Advanced Thermal Treatment of Municipal Solid Waste

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Department for Environment Food and Rural Affairs

Contents

Prepared by Enviros Consulting Limited on behalf of Defra as part of the New Technologies Supporter Programme.

We acknowledge support from the Department for Environment, Food & Rural Affairs (Defra), the Department of Communities & Local Government (DCLG), the Environment Agency (EA) and BeEnvironmental Ltd.

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Preamble

This Waste Management Technology Brief, updated in 2007, is one of a series of documents prepared under the New Technologies work stream of the Defra Waste Implementation Programme. The Briefs address technologies that may have an increasing role in diverting Municipal Solid Waste (MSW) from landfill. They provide an alternative technical option as part of an integrated waste strategy, having the potential to recover materials & energy and reduce the quantity of MSW requiring final disposal to landfill.

This Brief has been produced to provide an overview of Incineration Technology, which recovers energy from the combustion of MSW. Although not a new technology it can potentially form part of an overall integrated waste management strategy to divert MSW from landfill. Other titles in this series include: An Introductory Guide to Waste Management Options, Advanced Biological Treatment, Mechanical Biological Treatment, Mechanical Heat Treatment; Incineration, Renewable Energy and Waste Technologies, and Managing Outputs from Waste Technologies.

There technologies can assist in the delivery of the Government's key objectives as outlined in the *Waste Strategy for England 2007*, for meeting and exceeding the Landfill Directive diversion targets, and increasing recycling of resources and recovery of energy.

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. It should be noted that these documents are intended as guides to each generic technology area. Further information can be found at the Waste Technology Data Centre, funded by the Defra New Technologies Programme and delivered by the Environment Agency (www.environment-agency.gov.uk/wtd). These Briefs deal primarily with the treatment and processing of residual MSW. Information on the collection and markets for source segregated materials is available from Defra and from ROTATE (Recycling and Organics Technical Advisory Team) at the Waste & Resources Action Programme (WRAP).

The Defra New Technologies Demonstrator Programme has provided nine projects aimed at proving the economic, social and environmental viability (or not) of a selection of waste management technologies. For information on the demonstrator projects see the Defra website or email Wastetech@enviros.com.

1. Introduction

Municipal Solid Waste (MSW) is waste collected by or on behalf of a local authority. It comprises mostly household waste and it may include some commercial and industrial wastes. Historically, nationally the quantity of MSW has risen year on year[1], presenting a growing problem for local authorities particularly as legislation, now limits (by implication[2]) the amount of mixed MSW that can be sent to landfill, becomes more stringent over time.

One of the guiding principles 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 to landfill 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).

At present more than 62% of all MSW generated in England is disposed of in landfills[3]. However, European and UK legislation has been put in place to limit the amount of biodegradable municipal waste (BMW) sent for disposal in landfills[4]. A key driver for this focus on biodegradable waste is to reduce the uncontrolled release of greenhouse gas emissions to atmosphere. The Landfill Directive also requires waste to be pre-treated prior to disposal. The diversion of this material is one of the most significant challenges facing the management of Municipal Solid Waste in the UK.

There are a wide variety of alternative waste management options and strategies available for dealing with Municipal Solid Waste to limit the residual amount left for disposal to landfill. The aim of this guide is to provide impartial information about the range of technologies referred to as Advanced Thermal Treatment (ATT) – the principle ones being gasification and pyrolysis. These technologies are designed to recover energy (in the form of heat, electricity or fuel) and can contribute to the diversion of BMW from landfill. They are part of a range of new alternatives currently being assessed and investigated through the New Technologies work stream of Defra. Further details about the new technologies featured in this report are available from Defra's Waste Technology Data Centre: http://www.environment-agency.gov.uk/wtd

The technologies described in this Brief – Advanced Thermal Treatment - have a limited track record in the UK (and indeed internationally) on MSW. There are many examples of ATT processes that are established are viable and bankable on various waste streams (e.g. biomass, industrial wastes, tyres etc) but a lesser number proven on municipal wastes. The aim of this document is to raise awareness of the technologies available and help remove barriers to the development of appropriate ATT processes in England.

This guide is designed to be read in conjunction with the other Waste Management Technology Briefs in this series and with the case studies provided on Waste Technology Data Centre. Other relevant sources of information are identified throughout the document.

1 This is now showing signs of slowing and in some areas waste arisings are falling, and indeed in 2005/6 there was a 3% fall nationally. However this may be partly explained by other factors occurring in that particular financial year

2 Targets pertain to the biodegradable fraction

3 Results from WasteDataFlow for 2005/6 http://www.defra.gov.uk/environment/statistics/wastats/bulletin.htm

4 The Landfill Directive, Waste and Emissions Trading Act 2003 and Landfill Allowances Trading Scheme Regulations 2004

2. How it works

This section comprises an overview of the principles of Advanced Thermal Treatment processes.

2.1 Advanced Thermal Treatment

Advanced Thermal Treatment technologies are primarily those that employ pyrolysis and/or gasification to process municipal solid waste (MSW). It excludes incineration[5] of wastes which is already a mature and well established technology.

The gasification and pyrolysis of solid materials is not a new concept. It has been used extensively to produce fuels such as charcoal, coke and town or producer gas. Charcoal and coke are produced by pyrolysing wood and coal respectively and producer gas is a combustible gas produced by the gasification of coke in the presence of air and steam.

It is only in recent years that such pyrolysis and gasification have been commercially applied to the treatment of MSW. The development of pyrolysis and gasification technologies is in its infancy in the UK but large scale plants have been built and are in operation in Europe, North America and Japan.

2.2 Difference between Pyrolysis, Gasification and Incineration

There are a variety of differences promoted to differentiate Advanced Thermal Treatment from traditional Incineration technologies. One distinction is that smaller scale facilities are being marketed for treatment of MSW with some ATT processes than that typical of incineration. It is the difference in scale and size that can make it easier to find local markets for both heat and electricity produced. While incineration plants are typically centralised operations, the modular design of ATT operations allows a greater degree of flexibility in terms of location. Sections 6 and 7 discuss planning and public perception aspects of ATT and the process differences are described below.

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. Typically, incineration plant combustion (flame) 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, that contains a small amount of residual carbon.

Advanced Thermal Treatment - Pyrolysis

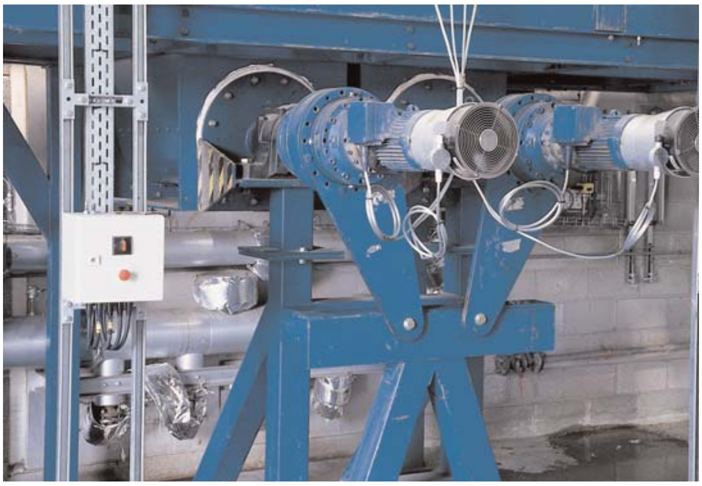
In contrast to combustion, pyrolysis is the thermal degradation of a substance in the absence of oxygen. This process requires an external heat source to maintain the temperature required. Typically, relatively low temperatures of between 300°C to 850°C are used during pyrolysis of materials such as MSW. The products produced from pyrolysing materials are a solid residue and a synthetic 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 VOCs). 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 20 MJ/Nm^3. If required, the condensable fraction can be collected by cooling the syngas, potentially for use as a liquid fuel.

[5] Incineration of MSW in the UK always involves some form of energy recovery, either in the form of electricity generation and/or heat recovery. As such it is also commonly termed Energy from Waste. In this document we will refer to 'incineration' to distinguish from Advanced Thermal Treatment

2. How it works

Advanced Thermal Treatment - Gasification

Gasification can be seen as 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 but some heat may be required to initialise and sustain the gasification process. 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 - 10 MJ/Nm^3. The other main product produced by gasification is a solid residue of non-combustible materials (ash) which contains a relatively low level of carbon. For reference, the calorific value of syngas from pyrolysis and gasification is far lower than natural gas, which has a NCV of around 38 MJ/Nm^3.



2.3 Waste Incineration Directive (WID)

In the UK, all waste incineration plant and ATT plant treating waste must comply with the Waste Incineration Directive (WID). The Directive sets the most stringent emissions controls for any thermal processes regulated in the European Union. The objectives of WID are to minimise the impact from emissions to air, soil, surface and ground water on the environment and human health resulting from the incineration and co-incineration of waste. WID also covers the combustion of syngas produced from ATT processes treating MSW.

The key requirements in the WID for the operation of a facility 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 (SO2)
  - Nitrogen Oxides (NOx)
  - Hydrogen Chloride (HCl)
  - Volatile Organic Compounds (VOCs)
  - Carbon Monoxide (CO)
  - Particulate (fly ash)
  - Heavy Metals
  - Dioxins
- a requirement that the resulting bottom ash that is produced has a total organic carbon content of less than 3%.

2.4 ATT Technology Overview

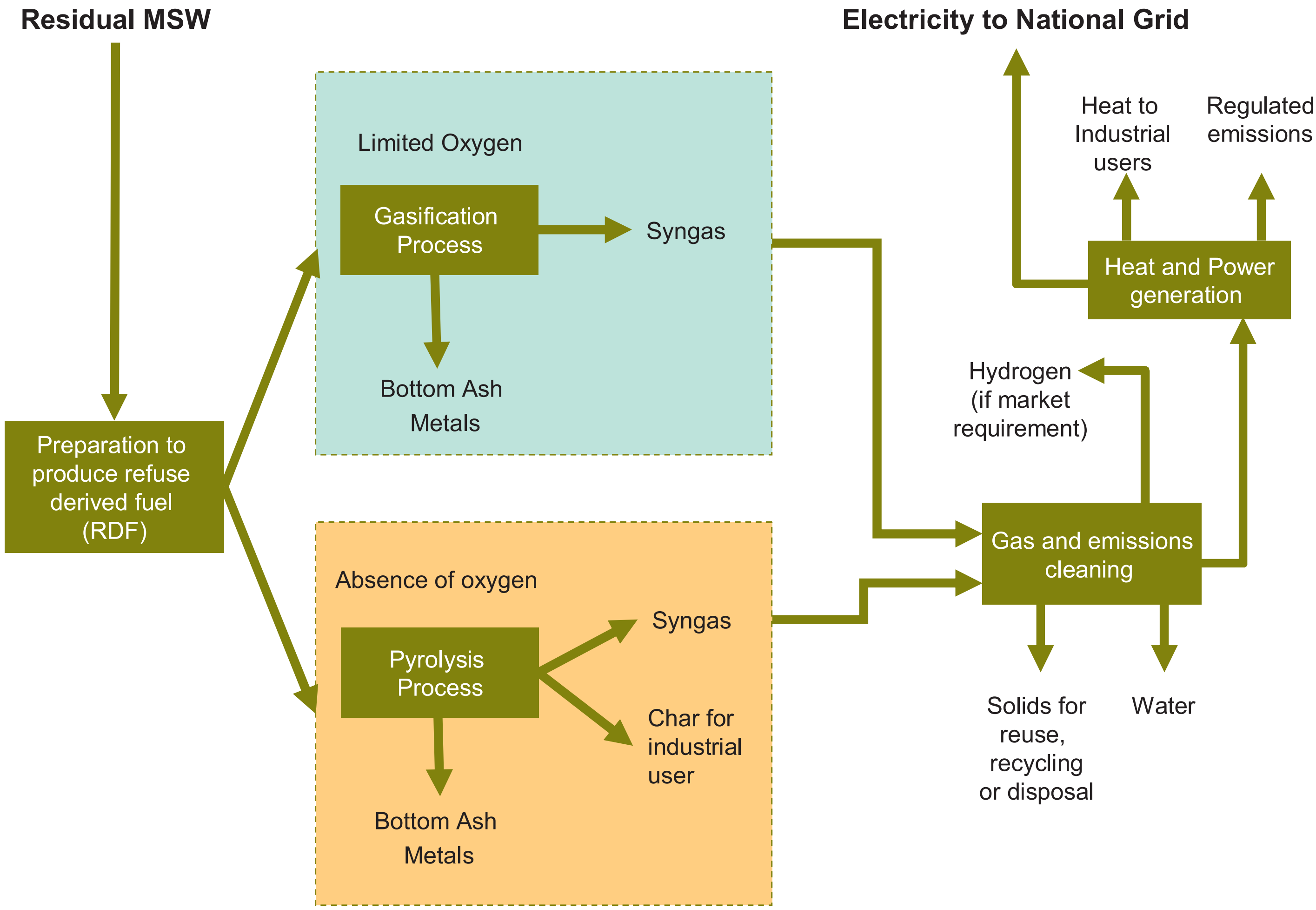
The actual plant design and configuration of ATT facilities will differ considerably between technology providers. However, an ATT plant will typically consist of the following key elements:

- Waste reception, handling and pre-treatment;
- Thermal treatment reactor;
- Gas and residue treatment plant (optional);
- Energy recovery plant (optional); and
- Emissions clean-up.

Figure 1 describes the generic process flows for ATT technologies.

2. How it works

Figure 1: ATT generic process flows



2. How it works

Waste Reception, Handling and Pre-treatment

The pyrolysis and gasification process is focused on treating the biodegradable based materials present in MSW (e.g. paper,card, putrescible waste, green waste, wood), as well as plastics. Therefore, it is common to remove non combustible materials and recyclables, (typically metals and glass) prior to the primary treatment reactor stage (2.3.2). In addition, depending on the technology employed, the feed material might require processing to remove excess moisture and shredding to reduce the size.

It is the preference (for most ATT processes) to treat only pre-processed residual MSW that makes these systems appropriate to be integrated into a wider municipal waste management strategy. ATT processes may be used in conjunction with other waste treatment technologies such as Mechanical Biological Treatment (MBT) and Mechanical Heat Treatment (MHT). Many MBT/MHT plant are designed to produce a fuel stream (primarily composed of paper, card and plastics) as one of the outputs from the process. This is commonly referred to as Refuse Derived Fuel or RDF (see Box 1). This may be more amenable to processing in an ATT plant rather than raw MSW. ATT facilities are identified as one of the 6 potential outlets identified by Defra as suitable for RDF. For more information on MBT, MHT and the potential outlets for RDF see the separate technology briefs in this series.

Box 1: Fuel from mixed waste processing operations

The current prevalent term used for a fuel produced from combustible waste is Refuse Derived Fuel (RDF). The types of technologies used to prepare or segregate a fuel fraction from MSW include the Mechanical Biological Treatment (MBT) and Mechanical Heat Treatment (MHT), described in separate Technology Briefs in this series.

A CEN Technical Committee (TC 343) is currently progressing standardisation work on fuels prepared from wastes, classifying a Solid Recovered Fuel (SRF). Preliminary standards have been published in June 2006, and are following an evaluation process, during which the functioning of the specifications will be verified. The technical specifications classify the SRF by thermal value, chlorine content and mercury content. For example, the thermal value class will be based on the number of megajoules one kilogram of recovered fuel contains. In addition, there are many characteristics for which no specific values have been determined. Instead, they can be agreed upon between the producer and the purchaser of SRF.

Along with the standardisation process, a validation project called QUOVADIS (http://quovadis.cesi.it/) on solid recovered fuels is currently being implemented.

It is anticipated that once standards are developed and become accepted by users, then SRF will become the terminology used by the waste management industry. Other terminology has also been introduced to the industry as various fuel compositions may be prepared from waste by different processes. Examples include 'Biodegradable Fuel Product' (BFP) and 'Refined Renewable Biomass Fuel' (RRBF).

European standards for SRF are important for the facilitation of trans-boundary shipments and access to permits for the use of recovered fuels. There may also be cost savings for co-incineration plants as a result of reduced measurements (e.g. for heavy metals) of incoming fuels. Standards will aid the rationalisation of design criteria for combustion units, and consequently cost savings for equipment manufacturers. Importantly standards will guarantee the quality of fuel for energy producers.

2. How it works

Thermal Treatment Reactor

The thermal treatment process, whether pyrolysis or gasification, will produce syngas and solid residue. The composition of the syngas and solid residue will depend on the process conditions employed, which include operating temperature, oxygen level, heating rate and residence time in the reactor. The main types of thermal treatment units available, their application and operating conditions are summarised in Table 1. There are also other factors influencing the process such as direction of gas flow (e.g. horizontally or vertically).

Table 1: Treatment Reactors

Reactor	Typical Application	Operating Conditions
Rotating Kiln	Pyrolysis	Typically operate at temperatures of between 300 – 850oC. Unit can accommodate large size feed material (200 mm). Kiln is heated externally and waste is fed in from one end of the kiln which slowly rotates creating a tumbling action. This mixes the waste and ensures contact with the heating surface and gases inside the kiln.
Heated Tube	Pyrolysis	The tubes are heated externally and temperatures as high as 800oC are used. The process can accommodate large size feed material. The waste passes through the tube at a set speed to ensure the pyrolysis process is complete.
Surface Contact	Pyrolysis	Small size feed material required and therefore significant pre-treatment is necessary. Process operates at high temperatures and the small size of the feed gives high heating rates. The application of this technology is to maximise the rate of pyrolysis.
Fluidised Bed	Gasification	Fluidised bed technology may be used for gasification or combustion processes. The bed is a mass of particles (typically alumina) that has similar characteristics to a moving fluid. This is achieved by blowing hot gases through the bed of particles. This system provides good mixing and heat transfer to the incoming waste. Waste is pre-treated to remove large sized material. This technology is well suited to the gasification of refuse derived fuels.
Fixed Bed	Gasification	There are a range of different reactor types that come under this heading. A typical example is a grate system where the feed passes along the grate and hot gases pass through the bed of waste heating it.

2. How it works

Gas and Residue Treatment Stages

Solids will inevitably be discharged from the process. These solids include metals together with carbon. In the case of gasification, the level of carbon is small; in pyrolysis it is significant. Larger particles of solids in the thermal treatment reactor are usually discharged as bottom ash and slag. Lighter ash is usually collected when the gas is separated with the use of cyclones and ultimately filters. In addition, volatile metals such as lead, tin, cadmium and mercury will be carried in the gas until such point that the gas is cooled for them to be sufficiently condensed.

Pollution control strategies for ATT plants will typically be on a smaller scale than for incineration technologies, hence less costly, due to the reduction in the volume of process air required however compliance with the Waste Incineration Directive would still be mandatory.

Energy Recovery/Utilisation of Syngas

One of the potential benefits of pyrolysis and gasification is that the syngas can be used in a number of different ways.

In terms of producing energy, the most common configuration is to burn the syngas in a boiler to generate steam. The steam can then be used to generate electricity by passing it through a steam turbine and, if there is a demand local to the plant, for heating. Using the heat in addition to generating electricity improves the overall energy efficiency of the system significantly.

The syngas can also be used to fuel a dedicated gas engine. A syngas from a very well run gasifier, or further processed for example by reforming, may be suitable for use in a gas turbine. Running these types of plant on syngas is still in its infancy and would require cleaning and cooling prior to use. However, using a gas engine or gas turbine could increase efficiencies for electricity generation. This is of particular relevance if a Combined Cycle Gas Turbine (CCGT) or Combined Heat and Power (CHP) configuration is used (see table 2). Whilst high efficiencies can be achieved using gas engines, the highest efficiencies can only be reached using a high calorific value gas. Efficiencies should be checked if using a lower calorific value gas.

To minimise costs for energy generation the ATT plant could be located adjacent to an existing power plant and the syngas transferred to it. This would also provide benefits if the existing plant has a higher efficiency than a standalone unit. The power plant may require upgrading to comply with the Waste Incineration Directive, to improve the abatement system for controlling emissions from the combustion of the syngas, which could incur additional costs.

In addition to using the syngas to produce energy, it could also be used as a chemical feedstock. This offers a further option for utilising the syngas but would require the treatment plant to be local to the end user, in order to be a practical solution. This would require very high gas cleanliness; pollutants, notably sulphur and halogens, may need to be removed prior to combustion of the gas. The reduced gas volumes involved in cleaning the combusted gas rather than the combustion gas gives a financial advantage to the process. Alkalis such as lime and sodium hydroxide are the favoured reagents for removal of the halogen streams. Sulphur can be removed by a variety of routes, largely dependant on the initial concentration (ranging from absorption to the Klaus reaction).

For reference a summary of the potential net electrical generating efficiencies for new build thermal treatment plant employing various energy recovery options is presented in Table 2. For comparison the performance of a new incinerator is also provided. Significantly greater efficiencies are possible by recovering useable heat as well as power.

Table 2: Potential net electrical generating efficiencies

Energy System	Efficiencies of Pyrolysis/ Gasification Treatment Plant	Efficiencies of Incinerator
Steam Boiler and Turbine	10% - 20%	14% - 27%[6]
Gas Engine	13% - 28%	n/a
Combined Cycle Gas Turbine	30%	n/a
Co-firing in existing power plant	Up to 27%	n/a

Syngas from waste has also been identified as a potential source of hydrogen, which could have applications in both power generation and as a vehicle fuel. There are predicted carbon dioxide reduction benefits of the hydrogen from waste route, compared with the current use of natural gas and electrolysis to produce the gas. There would however be significant purification and reforming required before the gas would be of an appropriate quality for power generation (in turbines) or transport (in fuel cells)[7].

The advantages of using ATT plants to produce the syngas would arise from their relatively small scale, flexibility to different inputs and modular development. Producing syngas to serve multiple end uses could complicate delivery of the plants but it could provide a higher degree of financial security than building the entire business case around customer. Although the national grid could take all of the electricity output these prices do fluctuate.

2.5 Examples of ATT technologies

Some descriptive examples of ATT processes are included here to illustrate the different technologies being promoted for MSW management. The technical details of these and other examples, including mass and energy balances and an analysis of the Strengths, Weaknesses, Opportunities and Threats are included on the Waste Technology Data Centre.

Waste Gen (Tech Trade) Hamm Germany

This is a pyrolysis plant that processes a pre-prepared RDF to produce a syngas that is immediately burnt in a dedicated burner in an otherwise coal fired power station boiler. The resulting char after recovery of metals using magnets and aggregate, using a

6 Typical incinerator efficiencies range from 14% to 24%. A recent report (Carbon Balances and Energy Impacts of the Management of UK Wastes, ERM and Golder Associates report for Defra, March 2006 www.defra.gov.uk/science/project_data/DocumentLibrary/WR0602/WR0602_4750_FRP.pdf) states an efficiency range for electricity only of between 20-27%

7 The Potential for Hydrogen Production from Waste in London; The London Hydrogen Partnership http://www.lhp.org.uk/content/images/articles/LHPReportFinal3LR(1).pdf

ballistic separator, is fed into the station coalbunkers. Fuel is delivered to the plant in bales or bulk form, from a range of RDF producers. The fuel is conveyed to the two rotary kiln, pyrolyser, units (20m in length x 2.8m in diameter). Natural gas burners heat the pyrolysis drums. The two pyrolysis drums replace 10% of the fuel input to a coal fired 330Mwe generating set.

KBI Waste & Energy Solutions GmbH

This is a Mechanical & Biological Treatment (MBT) plant followed by an oxygen blown 'down draught' gasifier. The purpose of the waste pre-treatment and the gasifier is to produce a gas of a quality and consistency such that the power plant can safely and reliably operate to a defined efficiency and emission limits.

Received waste is dried in a rotating compost drum and recyclates are removed. The waste then passes to a feed preparation area where additives such as coke, (typically 17%) and limestone are introduced prior to gasification.

In the gasifier oxygen is added at several points down the gasifier progressively raising the temperature towards the maximum, normally 1500°C. Additional feeds of steam and natural gas are used so as to control the composition of the produced gas. The gas is to be used for power generation via a gas turbine set. The gas is burned in a conventional gas turbine set and the exhaust gas from the turbine is used to raise steam. Some of the steam / electricity is used by the process with the excess available for export.

GEM, Graveson Energy Management, Port Talbot, UK

This process uses fast pyrolysis of a Refuse Derived Fuel (RDF see box 1) to produce a gas suitable for burning or powering an engine.

The essential principle behind the process is to rapidly heat the feed to around 820oC, in the absence of oxygen and hence induce rapid pyrolysis. To do this conventional RDF has to be ground such that one major dimension of each RDF particle is less than 2mm. The ground floc then has to be dried to 5% moisture prior to feeding into the pyrolyser. The Pyrolyser consists of a large vertical steel cylinder heated on its outside surface. A close fitting cylindrical drum is suspended and rotated within this cylinder. The RDF is fed at the top of the cylinder and by falling through the gap between the cylinder and drum is rapidly heated. Within a couple of seconds the RDF has been pyrolysed. Char is separated from the gas in a cyclone. The gas stream is cooled and scrubbed to remove acid gases. The cleaned gas is then fed to a spark ignition engine generator set. Waste heat from the pyrolyser heater, the engine exhaust, engine cooling and the produced gas cooler is collected and integrated with the local heat requirements which may be parasitic loads or potentially offsite heat demands, hence giving a combined heat and power system.

2.6 Summary

This section explains that Advanced Thermal Treatment processes are primarily pyrolysis and/or gasification based. ATT are capital intensive facilities and have a design life of 15 – 25 years. Rigorous evaluation of the technology is essential to reduce any operational risks when processing the anticipated feedstock. Over this timescale the composition of waste is likely to alter and the process selected should be robust or flexible enough to treat varying calorific values and compositions of waste feedstock.

3. Markets and outlets for the outputs

ATT processes will all produce a gas (usually for energy recovery) and a solid residue (slag, ash or char). Some facilities are also designed with mechanical preparation and sorting equipment to extract recyclables. Table 3 summarises the key outputs from ATT processes and the following sections address materials and energy recovery.

Table 3: Examples of outputs from ATT processes

Outputs	State	Potential Markets
Slag (from gasification)	Solid, fused	Aggregate
Ash (from gasification)	Un-fused residue	Aggregate replacement, metals can be separated
Flue Gas Treatment residue	Solid, powder/ sludge. Invariably a hazardous waste; some potential for neutralising waste acids	Specialist Disposal or treatment potential use in Chemical treatment works (e.g. neutralising acid waste)
Syngas	Gaseous	Heat or power generation/fuel/ some chemical application
Condensate	Liquid	Fuel/chemical application. Care needs to be taken with the chemical composition of this and the hazards associated with it
Char (from pyrolysis)	Solid	Hazardous waste but could be used as coal replacement in certain combustion applications or as a gasifier feedstock

The following section summarises some key issues with regard to these outputs.

3.1 Recovery from ATT

Materials Recycling

Recyclables derived from either the front end preparation stage of an ATT 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 generally have a lower value accordingly. The types of materials recovered from ATT processes almost always include metals (ferrous and non-ferrous), usually from the front end of the process. Metal removal can help enhance overall recycling levels and enable recovery of certain constituent parts that would not otherwise be collected in household systems (e.g. steel coat hangers, scrap metal etc.).

Pyrolysis plants produce a bottom residue that contains significant amounts of carbon. This will need to be disposed of to landfill, or treated further to reduce the carbon content for example by gasification or combustion. If treated further the final bottom residue could then be recycled as a secondary aggregate. Gasification tends to produce a bottom residue which has a lower carbon content and has usually been melted or fused, and this could therefore be recycled as aggregate. The recycling of bottom ash would need to be undertaken in accordance with relevant legislation but is likely to be of equivalent or potentially better quality than incinerator bottom ash, which is currently recycled in aggregate applications.

3. Markets and outlets for the outputs

For more information on the contribution of ATT to Best Value Performance Indicators and recycling see section 9, and for the latest developments see the local authority performance pages on the Defra website http://www.defra.gov.uk/environment/waste/localauth/perform-manage/index.htm and http://www.wastedataflow.org/Documents/BVPI%20FAQs.pdf. The Defra New Technologies Demonstrator also includes ATT facilities, more information on which is available through the Defra website or from Wastetech@enviros.com.

Energy Recovery

ATT processes are designed to recover energy from the waste processed either in the form of fuel production (liquid or gas) or combusting the syngas to generate electricity and/or heat for use on site and export off site. There is also potential for the syngas to be utilised in vehicles, after reforming to produce hydrogen. It is envisaged that the initial market for the hydrogen would be public transport fleets using fuel cell vehicles.

Examples of energy recovery from case studies are included on the Waste Technology Data Centre. Electricity generated from the biomass fraction of waste in gasification and pyrolysis plants is eligible for support under the Renewables Obligation.

It should be noted that the processes using RDF will have already incurred energy usage in the preparation of the fuel and this prepared material will have a higher calorific value than raw MSW.

4. Track record

Whilst ATT technologies are established technologies for the treatment of certain specific waste streams, it is only in recent years that pyrolysis and gasification have been commercially applied to the treatment of MSW.

The prime drivers in the UK for the development of these technologies are increasing landfill costs and the implementation of the Landfill Directive. The development of pyrolysis and gasification technologies for MSW is in its infancy in the UK but commercial scale plant have been built and are in operation in Europe, North America and Japan. Table 4 provides examples of ATT facilities in the UK and overseas, treating MSW and other types of waste.

Table 4: ATT facilities

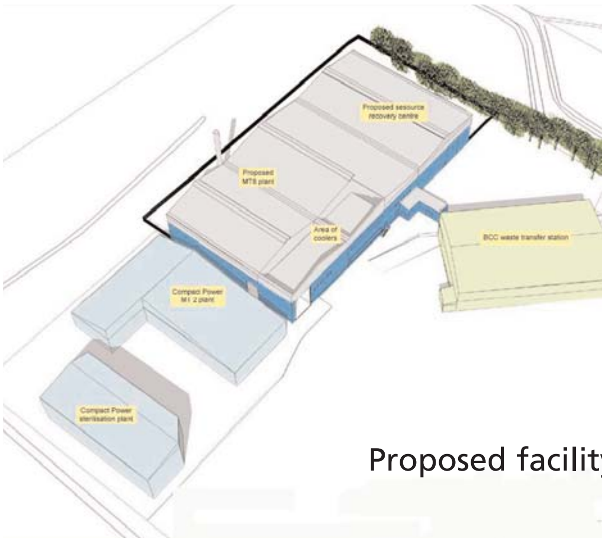
Manufacturer	Primary Technology	Country	Operational	Capacity, tpa	Feed
Compact Power	Tube Pyrolysis	UK - Avonmouth	2001	8,000	Clinical Waste
Energos	Grate Gasification	Norway	1997	10,000	Industrial & Paper Wastes
Energos	Grate Gasification	Norway	2000	34,000	MSW
Energos	Grate Gasification	Norway	2001	36,000	MSW & industrial waste
Energos	Grate Gasification	Norway	2002	70,000	MSW & industrial waste
Energos	Grate Gasification	Norway	2002	37,000	MSW
Energos	Grate Gasification	Germany	2002	37,000	MSW & industrial waste
Energos	Grate Gasification	Germany	2005	80,000	MSW, Commercial, Industrial
Energos	Grate Gasification	Sweden	2005	80,000	Municipal & Industrial Waste
Enerkem/Novera	Fluidised Bed Gasification	Spain	2002	25,000	Plastics
FERCO	Fluidised Bed Gasification	USA	1997	165,000	Biomass
Foster Wheeler	Fast (ablative) Pyrolysis	Finland	1998	80,000	Mix waste
Mitsui Babcock	Rotary Kiln Pyrolysis	Japan	2000	80,000	MSW
Mitsui Babcock	Rotary Kiln Pyrolysis	Japan	2002	150,000	MSW
Mitsui Babcock	Rotary Kiln Pyrolysis	Japan	2002	50,000	MSW
Mitsui Babcock	Rotary Kiln Pyrolysis	Japan	2003	95,000	MSW
Mitsui Babcock	Rotary Kiln Pyrolysis	Japan	2003	75,000	MSW
Mitsui Babcock	Rotary Kiln Pyrolysis	Japan	2003	60,000	MSW
Thermoselect	Tube Pyrolysis	Germany	1999	225,000	Domestic & Industrial Wastes
Thermoselect	Tube Pyrolysis	Japan	1999	100,000	Domestic & Industrial Wastes
Thermoselect	Tube Pyrolysis	Japan	2003	50,000	Industrial Wastes
Techtrade/ Wastegen	Rotary Kiln Pyrolysis	Germany	1984	35,000	RDF
Techtrade/ Wastegen	Rotary Kiln Pyrolysis	Germany	2002	100,000	Domestic & Industrial Wastes

4. Track record

The following case studies detail ATT plants under development as demonstration sites under the Defra New Technologies Demonstrator Programme. For more information see http://www.defra.gov.uk/environment/waste/wip/newtech/dem-programme/index.htm or contact wastetech@enviros.com.

Compact Power – Avonmouth, Bristol

- Compact Power - The Avonmouth Renewable Energy Plant, Bristol
- Advanced thermal conversion technology combines pyrolysis, gasification and high temperature oxidation
- 2 tube modular process with each unit processing up to 500 kg per hour tph of non-recyclable waste
- Capacity of approximately 24,000 tpa of MSW,
- Energy outputs from the process will be 2,400 kW of electricity and 7,620 kW of heat
- Collaboration with Bristol City Council, due to be commissioned and in operation by mid 2008.



Proposed facility

Energos - Isle of Wight

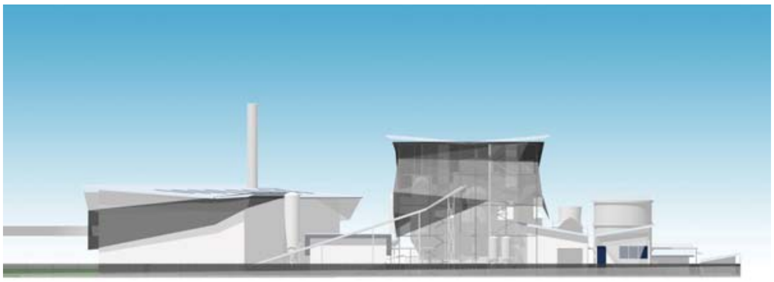
- Gasification facility will be integrated with existing MRF and in-vessel composting facilities to process residual MSW, in the form of RDF
- Capacity of 30,000 tpa RDF plant
- Consumes RDF with a high biodegradable content (70 - 80%) and a calorific value of 11 – 14 MJ/kg
- Will export approximately 1.8 MWe of renewable electricity and locally useable waste heat.

Example of Energos gasification site

4. Track record

Novera Energy – Havering, Essex

- Novera is a renewable energy company working in partnership with East London Waste Authority (ELWA) and Ford Motor Company
- The gasification plant is designed to process 70 - 90,000 tpa RDF from a near by Mechanical Biological Treatment (MBT) plant treating waste from ELWA
- Will provide between 8-10 MW of energy and heat to Ford plant at Dagenham (Equivalent to approximately £4 million per annum worth of electricity purchased from the National Grid. ELWA will benefit through having a LATS surplus
- The RDF will be of low moisture content (~13%) hence have a relatively high calorific value of around 17 MJ/kg
- This demonstrator is conceptually different the other projects. If successful it will showcase the possible relationships which can be built between high energy consumers in industry, the waste industry and local authorities.



Artists impression of the facility

Yorwaste - Seamer Carr, North Yorkshire

- The site will utilise 12,000 tpa of RDF from a complex Materials Recycling Facility sorting MSW
- The RDF will have an approximate calorific value of 15 MJ/kg.
- It will produce 2.4 MWe of renewable electricity and locally useable waste heat
- The pyrolysis facility will be integrated with an existing MRF and in-vessel composting facilities to process MSW
- Planning Permission was approved in April 2007 and a PPC Permit application submitted to the Environment Agency in March 2007

Yorwaste processing equipment

5. Contractual and financing issues

5.1 Grants & Funding

Development of ATT 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 new 'prudential' system of capital finance controls;

PFI Credits and Private Sector Financing: under the Private Finance Initiative a waste authority can obtain an annual subsidy from central government through a Special Grant;

Other Private-Sector Financing: A contractor may be willing to enter into a contract to provide a new facility and operate it. The contractor's charges for this may be expressed as gate fees; and

Other Existing sources of local authority funding: for example National Non-Domestic Rate payments (distributed by central government), credit (borrowing) approvals, local tax raising powers (council tax), income from rents, fees, charges and asset sales (capital receipts). In practice capacity for this will be limited but generally it is through raising taxes.

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

5.2 Contractual Arrangements

Medium and large scale municipal waste management contracts, since January 2007, are procured through EU Competitive Dialogue (CD). 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 4ps website.

The contractual arrangement between the private sector provider (PSP) and the waste disposal authority (or partnership) may be one of the following:

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;

Design & 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 Council owns the facility that is constructed and makes separate arrangements to raise capital. Operation would be arranged through a separate Operation and Maintenance contract;

Design, Build and Operate; Finance: The Design and Build and Operation and Maintenance contracts are combined. The waste authority owns the facility once constructed and makes separate arrangements to raise capital;

5. Contractual and financing issues

Design, Build, Finance and Operate (DBFO): This contract is a Design, Build and Operate Contract but the contractor also provides the financing of the project. The contractor designs, constructs and operates the plant to specified 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; and

DBFO with PFI: This is a Design, Build, Finance and Operate contract, but it is procured under the Private Finance Initiative. In this case the waste authority obtains funding for future payment obligations from Government as a supplement to finance from its own and private sector sources.

The majority of large scale waste management contracts currently being procured in England are Design, Build, Finance and Operate contracts. Many waste disposal authorities in two tier English arrangements (County Councils) seek 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.

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.

Further guidance on these issues can be obtained from:

- Local Authority funding http://www.defra.gov.uk/environment/waste/localauth/funding/pfi/index.htm
- The Local Government PFI project support guide www.local.odpm.gov.uk/pfi/grantcond.pdf
- For Works Contracts: the Institution of Civil Engineers ‘New Engineering Contract’ (available at www.ice.org.uk).
- For large scale Waste Services Contracts through PFI and guidance on waste sector projects see the 4ps, local government's project delivery organisation http://www.4ps.gov.uk/PageContent.aspx?id=90&tp=Y

6. Planning and permitting issues

This section contains information on the planning and regulatory issues associated with ATT facilities based on legislative requirements, formal guidance, good practice and in particular drawing on information contained in the Office of the Deputy Prime Minister's research report on waste planning published in August 2004[8].

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.

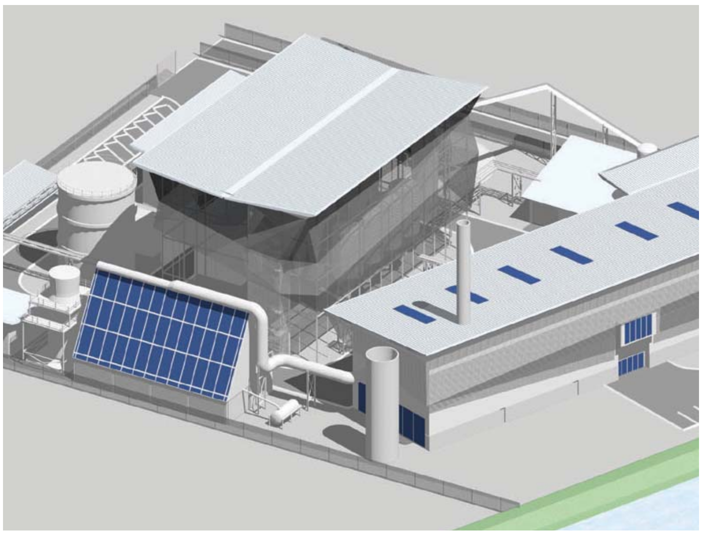
Under certain circumstances new waste facilities can be developed on sites previously used for General Industrial (B2) or Storage and Distribution (B8) activities. In practice even where existing buildings are to be used to accommodate new waste processes, variations to existing permissions are likely 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 July 2005. Supplementary guidance is also contained within the Companion Guide to PPS 10[9]. Both of these documents can be accessed via the Department of Communities and Local Government (DCLG) website .

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[10]. 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. It is important that prospective developers liaise closely with their Local Planning Authorities over the content and scope of planning applications.



8 http://www.communities.gov.uk/embeddedindex.asp?id=1145711
9 http://www.communities.gov.uk/index.asp?id=1143834
10 http://www.communities.gov.uk/pub/494/BestPracticeGuidanceontheValidationofPlanningApplicationsPDF326Kb_id1144494.pdf

6. Planning and permitting issues

6.2 Key Issues

When considering the planning implications of an ATT facility the key issues that will need to be considered are common to most waste management facilities and are:

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

A brief overview of the planning context for each of these issues is provided below.

6.3 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, however the following criteria are likely to apply to the siting of new ATT facilities:

- ATT processes 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 facilities producing RDF (such as MBT and MHT facilities) could be advantageous. The potential for co-location of such facilities on resource recovery parks or similar is also highlighted in 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 ATT facilities. The Renewables Obligation provides a price premium for electricity generated from renewable sources (the biomass fraction of waste) in gasification and pyrolysis plants Consideration should always be given to utilising not only the electricity from the plant but also the waste heat in order to maximise energy and carbon benefits.

6.4 Traffic

ATT facilities may be served by large numbers of HGVs (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.

6.5 Air Emissions/Health Effects

In terms of complying with the Waste Incineration Directive (WID) the major emission from a plant with energy recovery is the release of flue gases from the combustion of the syngas (and in some instances also the residual solid, if it has high carbon content). The clean-up required for the flue gases is dependent on the process from which they have been generated. One of the main benefits claimed by manufacturers for pyrolysis and gasification plant is that emissions of pollutants are lower than those from conventional incineration and that plant are designed to comply with the emission limits set out in the directive.

Entrained (fine) particles in the syngas can either be removed before or after combustion depending on the treatment process and combustion technology employed.

A further solid residue that is produced is from abatement plant used to clean-up the flue gases from the combustion process. Both of these solid streams are hazardous in nature and must be disposed of appropriately. Often they are combined as they are removed during the same stage of the flue gas clean-up.

An independent study on Health & Environmental impacts of waste management processes found no evidence of health effects linked to ATT facilities, although due to the emergent nature of these technologies the available data was only of a moderate quality[11].

6.6 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. Many ATT processes are designed to operate under negative pressure within buildings to minimise dust and odour problems.

6.7 Flies, Vermin and Birds

ATT processing is unlikely to attract vermin and birds due to majority of waste throughput and operations being completely enclosed in buildings. 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 used to bring temperatures in fresh input waste to levels above which flies can live. The use of RDF as a feedstock would reduce this issue relative to raw waste.

6.8 Noise

Noise is an issue that will be controlled under the waste licensing regulations and noise levels received at nearby receptors can be limited by a condition of a planning permission. The main contributors to noise associated with ATT 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 condenser units.

[11] http://www.defra.gov.uk/environment/waste/research/health/index.htm

6. Planning and permitting issues

6.9 Litter

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

6.10 Water Resources

Water will be used but this 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. The case studies on the Waste Technology Data Centre include an assessment of water usage.

6.11 Visual Intrusion

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;
- Use of screening features (trees, hedges, banks etc); and
- The number of vehicles accessing the site and their frequency.

6.12 Size and Land take

Table 5 shows the land area required for the building footprint and also for the entire site (including supporting site infrastructure) for examples of thermal processes.

Table 5: Landtake

TT Facility	Size, tonnes per annum	Buildings Area m2	Total Landtake Ha	Indicative Stack Height
Incineration*	90,000	5850	1.7	65m
Incineration*	250,000	6,600	4	70m
Pyrolysis†	60,000	-	0.98	-
Pyrolysis†	12,500	200	Plus access area	
Pyrolysis†	35,000	28,000 – 32,000	4	-
'General ATT'*	50,000	3,600	1-2	30 – 70m

Source:
* = Planning for Waste Management Facilities – A Research Study

† = Waste Technology Data Centre.

ATT plants are expected to be of modular design and scalable to suit the requirements of different waste management operators. For more information on Landtake for specific waste management operations, see the Waste Technology Data Centre.

6.13 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 perceived issue.

6.14 Environmental Impact Assessment

It is likely that an Environmental Impact Assessment (EIA) will be required for an ATT facility as part of the planning process.

Whether a development requires a statutory EIA is defined under the Town and Country Planning (Environmental Impact Assessment)(England and Wales) Regulations 1999. The existing additional guidance in the DETR circular 02/99 is currently being revised. This new guidance is likely to focus on appropriate criteria for establishing need for EIA and not relate to the general nature of proposals.

For more information on Planning issues associated with waste management options see Planning for Waste Management Facilities – A Research Study. Office of the Deputy Prime Minister, 2004. http://www.communities.gov.uk/pub/713/PlanningforWasteManagementFacilitiesAResearchStudy_id1145713.pdf

6.15 Licensing/Permitting

Currently, the interpretation of all ATT operations is that they require a Pollution Prevention & Control (PPC) permit. It would be prudent to assume that any facilities will be covered by the PPC Regulations. The Environmental Permitting Programme (EPP) is due to be implemented in April 2008 which will combine waste licensing and permitting systems. For more information on licensing & permitting see http://www.environment-agency.gov.uk/subjects/waste/?lang=_e

7. Social and perception issues

This section contains a discussion of the social and environmental considerations of ATT 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, landscape) are important considerations when siting any waste management facility. These issues are examined in more detail in the Planning & Permitting section of this Brief. Transport impacts associated with the delivery of waste and onward transport of process outputs may lead to impacts on the local road network. The Planning and Permitting section of this Brief provides an estimate of potential vehicle movements.

An ATT facility may also provide positive social impacts in the form of employment, educational opportunities and a source of low cost heat. Typical employment for a ATT plant of 50,000tpa capacity would be 2-6 workers per shift. The plant would operate on a shift system, to allow for 24-hour operations. These facilities are also likely to provide vocational training for staff. New facilities may be built with a visitor centre to enable local groups to view the facility and learn more about how it operates.

7.2 Public Perception

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.

At present there is a relatively low level of understanding of the concept of ATT by the public. There are no full scale commercial ATT operations in the UK processing MSW. In public consultations these technologies score inconsistently when explained in detail as a residual waste treatment technology. There is a general distrust of thermal systems in the UK, however some ATT providers accentuate the differences of their systems from incineration as a key part of the promotion of their technology.

Overseas development of Advanced Thermal Treatment again shows inconsistencies. In Australia developments of ATT plant received similar perceptions to that of incineration, partly due to campaigns from national environmental groups claiming parallels between the technologies. The national environment campaign organisations in the UK are divided on this issue. The public has yet to be tested in the UK on ATT.

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. Defra is funding the development of small to medium scale demonstration plant in England for local authorities to visit and for Defra to publish data on performance. For more information see the Defra website or contact Wastetech@enviros.com.

8. Cost

ATT plant have been applied to chemical and process industries; these have all been large scale, capital intensive applications.

The capital costs for an ATT facility 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 ATT 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 provided by ATT technology suppliers to the Waste Technology Data Centre are wide ranging. Examples of capital costs are list below:

- £9 million for a 25,000 tpa facility
- £12 million for a 40,000 tpa facility
- £19 million for a 80,000 tpa facility
- £17 million for a 100,000 tpa facility
- £50 million for a 60,000 tpa facility

Extreme care is required in utilising cost data such as that provided on the data centre website as it might not be fully inclusive. In addition, site specific criteria need to be taken into account, which are summarised above and actual costs will vary on a case by case basis.

9. Contribution to national targets

9.1 Recycling

Recyclate derived from an ATT plant processing household waste qualifies for BVPI 82a (Recycling) for any materials recovered prior to the thermal treatment reactor. Any materials recovered after the thermal treatment (e.g. metals from the ash), do not count towards BVPI 82a. Equally any slag, char or ash recycled does not count towards BVPI 82a.

The material must pass to the reprocessor (and not be rejected for quality reasons) to count as recycling. It should be noted that materials are extracted from the front end of the process for recycling are likely to be of a lower quality that source segregated recyclables and therefore may experience market limitations.

The Government has recently increased national recycling and composting targets for household waste through the *Waste Strategy for England 2007.* Targets are at least 40% by 2010, 45% by 2015 and 50% by 2020. For more information on the contribution of incineration to Best Value Performance Indicators and recycling see the local authority performance pages on the Defra website http://www.defra.gov.uk/environment/waste/localauth/perform-manage/index.htm and http://www.wastedataflow.org/Documents/BVPI%20FAQs.pdf

9.2 Landfill Allowance Trading Scheme (LATS)

The European Landfill Directive and the UK's enabling act, the Waste & Emissions Trading Act 2003, 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 (char or ash) will not be classified as biodegradable even if disposed to landfill. Up to date information can be obtained from Defra's LATS information webpage:

http://www.defra.gov.uk/environment/waste/localauth/lats/index.htm

9.3 Recovery

ATT technologies will contribute towards recovery targets on the tonnage of materials entering the thermal treatment process as all processes are designed to recovery energy. The Government has recently increased national recovery targets for municipal waste through the *Waste Strategy for England 2007.* Targets are 53% by 2010, 67% by 2015 and 75% by 2020. For more information see the Defra website and the guidance on BVPI 82c http://www.defra.gov.uk/environment/waste/localauth/perform-manage/index.htm.

9.4 Renewable Energy

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 15.4% by 2015/16. 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 ATT 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.

9. Contribution to national targets

The Department for Trade and Industry is considering providing greater support to technologies producing renewable energy and assessment methods for removing barriers to renewable energy generation. Up-to-date information regarding ROCs can be obtained from the DTI website http://www.dti.gov.uk/energy/sources/renewables/index.htlm.

10. Further reading and sources of information

WRATE (Waste and Resources Assessment Tool for the Environment)

http://www.environment-agency.gov.uk/wtd/1396237/?version=1&lang=_e

The Waste Technology Data Centre www.environment-agency.gov.uk/wtd

New Technologies Demonstrator Programme Wastetech@enviros.com

Defra New Technologies website, http://www.defra.gov.uk/environment/waste/wip/newtech/index.htm

Integrated Pollution Prevention and Control, Draft Reference Document on Best Available Techniques for the Waste Treatments Industries, *European Commission – Directorate General Joint Research Centre*, January 2004

Energy from Waste – A Good Practice Guide, Energy from Waste working group, CIWM, 2003

Refuse Derived Fuel, Current Practice and Perspectives (B4-3040/2000/306517/Mar/E3), *European Commission – Directorate General Environment*, July 2003

Review of Environmental & Health Effects of Waste Management, Enviros Consulting Ltd, University of Birmingham, Open University & Maggie Thurgood. Defra 2004.

AiIE Ltd, 2003, Review of residual waste treatment technologies, Report prepared on behalf of Kingston upon Hull City Council and East Riding of Yorkshire Council

http/www.eastriding.gov.uk/environment/pdf/waste_treatment_technologies.pdf

The Additional Paper to the Strategy Unit, Waste Not Want Not study, 'Delivering the Landfill Directive: The Role of New & Emerging Technologies', Dr Stuart McLanaghan
http://www.number10.gov.uk/files/pdf/technologies-landfill.pdf

Planning for Waste Management Facilities – A Research Study. Office of the Deputy Prime Minister, 2004.

http://www.communities.gov.uk/pub/713/PlanningforWasteManagementFacilitiesAResearchStudy_id1145713.pdf

Local Authority funding

http://www.defra.gov.uk/environment/waste/localauth/funding/pfi/index.htm

The Local Government PFI project support guide www.local.odpm.gov.uk/pfi/grantcond.pdf

For Works Contracts: the Institution of Civil Engineers 'New Engineering Contract' (available at www.ice.org.uk).

For large scale Waste Services Contracts through PFI and guidance on waste sector projects see the 4ps, local government's project delivery organisation

http://www.4ps.gov.uk/PageContent.aspx?id=90&tp=Y

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.
Aerobic	In the presence of oxygen.
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, wood 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	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 (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone, water vapour and some of the chlorofluorocarbons.
Green 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.
Materials Recycling Facility/Materials 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)	Household waste and any other wastes collected by the Waste Collection Authority, or its agents, such as municipal parks and gardens waste, beach cleansing waste, commercial or industrial waste, and waste resulting from the clearance of fly-tipped materials.
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)

11. Glossary

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 certificates (ROCs), within which each electricity supplier must demonstrate compliance with increasing Government targets for renewable energy generation.
Solid Recovered Fuel	Refuse Derived Fuel meeting a standard specification, currently under development by a CEN standards committee.
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.
Statutory Best Value Performance Indicators	Local Authorities submit performance data to Government in the form of annual performance indicators (PIs). The Recycling and Composting PIs have statutory targets attached to them that Authorities are required to meet.
Syngas	'Synthetic 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 and/or heat, or for transport applications in fuel cells.