Technology Brief, originally produced in 2007, is one of a series of documents prepared under the New Technologies work stream of the Defra Waste Implementation Programme. This Brief has been revised to accompany the 2013 Energy from Waste Guide while remaining a standalone document. The Briefs address the main technology types that have a role in diverting Municipal Solid Waste (MSW) from landfill.

This Brief has been produced to provide an overview of Incineration Technology, which recovers energy from the combustion of MSW. Other titles in this revised series include: Advanced Biological Treatment, Mechanical Biological Treatment, Mechanical Heat Treatment, Advanced Thermal Treatment.

The prime audience for these Briefs are local authorities, in particular waste management officers, members and other key decision makers for MSW management in England but also members of the public who require more detailed information on the technologies mentioned in the 2013 Energy from Waste Guide. It should be noted that these documents are intended as guides to each generic technology area.

These Briefs deal primarily with the treatment and processing of residual MSW.

1. Introduction

Residual Municipal Solid Waste (MSW) is waste that is household or household like. It comprises household waste collected by local authorities, some commercial and industrial wastes e.g. from offices, schools, shops etc that may be collected by the local authority or a commercial company. Legislation limits (by implication[1]) the amount of mixed MSW that can be sent to landfill.

One of the guiding principles, now enshrined in law, for European and UK waste management has been the concept of a hierarchy of waste management options, where the most desirable option is not to produce the waste in the first place (waste prevention) and the least desirable option is to dispose of the waste with no recovery of either materials and/or energy. Between these two extremes there are a wide variety of waste treatment options that may be used as part of a waste management strategy to recover materials (for example furniture reuse, glass recycling or organic waste composting) or generate energy from the wastes (for example through incineration, or digesting biodegradable wastes to produce usable gases).

Newer technology entrants delivering residual MSW treatment can be split into three main categories:

- Mechanical and Biological Treatment (MBT)
- Mechanical Heat Treatment (MHT)
- Advanced Thermal Treatment (ATT) – principally gasification and pyrolysis

In addition to these, incineration offers a further option for the treatment of residual MSW and is an already proven and bankable technology in the UK.

Throughout this document, the term 'incineration' is used to describe processes that combust waste and recover energy. Sometimes others use the term energy from waste or direct combustion to describe incineration. All municipal waste Incinerators in the UK recover energy from waste in the form of electricity and/or heat generation (see Box 1). Energy recovery can also be achieved from different methods of managing waste including:

- ATT – production of electricity and/or heat by the thermal treatment decomposition of the waste and subsequent use of the secondary products (typically syngas).

[1] Targets pertain to the biodegradable fraction in MSW.

- Anaerobic digestion – production of energy from the combustion of the biogas which is produced from the digestion of biodegradable waste.
- Landfill – production of electricity from the combustion of landfill gas produced as biodegradable waste decomposes.

Box 1: Energy Generation

Energy recovered from waste can be used in the following ways:

Generation of Power (electricity),

Generation of Heat,

Generation of Heat and Power (this is referred to as Combined Heat and Power (CHP).

The energy generation option selected for an incineration facility will depend on the potential for end users to utilise the heat and/or power available. In most instances power can be easily distributed and sold via the national grid and this is by far the most common form of energy recovery.

For heat, the consumer needs to be local to the facility producing the heat and a dedicated distribution system (network) is required. Unless all of the available heat can be used the generating facility will not always be operating at its optimum efficiency.

The use of CHP combines the generation of heat and power (electricity). This helps to increase the overall energy efficiency for a facility compared to generating power only. In addition, as power and heat demand varies a CHP plant can be designed to meet this variation and hence maintain optimum levels of efficiency.

Combustion of MSW results in the release of carbon dioxide (and other greenhouse gases). Part of the MSW is biomass derived material e.g. card, paper, timber which is a source of renewable energy. MSW also contains combustible elements which are fossil fuel derived materials e.g. plastics and are therefore not a source of renewable energy. Fossil fuel-based carbon dioxide contributes significantly towards the greenhouse effect and hence global warming. In the context of sustainable energy generation carbon emitted from biodegradable waste is classed as short cycle carbon (i.e. the amount given off when combusted equates to that absorbed during its lifetime).

The more efficient the energy generation process, e.g. CHP, the lower the carbon emissions are per unit of energy produced and the greater the energy and carbon benefits. Hence when considering energy recovery, carbon emissions need to be considered in terms of composition of the residual waste stream, the type of energy produced (heat and/or power) and the overall generating efficiency of the facility. The growing importance of climate change means the carbon footprint of waste management needs to be fully considered in selecting technologies. The purpose of this document is to provide an overview of incineration with energy recovery. This will include information on technologies, UK and European experience, regulatory issues, public perception and social issues and outputs.

There are a wide variety of alternative waste management options and strategies available for dealing with MSW to limit the residual amount left for disposal to landfill. This guide is designed to be read in conjunction with the other Waste Management Technology Briefs in this series. Other relevant sources of information are identified throughout the document.

2. How it Works

2.1 Incineration and the Waste Hierarchy

The revised Waste Framework Directive (rWFD[2]) sets out the waste hierarchy incorporating the broad options for waste management, with energy recovery from waste being a preferred option to landfill/disposal. However, it recognises that prior to energy recovery, waste prevention, preparation for re-use and recycling are preferable, where appropriate. European experience illustrates that recovery of energy from residual waste (including by incineration) is compatible with high recycling rates. Therefore, both incineration and Advanced Thermal Treatment (ATT) can form part of an overall waste management strategy but not at the expense of waste reduction or recycling.

The key to striking the right balance lies in early consultation between stakeholders when local waste strategies are being developed, and in suitably flexible facilities and contracts – i.e. that do not 'lock in' an unreasonably high proportion of waste, should waste prevention, reuse and recycling performance substantially increase. In addition, the commercial deliverability of a facility needs to be considered when determining capacities required and contract periods. In mainland Europe, Austria, Belgium, Denmark, Germany, the Netherlands, Sweden and Switzerland divert the most waste from landfill, whilst all being amongst the top performers for recycling and compositing performance. Incineration of waste is relied on for disposal of the remaining residual waste in all of these countries.

Defra has issued guidance on application of the waste hierarchy to different components of materials commonly arising in the municipal waste stream, see http://www.defra.gov.uk/publications/files/pb13530-waste-hierarchy-guidance.pdf.

2.2 Industrial Emissions Directive (IED) / Waste Incineration Directive (WID)

In the UK, all waste incineration plant must comply with the Waste Incineration Directive (WID[3]) 2000. This Directive sets the most stringent emissions controls for any thermal processes regulated in the EU. The requirements of the Directive have

[2] Directive 2008/98/EC on Waste.

[3] Directive 2000/76/EC on the Incineration of Waste.

been translated into the UK through The Waste Incineration (England and Wales) Regulations 2002[4]. The Industrial Emissions Directive (IED[5]) is a recast of the WID alongside six other European Directives, which will be transposed into English legislation no later than 6th January 2013. The objectives of the IED are to “reduce emissions into air, soil, water and land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole”. Operator’s combusting waste would need to comply with Annex VI of the IED.

The enforcement of the IED is undertaken by the Environment Agency through the Environmental Permitting regime[6], which provides the mechanism by which all major industrial processes are permitted and regulated, with respect to their environmental performance.

The key requirements in the IED (see Chapter IV and Annex VI) for the operation of an incineration plant are:

- A minimum combustion temperature and residence time of the resulting combustion products. For MSW this is a minimum requirement of 850°C for 2 seconds;
- Specific emission limits for the release to atmosphere of the following:
    - Sulphur Dioxide (SO_2);
    - Nitrogen Oxide and Nitrogen Dioxide (NO and NO_2);
    - Hydrogen Chloride (HCl);
    - Hydrogen Fluoride (HF);
    - Gaseous and vaporous organic substances expressed as Total Organic Carbon (TOC);
    - Carbon Monoxide (CO);
    - Dust;
    - Heavy Metals; and
    - Dioxins and furans;
- A requirement that the resulting bottom ashes and slag produced has a total organic carbon content of less than 3%.

The combustion conditions are required to ensure complete burnout of the waste is achieved. Emission limits to atmosphere are set to minimise any environmental and

[4] The Waste Incineration (England and Wales) Regulations 2002 (SI 2002/2980).

[5] Directive 2010/75/EU on Industrial Emissions (integrated pollution prevention and control) (Recast).

[6] The Environmental Permitting (England and Wales) (Amendment) Regulations 2012 (SI 2012/630). The regulations replace the 2010 and previously 2007 versions which had combined Waste Management Licenses (WML) and Pollution Prevention and Control (PPC) regulations.

health impacts. The carbon content in the ash represents minimisation of the combustible material and destruction of the waste.

Further information on environmental compliance for incineration plant can be obtained from the Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration, published by the European Commission in August 2006. This document can be accessed via the weblink, http://ec.europa.eu/environment/ippc/brefs/wi_bref_0806.pdf.

2.3 Difference between Incineration & Advanced Thermal Treatment

Both Incineration (combustion) and Advanced Thermal Treatment (ATT) technologies offer the option of treating residual waste and recovering energy. These technologies are different in how the waste is processed and the energy liberated for recovery, i.e. combustion directly releases the energy in the waste, whereas pyrolysis and gasification thermally treat the waste to generate secondary products (gas, liquid and/or solid) from which energy can be generated.

The main technical differences between Incineration and ATT are presented below. In addition, Figure 1 shows how the pyrolysis and gasification process differs from incineration (direct combustion) in terms of the levels of air present.

Established Thermal Treatment – Incineration

Incineration usually involves the combustion of unprepared (raw or residual) MSW. To allow the combustion to take place a sufficient quantity of oxygen is required to fully oxidise the fuel (waste). Typically, incineration plant combustion temperatures are in excess of 850°C and the waste is converted into carbon dioxide and water. Any non-combustible materials (e.g. metals, glass) remain as a solid, known as Bottom Ash, which contains a small amount of residual carbon. Incineration with energy recovery is a well-established technique for municipal waste treatment as discussed in section 4, and the process stages are described in more detail in section 2.4.

Advanced Thermal Treatment – Pyrolysis

In contrast to combustion, pyrolysis is the thermal degradation of a substance in the absence of oxygen. This process requires an external heat source to maintain the temperature required. Typically, lower temperatures of between 300°C to 850°C are used during pyrolysis of materials such as MSW. Raw municipal waste is usually not appropriate for pyrolysis and typically would require some mechanical preparation and separation of glass, metals and inert materials (such as rubble) prior to processing the remaining waste. In general pyrolysis processes tend to prefer consistent feedstocks and there is a very limited track record of commercial scale pyrolysis plant accepting municipal derived wastes in the world. The products produced from pyrolysing materials are a solid residue and a synthesis gas (syngas). The solid residue (sometimes described as a char) is a combination of non-combustible materials and carbon. The syngas is a mixture of gases (combustible constituents include carbon monoxide, hydrogen, methane and a broad range of other volatile organic compounds). A proportion of these can be condensed to produce oils, waxes and tars. The syngas typically has a net calorific value (NCV) of between 10 and 20MJ/Nm^3. If required, the condensable fraction can be collected by cooling the syngas, potentially for use as a liquid fuel. One key issue for use of syngas in energy recovery at ATT facilities are the problems related to tarring. The deposition of tars can cause blockages and other operational challenges and has been associated with plant failures and inefficiencies at a number of pilot and commercial scale facilities. Tarring issues may be overcome by higher temperature secondary processing, as referred to below.

Advanced Thermal Treatment - Gasification

Gasification can be considered a process between pyrolysis and combustion in that it involves the partial oxidation of a substance. This means that oxygen is added but the amounts are not sufficient to allow the fuel to be completely oxidised and full combustion to occur. The temperatures employed are typically above 650°C. The process is largely exothermic (heat producing) but some heat may be required to initialise and sustain the gasification process. Raw municipal waste is usually not appropriate for gasification and typically would require some mechanical preparation and separation of glass, metals and inert materials (such as rubble) prior to processing the remaining waste. The main product is a syngas, which contains carbon monoxide, hydrogen and methane. Typically, the gas generated from gasification will have a net calorific value (NCV) of 4-10MJ/Nm^3. For reference, the calorific value of syngas from pyrolysis and gasification is far lower than natural gas, which has a NCV of around 38MJ/Nm^3. One key issue for use of syngas in energy recovery at ATT facilities are the problems related to tarring. The deposition of tars can cause blockages and other operational challenges and has been associated with plant failures and inefficiencies at a number of pilot and commercial scale facilities. The application of a higher temperature secondary processing phase may be used to 'crack' the tars and clean up the syngas prior to application in energy recovery systems. This process is sometimes referred to as 'gas clean up' or 'polishing' and could enable higher efficiency energy recovery than applicable through other waste thermal treatment processes. It should be noted however that most commercial gasification facilities processing MSW derived feedstocks utilise a secondary combustion chamber to burn the syngas and recover energy via a steam circuit, and whilst this is not incineration, the differences between the processes in practical and efficiency terms are much more modest. The other main product produced by gasification is a solid residue of non-combustible materials (ash) which contains a relatively low level of carbon. Some Plasma gasification technologies are examples of where a high temperature (electric arc) method is applied potentially at various stages of the gasification process (in different configurations). Plasma, or other very high temperature thermal processing, can be applied to fuse the ash from the process into an inert (vitreous or glassy) residue and crack the tars to generate a relatively clean syngas. There are several initiatives[7] seeking to achieve high energy recovery efficiencies using gas engines and hydrogen fuel cells linked to gasifiers.

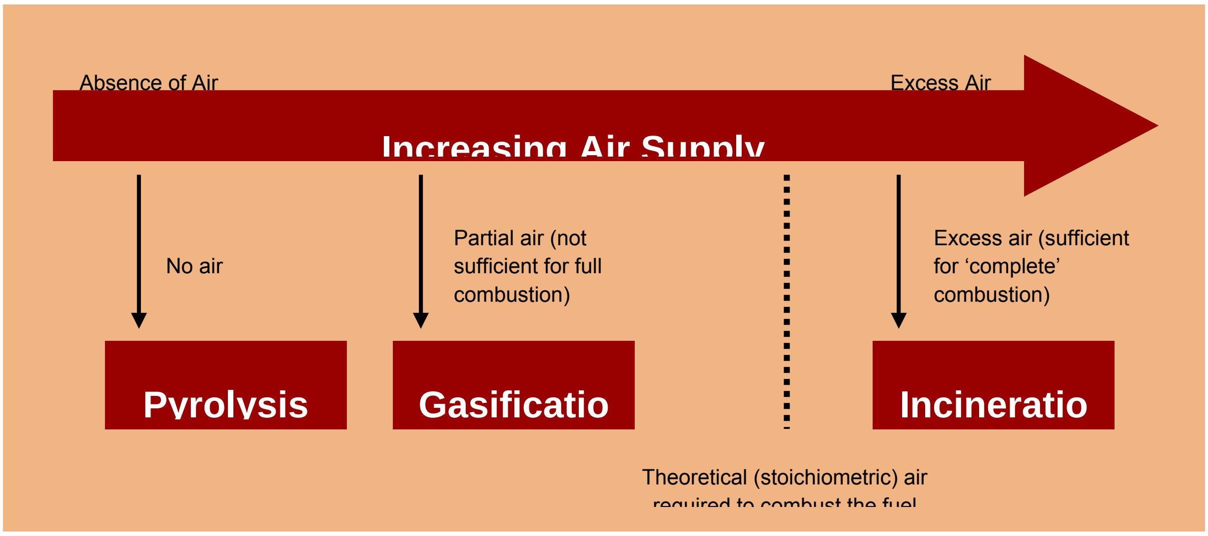

Figure 1: Levels of Air (Oxygen) Present During Pyrolysis, Gasification and Combustion Processes for MSW

2.4 Incineration Technology Overview

The actual plant design and configuration of incineration plant will differ considerably between technology providers. However, an Incinerator with energy recovery will comprise the following key elements:

- waste reception and handling,
- combustion chamber,
- energy recovery plant,
- emissions clean-up for combustion gases, and

[7] Example providers and initiatives include: Advanced Plasma Power (APP) / Air Products / AlterNRG / Waste2Tricity / CHO

- bottom ash handling and air pollution control residue handling.

Waste Reception and Handling

The incineration of MSW can be focused on either combustion of the raw residual waste (the waste left over after recycling, reuse and composting have taken place) or of pre-treated feed, for example a Refuse Derived Fuel (RDF, see Box 2). Plant configuration will change according to the feedstock. Typically, the application of incineration in the UK is to process untreated residual MSW. The waste is normally delivered via a waste collection vehicle and tipped into a bunker where it is mixed. The mixing is required to blend the waste to ensure that the energy input (calorific value of the waste feed) to the combustion chamber is as consistent as possible.

Box 2: Fuel from Mixed Waste Processing Options

Various terms are in use to describe solid fuel arising from MBT/MHT processes in the UK, the most common being solid recovered fuel and refuse derived fuel.

A CEN Technical Committee (TC 343) has developed standards on fuels prepared from wastes, where the suite of standards uses the terminology Solid Recovered Fuel (SRF) and classify the SRF by a number of characteristics, including by thermal value, chlorine content and mercury content. The use of Refuse Derived Fuel (RDF) as a term has no strict definition and could be generated from a wide variety of waste treatment processes.

A recent development in the UK is the separation between the procurement of waste treatment processes that give rise to a fuel output and the procurement of the market for the utilisation of the fuel generated. In these circumstances a specification of RDF/SRF would be required. WRAP 's Waste Derived Fuel (WDF) classification scheme (launched in November 2012) provides clear classification of WDFproperties . Link: http://www.wrap.org.uk/sites/files/wrap/WDF_Classification_6P%20pdf.pdfWithin this Brief, Refuse Derived Fuel will be used as a term to cover the various fuel products processed from MSW.

Raw MSW typically has an energy content of 8-11MJ/kg, whereas an RDF can have an energy content of 12-17MJ/kg. Typically where raw MSW is processed into an RDF, the increase in the energy content of the RDF is achieved due to the drying of the waste (removal of water) and the removal of recyclables (glass, metals) and inert materials (stones etc.), which do not contribute to the energy content of the waste. Therefore, the remaining waste going into the RDF mainly comprises wastes with significant energy content, plastics, dried biodegradable materials, textiles etc. RDF produced from source-separated wastes and purely commercial waste will usually have a greater calorific value than RDF from MSW, in the range of 18-23MJ/kg.

Combustion Technology

There are four combustion technologies that can be employed to burn MSW or RDF. A brief overview of the main combustion technologies is presented overleaf in table 1. All of the combustion technologies presented can be designed to meet the technical requirements of the IED/WID, e.g. a minimum temperature of 850°C and a two second residence time, for processing MSW.

Energy Recovery

The standard approach for the recovery of energy from the incineration of MSW is to utilise the combustion heat through a boiler to generate steam. Of the total available energy in the waste up to 80% can be retrieved in the boiler to produce steam. The steam can be used for the generation of power via a steam turbine and/or used for heating. An energy recovery plant that produces both heat and power is commonly referred to as a Combined Heat and Power (CHP) Plant and this is the most efficient option for utilising recovered energy from waste via a steam boiler.

Technology	Description
Grate Technologies	MOVING GRATE The moving grate furnace system is the most commonly used combustion system for high through-put MSW processing in the UK. The waste is slowly propelled through the combustion chamber (furnace) by a mechanically actuated grate. Waste continuously enters one end of the furnace and ash is continuously discharged at the other. The plant is configured to enable complete combustion as the waste moves through the furnace. Process conditions are controlled to optimise the waste combustion, to ensure complete combustion of the feed. The end of the grate normally passes the hot ash to a quench to rapidly cool the remaining non-combustibles. There are three main sub categories of moving grate combustion systems used for MSW. These are as follows: **The Roller Grate** – this consists of adjacent drum or rollers located in a stepped formation, with the drums rotating in the direction of the waste movement **The Stepped Inclined Grate** – this system uses bars, rockers or vibration to move the waste down each of the grates (typically three) **Inclined Counter-Rotating Grates** – grate bars rotate backwards to agitate the waste and prevent it tumbling down the forward inclined grate until burn out is

Technology	Description
	complete. <u>FIXED GRATES</u> These are typically a series of steps (normally 3) with the waste being moved by a series of rams. The first step is a drying stage and initial combustion phase, the second is where the remaining combustion takes place and the third grate is for final carbon burn-out.
Fluidised Bed	The combustion of MSW using a fluidised bed (FB) technique involves pre-sorting of MSW material to remove heavy and inert objects, such as metals, prior to processing in the furnace. The waste is then mechanically processed to reduce the particle size. Overall, the waste requires more preparation than if a moving grate was used. The combustion is normally a single stage process and consists of a lined chamber with a granular bubbling bed of an inert material such as coarse sand/silica or similar bed medium. The bed is 'fluidised' by air (which may be diluted with recycled flue gas) being blown vertically through the material at a high flow rate. Wastes are mobilised by the action of this fluidised bed of particles. There are two main sub-categories of fluidised bed combustors: **Bubbling FB** – the airflow is sufficient to mobilise the bed and provide good contact with the waste. The airflow is not high enough to allow large amounts of solids to be carried out of the combustion chamber. **Circulating FB** – the airflow for this type of unit is higher and therefore particles are carried out of the combustion chamber by the flue gas. The solids are removed and returned to the bed. The use of fluidised bed technology for MSW incineration is limited in the UK, although it is widely applied to sewage sludge. Examples of this technology being used in the UK on pre-sorted waste include the Incinerators operating in Dundee and Allington, Kent.
Rotary Kiln	Rotary kilns have wide application and can be a complete rotation vessel or partial rotational type. Incineration in a rotary kiln is normally a two stage process consisting of a kiln and separate secondary combustion chamber. The kiln is the primary combustion chamber and is inclined downwards from the feed entry point. The rotation moves the waste through the kiln with a tumbling action which exposes the waste to heat and oxygen. There is also a proprietary system which oscillates a rotating kiln for smaller scale incineration of MSW with energy recovery. In the UK there is currently one oscillating type rotary kiln Incinerator processing MSW, which is located in North East Lincolnshire.

Table 1: Incineration Technologies

An Incinerator producing exclusively heat can have a thermal generating efficiency of around 80-90%; this heat may be used to raise steam for electrical generation at approximately 17-30% gross efficiency[8]. Net electrical efficiencies (taking account of the parasitic load of the plant) are often cited up to ~27% for Incinerators recovering electricity only, although some facilities have reported exceeding this. The choice of a steam turbine generator set to produce electricity will limit the upper efficiency based on acceptable boiler temperatures.

In contrast, the efficiency of an Incinerator for power generation is lower than a large coal or gas fired power station. Typically, a coal fired power station will have an efficiency of 33%-38% and a combined cycle gas turbine (CCGT) power station can have an electrical efficiency in excess of 50%. The reason for the higher efficiencies is a combination of technical issues and the generally far larger scale of coal and gas fired power plant. Where the energy recovered from an Incinerator is used to generate steam for heating, the efficiency is comparable with a boiler fired with natural gas or oil. It is possible that in future the efficiency of electricity generation using incineration will increase given the trend in other solid fuel applications of more severe operating conditions at higher temperature.

For an Incinerator that produces combined heat and power (CHP plant), the electrical and thermal generating efficiencies will vary depending on the split between the two forms of energy (heat and power).

An Incinerator will typically have a higher net electrical and thermal efficiency than a comparable ATT process that also generates steam for power generation or direct heating. This is mainly due to the energy required to sustain the gasification or pyrolysis process. There is scope however for ATT to use other power generation technologies that could yield greater efficiencies; these are considered in the Advanced Thermal Treatment Brief, in this series of publications.

The actual electrical and/or heat output from an Incinerator would be dependent on establishing energy customers. Electricity can easily be supplied into the national grid, once an appropriate connection is established, and therefore sold and distributed. In contrast heat will need to be used locally to the Incinerator. The use of heat will therefore be dependent on identifying and establishing a local need, for example by using a district heating system for buildings/housing and/or supply of heat to a factory for industrial use. The UK does not have a substantial history in the

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[8] IPPC Reference document on Best Available Technologies for Waste Incineration, August 2006. Please note that the efficiency quoted is based on the boiler efficiency and does not include the energy input to the plant and therefore the net efficiency.

use of district heating systems (with the main notable exceptions of systems associated with the Sheffield CHP and Nottingham CHP facilities) having relied, in part, on indigenous fossil fuel reserves, unlike in Scandinavian countries where it is common place to use locally available resources such as wood and peat. With increasing energy costs, district heating may become financially attractive in the UK, and the Government has incentivised the use of heat through the development of the Renewable Heat Incentive (RHI) and qualifying Incineration with energy recovery for Renewables Obligation Certificates (ROCs) where good quality CHP is in place. For further information on these incentives see section 9.4.

Emissions Control for Releases to Atmosphere

The emissions limits for specific pollutants that are present in the combustion products (flue gases) from the incineration of MSW are defined in the IED/WID and applied through the Environmental Permitting Regulations. An environmental permit will be required to operate an Incinerator fuelled by MSW in the UK and will set-out a range of necessary conditions, including the emission limits for releases to atmosphere, operating and monitoring requirements.

To meet these emissions limits, the combustion process must be correctly controlled and the flue gases cleaned prior to their final release. The technology supplier for the Incinerator plant will define the exact emissions clean-up processes that will be employed to achieve the required standards and utilising Best Available Techniques (BAT). A common approach for control of emissions is as follows:

- Ammonia injection into the hot flue gases for control of NO_x emissions;
- Lime or Sodium Bicarbonate injection for control of SO_2 and HCl emissions;
- Carbon injection for capture of heavy metals; and
- Filter system for removal of fly ash and other solids (lime or bicarbonate and carbon).

The control of CO, VOCs and dioxins, in terms of their concentration, is primarily though correct combustion conditions being maintained. For more information on flue gas cleaning see the IPPC Reference Document on Best Available Techniques for Waste Incineration[9], which still applies under the recast IED.

The clean-up of the flue gases will produce solid residues comprising fly-ash, lime/bicarbonate and carbon. These residues are usually combined (although some systems may separate fly ash and other components), and are often referred to as Air Pollution Control (APCr) residues and classified as hazardous waste. Therefore,

[9] 'Reference Document on the Best Available Techniques for Waste Incineration', European Commission 2006.

their disposal must be undertaken in accordance with relevant regulations and guidance. Typically, the weight of APCr produced will be around 2%-6% of the weight of the waste entering an Incinerator.

Bottom Ash Handling

The main residual material from the incineration of MSW is referred to as ‘bottom ash’ or ‘Incinerator Bottom Ash’ (IBA). This is the residual material in the combustion chamber and consists of the non-combustible constituents of the waste feed. The bottom ash typically represents around 20%-30% of the original waste feed by weight, and only about 10% by volume. The bottom ash is continually discharged from the combustion chamber and is then cooled. The amount of ash will depend on the level of waste pre-treatment prior to entering the Incinerator and will also contain metals that can be recovered for recycling. Table 2 includes the typical outputs from an MSW Incinerator.

3. Markets and Outlets for Incineration Outputs

Incineration processes all produce a solid residue (bottom ash), and this material may be recycled into construction applications as described in this section. Some systems, for example fluidised bed Incinerators are also designed with mechanical preparation and sorting equipment to extract recyclables before combustion, whereas others extract metals from the bottom ash after thermal treatment. The table below summarises the key outputs from incineration processes, with the following sections addressing material and energy recovery.

Outputs	State	Quantity by Wt of Original Waste	Comment
Incinerator Bottom Ash (IBA)	Solid residue	20-30%	Potential use as aggregate replacement or non-biodegradable, non-hazardous waste for disposal.
Metals (ferrous and non-ferrous)	Requires separation from MSW or IBA	2-5%	Sold for re-smelting.
APC residues (including fly ash, reagents and waste water)	Solid residue / liquid	2-6%	Hazardous waste for disposal.
Emissions to atmosphere	Gaseous	Represents ~70%–75%	Cleaned combustion products.

Table 2: Outputs from Incineration Technologies

3.1 Recovery from Incineration

Materials Recycling

Recyclables derived from either the front end preparation stage of an Incineration plant or metals extracted from the back end of the process (i.e. out of the ash) are typically of a lower quality than those derived from a separate household recyclate collection system and therefore have a lower potential for high value markets. They do however have a significant value and can be sold into the secondary metals markets for recycling. Non-ferrous and/ or ferrous metals are recovered and recycled from most Incinerators in the UK and can help enhance overall recycling levels. They will also contribute to significant carbon savings in terms of climate change impacts.

The Bottom Ash (or IBA) produced can also be recycled as a secondary aggregate in a variety of construction applications. An example is provided in Box 3. However, the recycling of IBA would need to be undertaken in accordance with relevant legislation and guidance, and the Environment Agency is currently working on a Quality Protocol project[10] to seek to define a specification where IBA may be classified as a product rather than a waste. Typically bottom ash is used as infill or in construction products subject to specific conditions in terms of the deployment of the materials.

Box 3: Use of Incinerator Bottom Ash Aggregate as a fill to structure

Ballast Phoenix worked with Skanska / Balfour Beatty Joint Venture to provide Incinerator Bottom Ash Aggregate (IBAA) product for use in the project to widen junctions 29 – 30 of the M25. IBAA was applied as a backfill material to a retaining wall in 250mm layers, using 40,000 tonnes of IBAA graded to <10mm and complying with a variety of specifications.

[10] http://www.environment-agency.gov.uk/business/sectors/124299.aspx

Application of Incinerator Bottom Ash Aggregate in the M25 widening, courtesy of Ballast Phoenix Limited

Further information on bottom ash use can be gained through the WRAP Aggregates and AggRegain websites[11].

Energy Recovery

Incineration processes are designed to recover energy from the waste processed by generating electricity and/or heat for use on site and export off site. The useful energy that can be generated from an incineration plant using a boiler to generate steam is presented in table 3. Electricity generated from the biodegradable fraction of waste in an Incinerator with good quality heat[12] and power can benefit from support under the Renewables Obligation[13] and Renewable Heat Incentive[14] scheme.

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[11] http://www.wrap.org.uk/category/materials-and-products/aggregate

[12] For further information, see https://www.chpqa.com/guidance_notes/GUIDANCE_NOTE_44.pdf

[13] DECC RO website: http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/renew_obs/renew_obs.aspx.

Outputs	Efficiency	Use
Heat Only	Up to 80-90%[15] thermal efficiency.	Local district heating for buildings (residential, commercial) and or for industrial processes.
Electricity	14%-27%*	Can be supplied to national grid for sale and distribution.
Heat and Power	Dependent on specific demand for heat and power.	Combination of above.
* The lower efficiency performance is more typical of older facilities and it is possible that in the future the efficiency of electricity generation using incineration will increase.		

Table 3: Examples of Energy Efficiency for Incineration

[14] DECC RHI website: http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/incentive/incentive.aspx.

[15] ‘Reference document on Best Available Technologies for Waste Incineration’, European Commission 2006. Please note that the efficiency quoted is based on the boiler efficiency and not the energy input to the plant.

4. Track Record

4.1 UK Experience

The term incineration, for the purposes of this document, covers those technologies that directly combust waste and then recover the energy for generating electricity (power) and/or heat.

In terms of its current status incineration accounts for the disposal of 15.1% of the total MSW produced in England in 2010/11[16], which equates to approximately 3.98million tonnes per annum. There are 73 permitted Incinerators and co-Incinerators (as of 31st March 2010[17]) in England, of which 18 process MSW. Of the 8,300,000tpa permitted capacity in England, 4,521,600tpa is for MSW; with a range in annual throughput of waste at these facilities from 3,500tpa up to 675,000tpa. A list of MSW incineration facilities in England is presented in Table 4. Four of the permitted MSW facilities are recovering heat and power under the Combined Heat and Power Quality Assurance Programme[18], as well as Slough Heat and Power (co-incineration process):

- Sheffield – 225,000tpa MSW throughput recovering 17MWe (electrical) and 39MWth (thermal).
- Nottingham – 160,000tpa MSW throughput recovering 14.4MWe and 44.2MWth.
- Coventry – 250,000tpa MSW throughput recovering 18MWe and 7.5MWth.
- Grimsby – 56,000tpa MWS throughput recovering 3.2MWe and 3.3MWth.
- Slough Heat and Power – 110,000tpa throughput recovering 104MWe and 22MWth.

In addition to the operational facilities presented in Table 4 further example incineration plant are included which are in the process of planning and construction in England.

[16] See Defra 'Local Authority Collected Waste' quarterly statistics, http://www.defra.gov.uk/statistics/environment/waste/wrfg22-wrmswqtr/.

[17] 'England's Waste Infrastructure 2010: Report on facilities covered by environmental permitting', Environment Agency 2011.

[18] For further information, see https://www.chpqa.com/guidance_notes/GUIDANCE_NOTE_44.pdf

Incinerator Plant	Scale	Energy recovery	Established	Website for further information
Edmonton, London	675,000tpa	55MWe	1975	www.londonwaste.co.uk
SELCHP, London	420,000tpa	35MWe	1994	www.selchp.com
Tysesley, Birmingham	350,000tpa	25MWe	1996	www.veoliaenvironmentalservices.co.uk
Teesside	390,000tpa	30MWe	1998	www.sita.co.uk
Coventry	240,000tpa	17.7MWe 7.5MWth	1975	www.cswdc.co.uk
Stoke	200,000tpa	12.5MWe	1997	[n/a]
Marchwood, Southampton	165,000tpa	17MWe	2004	www.veoliaenvironmental services.co.uk
Portsmouth	165,000tpa	17MWe	2005	www.veoliaenvironmental services.co.uk
Nottingham	160,000tpa	14.4Mwe 44.2MWth	1973	www.wrg.co.uk/eastcroft
Sheffield	225,000tpa	17MWe 39MWth	2006	www.veoliaenvironmentalservices.co.uk
Wolverhampton	110,000tpa	7MWe	1998	[n/a]
Dudley	105,000tpa	7MWe	1998	[n/a]
Chineham	102,000tp	7MWe	2003	www.veoliaenvironmentalservices.co.uk

Incinerator Plant	Scale	Energy recovery	Established	Website for further information
	a			
Kirklees	136,000tpa	10MWe	2002	www.sita.co.uk
Grimsby	56,000tpa	3.2MWe 3.3MWth	2004	www.newlincs.com
Isles of Scilly	3,700tpa	No energy recovery	1987	www.scilly.gov.uk
Allington	500,000tpa	43MWe	2008	www.kentenviropower.co.uk
Bolton	130,000tpa	7MWe	1971	www.gmwda.gov.uk
Ardley, Oxfordshire	300,000tpa	24MWe	2014*	www.viridor.co.uk
Lakeside, Colnbrook	410,000tpa	37MWe	2010	www.grundon.com
Runcorn (phases 1 & 2) CHP facility	850,000tpa	86MWe 110t per hr steam	2013/14*	http://www.ineoschlor.com http://www.viridor.co.uk
Devon	275,000tpa	20MWe	2014**	www.viridor.co.uk
Cornwall	240,000tpa	16MWe	2014***	www.sitacornwall.co.uk

* Under construction – expected operational date

** Planning and Permitting permissions granted – construction to begin 2012

*** Planning permission granted after high court appeal – currently undergoing appeal to European courts

Table 4: MSW Incineration Plant in England

4.2 European Experience

In 2009 there were 449[19] Incineration plants operating across twenty Western and Central European countries (not including hazardous waste incineration plants). A total throughput of c.69.4million tonnes of waste was recorded for 2009.

Denmark, France, Germany, the Netherlands, Sweden and Switzerland have the largest installed incineration capacities as a percentage of total MSW generated. The current trend is for larger facilities to realise cost savings per unit of waste processed, most also feature material recovery operations in parallel with the incineration plant.

Incineration is also widely utilised outside of Europe with facilities in operation in most developed countries.

Some descriptive examples of Incineration processes are included here to illustrate the different technologies being promoted for MSW management.

Example of Small Scale Incineration, Shetland

The Shetland and Orkney Isles have entered into a waste management partnership that has resulted in the installation of an Incinerator in Lerwick on Shetland. The Incinerator processes approximately 23,000tonnes of MSW per annum. This is the smallest and only MSW Incinerator in the UK to generate purely a heat output (i.e. no electricity generation).

The planning for the facility commenced in 1992 and the time required through to commissioning was approximately 8 years, with the plant being in operation in 2000. The plant has been designed to meet with all relevant legislation including the WID / IED.

The proposed plant was designed to provide heat which is supplied to both commercial and domestic customers. The thermal efficiency of the Incinerator in terms of heat recovered is 80%. The capital cost for the Incinerator plant was

[19] Figures taken from Confederation of European Waste-to-Energy Plants (CEWEP) 'Interactive Map European Waste-to-Energy Plants in 2009',

http://www.cewep.eu/information/data/studies/index.html approximately £10m and the district heating network a further £11.5m. The heat supplied is provided at a competitive rate and has been well received by the end consumers. The cost of installing the heat exchangers per property to allow the heat to be used was between £2,000 and £5,000. The Incinerator and heating network provide a significant financial benefit to the Shetland Isles.

Combined Heat & Power in Sheffield

Sheffield City Council has a long history of provision of district heating to municipal and other buildings in the City Centre through energy provided by the incineration plant (see Section 4.1). Veolia constructed a new Energy from Waste plant in 2005 and this generates both electricity to the grid and heats over 140 buildings (including Leisure Centres, Offices, Theatres, University Buildings and homes). This also provides an effective landfill diversion measure for residual waste arising in the City.

Sheffield Energy from Waste plant. Image courtesy of Veolia Environmental Services (UK) PLC.

Integrating incineration with the proximity principle, Marchwood, Hampshire

Hampshire's waste management strategy for MSW includes the development of three incineration plants. The public rejected a single, more economic large scale Incinerator in favour of three smaller scale facilities distributed around the county. This is an example of a local community determining the solution that best suits its needs and being willing to take on the additional costs to the local taxpayer. One of the three Incinerators is located at Marchwood and is the focus for this case study.

The Marchwood Incinerator is sized to accept 165,000 tonnes of waste per year and has been designed to serve the needs of the South-West of the county. The original plan for developing a waste management strategy which included incineration was put forward in the early 1990s. Planning permission for the Incinerator was granted in 2001 and it was commissioned in late 2004. The Incinerator generates sufficient electricity to export 14MWe to the local grid, which is enough power for 14,000 homes. The Incinerator is clad in an aluminium dome which is 36m high and 110 metres in diameter. The chimney is approximately 65m high.

The delivery of the Incinerator at Marchwood is part of an overall long-term waste management contract which was let by Hampshire Waste Services in 1996, which included new transfer stations, composting plants, material recovery facilities and two further Incinerators at Chineham and Portsmouth.

5. Contractual and Financing Issues

5.1 Grants & Funding

Development of incineration plant will involve capital expenditure of several million pounds. There are a number of potential funding sources for Local Authorities planning to develop such facilities, including:

> **Capital Grants:** general grants may be available from national economic initiatives and EU structural funds;
>
> **Prudential Borrowing:** the Local Government Act 2003 provides for a 'prudential' system of capital finance controls, which is covered in detail by the Chartered Institute of Public Finance and Accountancy (CIPFA) 2009 Prudential Code for Capital Finance;
>
> **Waste Infrastructure (WI) credits and Private Sector Financing:** a waste authority can obtain grant funding from central Government to support the capital expenditure required to deliver new facilities. This grant has the effect of reducing the financing costs for the Private Sector, thereby reducing the charge for the treatment service. However, there is no intention to issue new WI credits at the date of this publication;
>
> **Other Private-Sector Financing:** a contractor may be willing to enter a contract to provide a new facility and operate it. The contractor's charges for this may be expressed as gate fees;
>
> **Existing sources of local authority funding:** for example from National Non-Domestic Rate payments (distributed by central government)[20], credit borrowing where government credit approvals are received, local tax rising powers (council tax), and income from rents, fees, charges and asset sales (capital receipts). In practice capacity for this will be limited.

The Government is encouraging the use of different funding streams, otherwise known as a 'mixed economy' for the financing and procurement of new waste infrastructure to reflect the varying needs of local authorities. The Government Green

[20] Except, for example, in 'Core Cities' where authorities may be eligible for infrastructure support through the application of business rates under the 'New Development Deals' and 'Economic Investment Funds' mechanisms of the Governments City Deals programme. See 'Unlocking Growth in Cities: City Deals – Wave 1', HM Government Cabinet Office, July 2012.

Investment Bank is investing in waste infrastructure. This option may provide financing for appropriate projects moving forward.

5.2 Contractual Arrangements

Medium and large scale municipal waste management contracts, since January 2007, are likely to be procured through the EU Competitive Dialogue (CD) programme under the Public Contact Regulations[21]. This is dialogue between an authority and the bidders with the aim of developing a suitable technical or legal position against which all the bidders can submit a formal bid. More information on CD is available from the Local Partnership website at http://www.localpartnerships.org.uk/PageContent.aspx?id=9&tp=Y.

The available contractual arrangement between the Private Sector Provider (PSP) and the waste disposal authority (or partnership) may be one of the following:

[21] The Public Procurement (Miscellaneous Amendments) Regulations 2011 (SI 2011/2053).

Design	Build	Operate	Finance	Contractual arrangement description
A	**B**	**C**	**D**	**Separate Design; Build; Operate; and Finance:** The waste authority contracts separately for the works and services needed, and provides funding by raising capital for each of the main contracts. The contract to build the facility would be based on the council's design and specification and the council would own the facility once constructed.
A		**B**	**C**	**Design and Build; Operate; Finance:** A contract is let for the private sector to provide both the design and construction of a facility to specified performance requirements. The waste authority owns the facility that is constructed and makes separate arrangements to raise capital. Operation would be arranged through a separate Operation and Maintenance contract.
A			**B**	**Design, Build and Operate; Finance:** The Design, Build, Operation and Maintenance contracts are combined. The waste authority owns the facility once constructed and makes separate arrangements to raise capital.
A				**Design, Build, Finance and Operate (DBFO):** This contract is a Design, Build and Operate but the contractor also provides the financing of the project. The contractor designs, constructs and operates the plant to agreed performance requirements. Regular performance payments are made over a fixed term to recover capital and financing costs, operating and maintenance expenses, plus a reasonable return. At the end of the contract, the facility is usually transferred back to the client in a specified condition.
A				**DBFO with WI:** This is a Design, Build, Finance and Operate contract, but it is procured under the Waste Infrastructure (WI) Initiative. In this case the waste authority obtains grant funding from Government as a supplement to finance from its own and private sector sources. The WI grant is only eligible for facilities treating residual waste and is payable once capital expenditure is incurred.

Table 5: Available Contractual Arrangement Configurations

The majority of large scale waste management contracts currently being procured in England are DBFO contracts and many waste disposal authorities in two tier English arrangements (County Councils) are currently seeking to partner with their Waste Collection Authorities (usually District or Borough Councils). Sometimes partnerships are also formed with neighbouring Unitary Authorities to maximise the efficiency of the waste management service and make the contract more attractive to the Private Sector Provider, for example the Greater Manchester Waste Disposal Authority combining nine of ten unitary authorities in the city region.

Contracts are becoming more 'output' led since contractors increasingly have to build proposals around obligated targets placed on authorities such as for recycling yields.

Before initiating any procurement or funding process for a new waste management treatment facility, the following issues should be considered: performance requirements; waste inputs; project duration; project cost; available budgets; availability of sites; planning status; interface with existing contracts; timescales; governance and decision making arrangements; market appetite and risk allocation.

A fundamentally important issue in consideration of the bankability of any waste treatment project is the acceptable risk profile of the procurement in question (i.e. risk allocation within the contract), and project risk in terms of ability to deliver the infrastructure required (planning, technology, availability, reliability and available secure markets for process outputs). There are a number of steps that may be taken by contracting authorities and waste management solution providers in order to minimise the risk profile and help in the delivery of the project as a whole. The following examples of further reading explore these issues:

- 'Rubbish to Resource: Financing New Waste Infrastructure', Associate Parliamentary Sustainable Resource Group (APSRG), September 2011, available at http://www.policyconnect.org.uk/apsrg/rubbish-resource-financing-new-waste-infrastructure.
- Local Authority funding examples http://www.defra.gov.uk/environment/waste/local-authorities/widp/pfi-projects/.
- Guidance documents on waste management procurement http://www.defra.gov.uk/environment/waste/local-authorities/widp/widp-guidance/.
- For Works Contracts: the NEC3 contracts (available at www.neccontract.com – formerly the Institute of Civil Engineers 'New Engineering Contract').
- Local Partnerships provide guidance to local authorities concerning partnership opportunities and achieving optimum service delivery and efficiencies, http://www.localpartnerships.org.uk/PageContent.aspx?id=198&tp=Y.

6. Planning and Permitting Issues

This section contains information on the planning and regulatory issues associated with waste incineration facilities based on legislative requirements, formal guidance and good practice.

6.1 Planning Application Requirements

All development activities are covered by Planning laws and regulations. Minor development may be allowed under Permitted Development rights but in almost all cases new development proposals for waste facilities will require planning permission.

Under certain circumstances new waste facilities can be developed on sites previously used for General Industrial (B2) or Storage and Distribution (B8) activities. In practice even where existing buildings are to be used to accommodate new waste processes, variations to existing permissions are likely to be required to reflect changes in traffic movements, emissions etc.

Under changes to the planning system introduced in 2006 all waste development is now classed as 'Major Development'. This has implications with respect to the level of information that the planning authority will expect to accompany the application and also with respect to the likely planning determination period. The target determination periods for different applications are:

- Standard Application – 8 weeks
- Major Development – 13 weeks
- EIA Development – 16 weeks

The principal national planning policy objectives associated with waste management activities are set out in Planning Policy Statement (PPS) 10 'Planning for Sustainable Waste Management' published in March 2011. Supplementary guidance is also contained within the Companion Guide to PPS 10[22]. Both of these documents can be accessed via the Department of Communities and Local Government (DCLG) website.

It should be noted that with the publication of the National Planning Policy Framework (NPPF) in March 2011, virtually all pre-existing Planning Policy

[22] http://www.communities.gov.uk/documents/planningandbuilding/pdf/150805.pdf.

Statements (PPS) and Planning Policy Guidance (PPG) notes have now been replaced. However, as the Framework does not contain specific waste policies since these will be published alongside the national waste management plan for England, PPS10 will remain in place until the new Plan is adopted.

PPS 10 places the emphasis on the plan led system, which should facilitate the development of new waste facilities through the identification of sites and policies in the relevant local development plan. Separate guidance on the content and validation of planning applications is also available from DCLG through their website[23]. Individual Planning Authorities can set out their own requirements with respect to supporting information and design criteria through Supplementary Planning Documents linked to the Local Development Framework (which is likely to be referred to as the 'Local Plan' in the future under the NPPF system). It is important that prospective developers liaise closely with their Local Planning Authorities over the content and scope of planning applications.

Key Issues

When considering the planning implications of an incineration facility the other issues that will need to be considered are common to most waste management facilities. The key issues are therefore:

- Plant/Facility Siting;
- Traffic;
- Air Emissions / Health Effects;
- Dust / Odour;
- Flies, Vermin and Birds;
- Noise;
- Litter;
- Water Resources;
- Design Principles and Visual Intrusion;
- Size and Landtake; and
- Public Concern.

A brief overview of the planning context for each of these issues is provided in the following pages.

[23] http://www.communities.gov.uk/documents/planningandbuilding/pdf/1505220.pdf.

Plant Siting

PPS 10 and its Companion Guide contain general guidance on the selection of sites suitable for waste facilities. This guidance does not differentiate between facility types and states:

> *"Most waste management activities are now suitable for industrial locations, many fall within the general industrial class in the Use Classes Order (as amended).*[24]

The move towards facilities and processes being enclosed within purpose designed buildings, rather than in the open air, has accentuated this trend. The guidance goes on to state:

> *"With advancement in mitigation techniques, some waste facilities may also be considered as light industrial in nature and therefore compatible with residential development. In more rural areas, redundant agricultural and forestry buildings may also provide suitable opportunities, particularly for the management of agricultural wastes".*

The following general criteria would also apply to the siting of new incineration plants:

- Buildings which house incineration facilities can be similar in appearance and characteristics to various process industries. It would often be suitable to locate facilities on land previously used for general industrial activities or land allocated in development plans for such (B2) uses;
- Facilities are likely to require good transport infrastructure. Such sites should either be located close to the primary road network or alternatively have the potential to be accessed by rail or barge;
- The location of such plants together with other waste operations such as MRFs and MBT plant can be advantageous. The potential for co-location of such facilities on resource recovery parks or similar is also highlighted in the PPS 10 and the Companion Guide; and
- The potential for export of energy to host users or the national grid should also be a key consideration in the siting of incineration plants; and
- Unlike a number of other new waste treatment processes incineration proposals are likely to have very exacting siting and design requirements. This is due in part to negative public perception but also to the scale of

[24] For more information on change of use classes see, http://www.planningportal.gov.uk/permission/commonprojects/changeofuse/

operations which will often require sites that are capable of accommodating large built structures and associated infrastructure.

Traffic

Incineration facilities may be served by large numbers of Large (Heavy) goods vehicles (LGVs) (depending on the scale of the facility) with a potential impact on local roads and the amenity of local residents. It is likely that the site layout/road configuration will need to be suitable to accept a range of light and heavy vehicles. For a 50,000tpa capacity plant, up to 20 Refuse Collection Vehicles per day would be anticipated.

Air Emissions / Health Effects

In terms of complying with the Industrial Emissions Directive (IED) the major emission from a plant with energy recovery is the release of flue gases. The control of emissions from a waste Incinerator starts with the design of the combustion process. This ensures good mixing of waste to provide complete burn-out of waste materials. The flue gases are maintained at high temperatures for a specified minimum time, before being rapidly cooled. These stages minimise the formation of potentially harmful substances. Following the combustion stage, the flue gases are normally treated to remove oxides of nitrogen, mercury, dioxins and furans, and acid gases, although specific treatment may not be needed if the in-process controls give the required performance. The air stream is then passed through a bag filter to remove particulate matter. The residual emissions to air from waste incineration processes are discharged from a stack which is designed to provide sufficient dispersion of the low levels of remaining air pollutants.

Waste incineration facilities need to rely on post-combustion gas clean-up measures such as those described above to achieve the requirements of the Directive. The use of an air filtration system to remove particulate matter from the flue gases results in a fine, dusty waste stream referred to as “air pollution control residues” (or in some cases Flue Gas Treatment residues). This waste stream must be disposed of appropriately.

Emissions of many parameters need to be monitored continuously. This enables process operators to comply with the emissions limits set out in operating permits, which as a minimum reflect those in the **Industrial Emissions Directive** (**IED**). Some substances, including dioxins, furans and some metals, cannot be measured continuously or it may be prohibitively expensive to do so. Some substances such as dioxins and furans can be continuously sampled, with analysis carried out periodically to give the average amount emitted over a longer period. Emissions of substances which cannot be measured continuously are normally measured periodically under the terms of the operating permit. Routine day-to-day control is achieved by ensuring that surrogate indicators such as combustion temperature, particulate emissions and hydrogen chloride emissions are within the permitted limits.

Incinerator emissions have reduced substantially over the past 25 years – most emissions are less than 10% of the level 25 years ago. Because waste incineration has a long operating record, there is a good database of information on emissions and potential health effects compared to other options for managing waste. Emissions from an Incinerator typical of those currently operating in the UK (230,000 tonnes per year) are approximately equivalent to[25]:

- Oxides of nitrogen – Emissions from a 7 km stretch of typical motorway.
- Particulate matter – Emissions from a 5 km stretch of typical motorway.
- Dioxins and furans – Emissions from accidental fires in a town the size of Milton Keynes.
- Cadmium – A twentieth of the emissions from a medium sized UK coal-fired power station.

These emissions are approximately equivalent over the same time period. So, emissions of oxides of nitrogen from a typical incineration over a period of an hour are approximately the same as emissions of oxides of nitrogen from a typical motorway 7 km in length over a one hour period.

The Health Protection Agency (HPA) consider the potential health impacts of thermal treatment plant, notably Incinerators, and provides input into each Environmental Permit application. They have provided a position statement[26] on the subject which states:

> *"While it is not possible to rule out adverse health effects from modern, well regulated municipal waste Incinerators with complete certainty, any potential damage to the health of those living close-by is likely to be very small, if detectable. This view is based on detailed assessments of the effects of air pollutants on health and on the fact that modern and well managed municipal waste Incinerators make only a very small contribution to local concentrations of air pollutants."*

[25] Enviros Consulting Ltd, using Department for Transport Design Manual for Roads and Bridges, Defra review of Health and Environmental Effects of Waste Management Facilities, National Atmospheric Emissions Inventory, and Environment Agency Pollution Inventory.

[26] The Impact on Health of Emissions to Air from Municipal Waste Incinerators, HPA, September 2009

Dust / Odour

Any waste management operations can give rise to dust and odours. These can be minimised by good building design, performing all operations under controlled conditions indoors, good working practices and effective management undertaken for dust suppression from vehicle movements. The control of odour from waste reception areas of Incineration facilities needs careful consideration. Because waste Incineration plant are generally enclosed buildings, potential odour emissions can normally be controlled through the building ventilation system. Additionally, incineration processes normally use the air demand of the combustion process to operate the working areas under negative pressure. This means that air is in general drawn into the building through the waste handling area to minimise the risk of dust and odour problems. With these controls in place, waste incineration processes are not normally sources of dust and odour.

Flies, Vermin and Birds

The enclosed nature of waste incineration operations will limit the potential to attract vermin and birds. However, during hot weather it is possible that flies could accumulate, especially if they have been brought in during delivery of the waste.

Effective housekeeping and on site management of tipping and storage areas is essential to minimise the risk from vermin and other pests. In some operations waste heat from the process may be passed through fresh inputs waste so temperatures exceed levels at which flies can survive. Similarly, waste storage time in some Incineration plant is designed to be less than the breeding cycle of vermin such as rats. The use of RDF as a feedstock would reduce this issue relative to raw waste.

Noise

Noise is an issue that will be controlled under permitting regulations and noise levels at nearby sensitive receptors can be limited by a condition of a planning permission. The main contributors to noise associated with incineration are likely to be:

- Vehicle movements / manoeuvring;
- Traffic noise on the local road networks;
- Mechanical processing such as waste preparation;
- Air extraction fans and ventilation systems;
- Steam turbine units; and
- Air cooled / other condenser units.

Litter

Any waste which contains plastics and paper is more likely to lead to litter problems. With Incineration, litter problems can be minimised if good working practices are adhered to, vehicles use covers and reception and processing are undertaken indoors.

Water Resources

Common to many new waste treatment processes the enclosed nature of the operations significantly reduces the potential for impacts on the water environment. The greatest potential for pollution to surface/ground water is linked to the arrangement for delivery of waste, the collection of processed materials and the treatment of flue gases using chemicals. Pollution of water is unlikely due to waste Incineration facilities being under cover and rainfall is unlikely to come into contact with the process. Even so, any wash down waters or liquid within the waste will need to be managed using a drainage system on site.

The level of water usage will be specific to the technology and therefore it is not possible to provide detail on the nature of the effluent that might be generated and how it should be managed. However, as part of the permitting requirements for a facility a management plan would be required for effluent.

Design Principles and Visual Intrusion

Current planning guidance in PPS 10 emphasises the importance of good design in new waste facilities, the importance of which echoed by the NPPF in relation to the design of the built environment as a whole. Good design principles and architect input to the design and physical appearance of large scale buildings and structures such as waste Incineration plant is essential. Buildings should be of an intrinsically high standard and should not need to be screened in most cases.

Good design principles also extend to other aspects of the facility including having regard to issues such as:

- Site access and layout;
- Energy efficiency;
- Water efficiency; and
- The general sustainability profile of the facility.

Construction of any building will have an effect on the visual landscape of an area. Visual intrusion issues should be dealt with on a site specific basis and the following items should be considered:

- Direct effect on landscape by removal of items such as trees or undertaking major earthworks;
- Site setting – is the site close to listed buildings, conservation areas or sensitive viewpoints;
- Existing large buildings and structures in the area;
- The potential of a stack associated with some air clean up systems for mixed waste processing operations may impact on visual intrusion;
- Appropriate use of landscaping features (trees, hedges, banks etc.) not for screening but to enhance the setting of the facility;
- The number of vehicles accessing the site and their frequency; and
- Many of these facilities are housed in 'warehouse' type clad steel buildings, however use of good design techniques can help minimise visual intrusion.

For more information on the role of good design in waste facilities, please see the Defra publication 'Designing Waste Facilities: A Guide to Modern Design in Waste', which can be found at http://archive.defra.gov.uk/environment/waste/localauth/documents/designing-waste-facilities-guide.pdf.

Due to the scale of most incineration plant, consideration should be given to the value of investing significant resources into the appearance of the building. Recent examples of Incinerators which have become iconic landmark structures include those in the Isle of Man and Marchwood, Hampshire. In mainland Europe, the Vienna incineration plant in the centre of the city is an extreme example.

Size and Landtake

Table 6 shows the land area required for the building footprint and also for the entire site (including supporting site infrastructure) for a sample of proposed and constructed incineration facilities. For examples of Advanced Thermal Treatment facilities see the ATT brief in this series.

Thermal Treatment Facility	Capacity	Buildings Area	Total Landtake	Indicative Stack Height
Newhaven, Hampshire	210,000 tpa	9,435 m^2	37,000 m^2	65 m
North Hykeham, Lincolnshire	150,000 tpa	15,750 m^2	32,000 m^2	75 m
New England, Devon	275,000 tpa	15,129 m^2	307,000 m^2	90 m

Great Blakenham, Suffolk	269,000 tpa		38,000 m^2	81 m
Lakeside, Slough	410,000 tpa		27,000 m^2	75 m
St Austell, Cornwall	240,000 tpa	<8,468.1 m^2	66,000 m^2	120 m
Note. All data taken from planning application documents.				

Table 6: Examples of Size and Landtake of Incineration Type Thermal Treatment Facilities

Public Concern

Section 7, Social and Perception Issues, relates to public concern. In general public concerns about waste facilities relate to amenity issues (odour, dust, noise, traffic, litter etc.). With thermal based facilities health concerns can also be a key perceived issue. Public concern is a material planning consideration and has in part led to previous applications being refused (e.g. Kidderminster). Public concern founded upon valid planning reasons can be taken into account when considering a planning application.

Environmental Impact Assessment

It is likely that an Environmental Impact Assessment (EIA) will be required for an incineration facility as part of the planning process. Whether a development requires a statutory EIA is defined under the EIA Regulations 2011[27]. Care should be taken with the difference in meaning between 'treatment' and 'disposal' when applying these regulations, an incineration facility is a waste treatment facility and is not a waste disposal installation. The existing additional guidance in DETR circular 02/99 is to be withdrawn following the publication of the new EIA Regulations; however no proposals have yet been made as to a replacement.

6.2 Licensing / Permitting

The Environmental Permitting Regulations (EPR) have been amended on several occasions[28] and combined the previously separate Pollution Prevention and Control

[27] 'The Town and Country Planning (Environmental Impact Assessment) Regulations 2011 (SI 2011/1824).

[28] The latest amendment is the Environmental Permitting (England and Wales) (Amendment) Regulations 2012

(PPC) and Waste Management Licensing (WML) Regulations. All commercial scale Incineration facilities require a permit.

It is the scope of the proposal, in addition to local environmental circumstances, that will determine the nature and complexity of the permit, and hence the process and, to a certain degree, timescale from initiation to permit determination. Figure 2 shows example permit timescales for Incineration processes in the UK. The wide variation evident is an indication of how the site specific nature and the scope of the proposal can have a significant influence on the duration of the process as a whole. Furthermore, in some instances multi-operator permits are needed where, for example, the Incinerator may be operated by one contractor and an IBA recycling facility on the same site may be operated by another, again such aspects can add time and complexity into the permitting process.

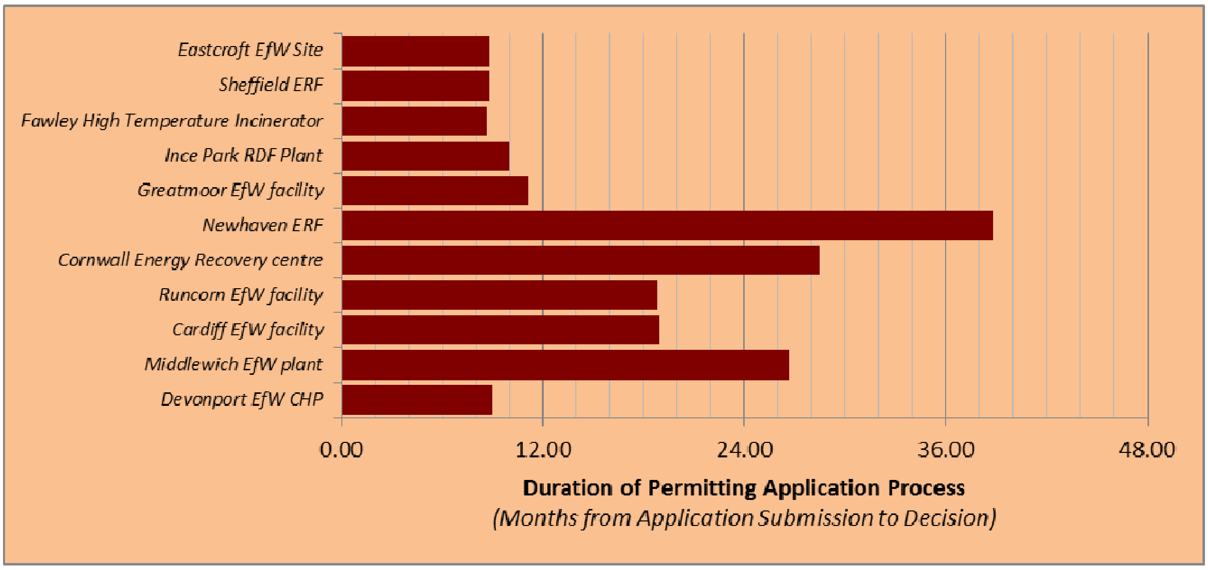

Figure 2: Example Environmental Permit Timescales for Incineration Facilities

The process of obtaining an environmental permit is an initial step in an on-going management process for delivery of the requirements of the Permit and ensuring compliance and use of Best Available Techniques. This may include reporting, improvement plans and other on-going activities. There is also a facility within the regulations for the variation of Permits. In the case of municipal waste treatment facilities, where there is a significant operational life anticipated (15 – 30 years), the option to vary may be an important one to allow incorporation of new technology or methods within the installation. In addition, the Permit may be transferred or surrendered (e.g. at the end of a projects operational life). These aspects should be appropriately considered and will involve management processes and reporting / actions as required by the Environment Agency (for example completion reports, decommissioning plans, etc.).

The regulatory requirements for a municipal incinerator are likely to entail a bespoke Permit with provision of a substantial amount of supporting information. Associated infrastructure such as facilities for recycling Incinerator Bottom Ash, may be appropriate for a standard Permit, as described under standard rules no.13[29].

For more information, please see the permitting pages of the Environment Agency's site at http://www.environment-agency.gov.uk/business/topics/permitting/default.aspx.

[29] Currently (2012) out to consultation: "SR2012 No13 Treatment of Incinerator Bottom Ash (IBA) Part A Installation (capacity over 75 tonnes/day)", Environment Agency, 2012

7. Social and Perception Issues

This section contains a discussion of the social and environmental considerations of incineration facilities.

7.1 Social Considerations

Any new facility is likely to impact on local residents and may result in both positive and negative impacts. Potential impacts on local amenity (odour, noise, dust, traffic, landscape) are important considerations when siting any waste management facility. The Planning and Permitting chapter of this Brief provides an estimate of potential vehicle movements.

An Incinerator may also provide positive social impacts in the form of employment and educational opportunities, and potentially as a cheap source of domestic or industrial heating. Typical employment for an incineration plant of 50,000tpa capacity would be 2-6 workers per shift. The plant usually operate on a three shift system, to allow for 24-hour operations. These facilities are also likely to provide vocational training for staff. New facilities are often built with a visitor centre to enable local groups to view the facility and learn more about how it operates.

7.2 Public Perception

Change to waste management arrangements in local areas is gaining a higher profile through the media. Many people, as a result of greater publicity, targeted education and more comprehensive waste services, are participating, to a greater extent, in waste reduction and recycling activities. This leads to a greater level of engagement in waste management activity. There is still, however, a significant challenge with regard to acceptance of waste management facilities.

Public opinion on waste management issues is wide ranging, and can often be at extreme ends of the scale. Typically, the most positively viewed waste management options for MSW are recycling and composting. However, this is not necessarily reflected in local attitudes towards the infrastructure commonly required to process waste to compost, or sort mixed recyclables. It should be recognised that there is always likely to be some resistance to any waste management facility within a locality.

Public perception of waste incineration tends to be linked to issues associated with older facilities where the general site management requirements and pollution control measures were not as exacting as they are today.

The emissions from incineration, particularly those to atmosphere, must be carefully controlled and monitored. The IED sets stringent emissions controls for any type of thermal process regulated in the EU.

The Health Protection Agency (HPA) are consultees on environmental permit applications as regards health issues (which is an area commonly raised as a concern) and have issued a position statement[30] on Incinerators, as discussed in section 6.1.

Overall, experience in developing waste management strategies has highlighted the importance of proactive communication with the public over waste management options. The use of realistic and appropriate models, virtual 'walk – throughs' / artists impressions should be used to accurately inform the public. Good practice in terms of public consultation and engagement is an important aspect in gaining acceptance for planning and developing waste management infrastructure.

The Associate Parliamentary Sustainable Resource Group (APSRG) have produced a report concerning waste infrastructure developments including 'incentivising community buy-in'[31], which provides examples of waste infrastructure development in the UK with the techniques utilised to gain public approval.

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[30] 'The Impact of Health Emissions to Air from Municipal Waste Incinerators', HPA 2009, http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1251473372218.

[31] 'Waste Management Infrastructure: Incentivising Community Buy-In', APSRG, February 2011. More information and download available at, http://www.policyconnect.org.uk/apsrg/waste-management-infrastructure-incentivising-community-buy.

8. Cost

8.1 Capital Costs

The capital costs for an Incinerator will be dependent on the quality of waste to be processed, the technology employed and its location. Costs will not only comprise those associated with the purchase of the Incinerator plant, but also costs for land procurement and preparation prior to build and also indirect costs, such as planning, permitting, contractual support and technical and financial services over the development cycle.

Capital costs of an EfW facility can be substantial. Recent example estimates and actual costs for the construction of incineration plants fall in the range of:-

- £145m - £200m for moving grate EfW facilities of 150ktpa – 350ktpa capacity.

8.2 Gate Fees

The WRAP Gate Fees Report 2012[32] records the following 2011 gate fees data for the UK, showing that newer facilities are generally more expensive than existing older facilities:

- Pre-2000 facilities: £64 per tonne (£32-£75 range)
- Post-2000 facilities: £82 per tonne (£44-£101 range)

The report also shows that larger facilities (>350,000tpa) have a slightly lower gate fee due to 'the limited' but observable effect of economies of scale.

[32] 'Gate Fees Report, 2012: Comparing the Cost of Alternative Waste Treatment Options', WRAP 2012.

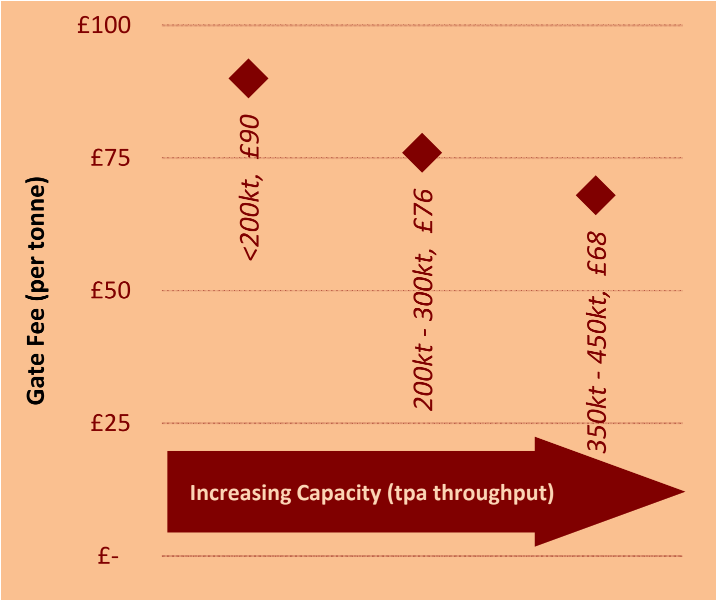

Figure 3: Economies of Scale for Incineration Plant Gate Fees

Extreme care is required in utilising cost data such as that provided above from press releases and gate fee surveys as it might not be fully inclusive or representative. In addition site specific criteria, as noted above, and the design and detail of the procurement in question need to be taken into account; hence actual costs will vary on a case by case basis.

9. Contribution to National Targets

9.1 Recycling

Recyclate derived from an Incineration plant processing household waste qualifies for Recycling on any materials recovered prior to the primary treatment reactor, for example if the plant has a 'front end' Materials Recovery Facility extracting metals, glass or plastics. In addition, metals extracted after thermal treatment also qualify for recycling targets. Any other materials recovered after the thermal treatment process (e.g. Incinerator bottom ash or flue gas treatment residues) do not count towards recycling targets.

Recyclate must pass to the reprocessor (and not be rejected for quality reasons) to count as recycling. It should be noted that some materials may have market limitations due to being derived from a mixed MSW source.

Defra's Waste Policy Review[33] (2011) identified the national recycling and composting targets for household waste of 50% by 2020, in line with the requirements of the revised Waste Framework Directive[34].

9.2 Landfill Directive Diversion Performance

The European Landfill Directive[35] and the UK's enabling act, the Waste & Emissions Trading Act 2003[36], require the diversion of biodegradable municipal waste (BMW) from landfill. Incineration systems will divert 100% of the BMW passing through the thermal process from landfill as the output (ash) will not be classified as biodegradable even if disposed to landfill. More information on the Landfill Directive can be obtained from Defra on http://www.defra.gov.uk/environment/waste/legislation/.

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[33] 'Government Review of Waste Policy in England 2011', Defra, www.defra.gov.uk/publications/files/pb13540-waste-policy-review110614.pdf.

[34] Directive 2008/98/EC on Waste.

[35] Directive 1999/31/EC on the Landfill of Waste.

[36] The Waste and Emissions Trading Act 2003 (Amendments) Regulations 2011 (SI 2011/1499).

9.3 Recovery

Incineration technologies will contribute towards national recovery targets on the tonnage of materials entering the thermal treatment process as all processes are designed to recover energy.

9.4 Renewables

The Renewables Obligation (RO) was introduced in 2002 to promote the development of electricity generated from renewable sources of energy. The Obligation requires licensed electricity suppliers to source a specific and annually increasing percentage of the electricity they supply from renewable sources, demonstrated by Renewables Obligation Certificates (ROCs). The target currently rises to 15% by 2020, or an estimated 234TWh/y of renewable energy. In essence, the RO provides a significant boost to the market price of renewable electricity generated in eligible technologies.

Electricity generated from the biomass (renewable) fraction of waste in incineration plant with good quality heat and power is eligible for support under the RO. This can provide an important additional revenue stream for a proposed plant, as long as it meets the qualifying requirements. As the value of a ROC is not fixed, the long term value would need to be assessed in detail to determine its overall financial value to the project.

Where good quality combined heat and power is introduced, the project may qualify for the Renewable Heat Incentive (RHI) on the heat generated.

Up-to-date information regarding the RO, ROCs and RHI can be obtained from the DECC website:
http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/renewable_ener.aspx.

10. Further Reading and Sources of Information

CIWM Incineration guidance: http://www.ciwm.co.uk/CIWM/InformationCentre/AtoZ/IPages/Incineration.aspx
DCLG planning guidance: http://www.communities.gov.uk/planningandbuilding/planningenvironment/.
'Designing Waste Facilities: A Guide to Modern Design in Waste', Defra, 2008: http://archive.defra.gov.uk/environment/waste/localauth/documents/designing-waste-facilities-guide.pdf.
'England's Waste Infrastructure: Report on facilities covered by environmental permitting: 2010', Environment Agency, October 2011: http://www.environment-agency.gov.uk/research/library/data/134327.aspx.
General thermal treatment briefings available from industry and environmental groups: http://www.esauk.org/energy_recovery/combustion.html , http://www.r-e-a.net/renewable-technologies/energy-from-waste , http://www.foe.co.uk/resource/media_briefing/up_in_smoke.pdf , http://wtert.co.uk/index.php
Health Protection Agency statement on Incineration http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1195733829068
'Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques for Waste Incineration, European Commission' – Directorate General Joint Research Centre, August 2006: http://eippcb.jrc.es/reference/wi.html
Local Authority funding:

http://www.defra.gov.uk/environment/waste/local-authorities/widp/
Local Partnerships guidance: http://www.localpartnerships.org.uk/PageContent.aspx?id=198&tp=Y.
‘Review of Environmental & Health Effects of Waste Management’, Enviros Consulting Ltd, University of Birmingham, Open University & Maggie Thurgood, Defra, 2004: http://archive.defra.gov.uk/environment/waste/statistics/documents/health-report.pdf.
Renewables Obligation (RO) and Renewable Heat Incentives (RHI) guidance: http://www.decc.gov.uk/en/content/cms/funding/funding_ops/funding_ops.aspx.
‘Rubbish to Resource: Financing New Waste Infrastructure’, Associate Parliamentary Sustainable Resource Group (APSRG), September 2011: http://www.policyconnect.org.uk/apsrg/rubbish-resource-financing-new-waste-infrastructure
‘Waste Management Infrastructure: Incentivising Community Buy-In’, APSRG, February 2011: http://www.policyconnect.org.uk/apsrg/waste-management-infrastructure-incentivising-community-buy.
WRATE (Waste and Resources Assessment Tool for the Environment): http://www.environment-agency.gov.uk/research/commercial/102922.aspx.

11. Glossary

Advanced Thermal Treatment (ATT)	Waste management processes involving medium and high temperatures to recover energy from the waste. Primarily pyrolysis and gasification based processes, excludes incineration.
Biodegradable	Capable of being degraded by plants and animals.
Biodegradable Municipal Waste (BMW)	The component of Municipal Solid Waste capable of being degraded by plants and animals. Biodegradable Municipal Waste includes paper and card, food and garden waste, and a proportion of other wastes, such as textiles.
Co-combustion	Combustion of wastes as a fuel in an industrial or other (non-waste management) process.
Feedstock	Raw material required for a process.
Floc	A small loosely aggregated mass of flocculent material. In this instance referring to Refuse Derived Fuel or similar.
Gasification	Gasification is the process whereby carbon based wastes are heated in the presence of air or steam to produce a solid, low in carbon and a gas. The technology is based on the reforming process used to produce town gas from coal.
Greenhouse Gas (GHG)	A term given to those gas compounds in the atmosphere that reflect heat back toward earth rather than letting it escape freely into space. Several gases are involved, including carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), ozone, water vapour and some of the chlorofluorocarbons.
Green / Garden Waste	Waste vegetation and plant matter from household

	gardens, local authority parks and gardens and commercial landscaped gardens.
Incineration	The controlled thermal treatment of waste by burning, either to reduce its volume or toxicity. Energy recovery from incineration can be made by utilising the calorific value of the waste to produce heat and/or power.
Local Authority Collected Municipal Waste (LACMW)	Refers to the previous 'municipal' element of the waste collected by local authorities. That is household waste and business waste where collected by the local authority and which is similar in nature and composition as required by the Landfill Directive. This is the definition that will be used for LATS allowances.
Local Authority Collected Waste (LACW)	All waste collected by the local authority. This is a slightly broader concept than LACMW as it would include both this and non-municipal fractions such as construction and demolition waste. LACW is the definition that will be used in statistical publications, which previously referred to municipal waste.
Materials Recycling Facility/ **Material Recovery Facility** **(MRF)**	Dedicated facility for the sorting / separation of recyclable materials.
Mechanical Biological Treatment (MBT)	A generic term for mechanical sorting / separation technologies used in conjunction with biological treatment processes, such as composting.

Municipal Solid Waste (MSW)	LACMW plus commercial and industrial waste similar to that generated by households which is collected by commercial operators (i.e. not by or on behalf of a local authority). This is the definition which will be used by the UK for reporting against EU landfill diversion targets. It includes all waste types included under European Waste Catalogue Code 20 and some wastes under Codes 15 and 19.
Proximity Principle	The proximity principle advocates that waste should be disposed of (or otherwise managed) close to the point at which it is generated, thus aiming to achieve responsible self-sufficiency at a regional/or sub regional level. Where this is not possible, priority should be given to transportation by rail or water.
Pyrolysis	During Pyrolysis organic waste is heated in the absence of air to produce a mixture of gaseous and/or liquid fuels and a solid, inert residue (mainly carbon).
Recyclate/Recyclable Materials	Post-use materials that can be recycled for the original purpose, or for different purposes.
Recycling	Involves the processing of wastes, into either the same product or a different one. Many non-hazardous wastes such as paper, glass, cardboard, plastics and scrap metals can be recycled. Hazardous wastes such as solvents can also be recycled by specialist companies.
Refuse Derived Fuel (RDF)	A fuel produced from combustible waste that can be stored and transported, or used directly on site to produce heat and/or power.
Renewables Obligation	Introduced in 2002 by the Department of Trade and Industry, this system creates a market in tradable renewable energy certificates (ROCs), within each electricity supplier must demonstrate compliance with increasing Government targets for renewable energy generation.

Solid Recovered Fuel	Refuse Derived Fuel meeting a standard specification.
Source-segregated/ **Source-separated**	Usually applies to household waste collection systems where recyclable and/or organic fractions of the waste stream are separated by the householder and are often collected separately.
Syngas	‘Synthesis gas’ produced by the thermal decomposition of organic based materials through pyrolysis and gasification processes. The gas is rich in methane, hydrogen and carbon monoxide and may be used as a fuel or directly combusted to generate electricity.