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West of England Waste Management and Planning Partnership

Issue and Options Consultation Website Content

The Technology Options

03 January 2007

Draft

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DOCUMENT CONTROL SHEET FORM IP180/B

Client: West of England Waste Management and Planning Partnership

Project: West of England Waste Advice Job No: B2039100

Title: Consultation Website Content – Technology Options

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The Technology Options

The West of England Waste Management and Planning Partnership (the Partnership) appraised a series of technology options for potentially treating residual municipal waste as part of the development of a Joint Residual Municipal Waste Management Strategy (JRMWMS).

The technologies that were short-listed for appraisal were selected on the basis of the best available information and knowledge at the time they were selected (March 2006 to June 2006). It should be recognised that the waste management industry is in a period of considerable change, with rapid developments in treatment technologies being just one area where progress is constantly being made. The technologies were short-listed on the basis that they are operating on the market (not just in the UK), that they are being proposed in UK local authority contracts at that time and that they are considered not to have unacceptable risks associated with delivering them. The technology options short listed do not necessarily contain a single process; certain options identify a series of interdependent processes, which are described in greater detail on this website. It is anticipated that the variety of treatment technology types modelled should cover any alternative technology processes that may emerge in the future.

The technologies are set out in the table below. An overview of each technology option is presented in the Introduction i.e. a brief explanation. These pages present more detailed information on the technology options, providing an explanation of the technology option for those who wish to understand the process more thoroughly. Example facilities are identified where appropriate and links are given for further information if the reader wishes to find out more.

Options for the management of residual municipal waste within the Partnership

Option	Description	Acronyms
SQ	The Status Quo	SQ
PSI	Programmed Service Improvements	PSI
1	Energy from Waste (EfW)	EfW
2	Biological Mechanical Treatment + 3rd Party Thermal Treatment of solid recovered fuel (SRF) + In-Vessel Composting of waste derived compost	BMT + IVC + TT (3rd)
3	Mechanical Biological Treatment + 3rd Party Thermal Treatment of SRF + Landfill of stabilised output	MBT + TT (3rd) + Lf
4	Autoclave + Anaerobic Digestion of Fibres	AC + AD
5	Mechanical Treatment + 3rd Party Thermal Treatment of SRF + Anaerobic Digestion of waste derived compost + maturation of digested compost product	MT + TT (3rd) + AD + Mtn
6	Autoclave + Thermal Treatment of Fibre	AC + TT (gas)
7	Pyrolysis / Gasification (with mechanical fuel preparation)	MT + TT (pyrolysis/ gas)

(These options should be hyperlinked to each individual technology page).

Status Quo
The Status Quo option illustrates the current status of waste disposal in the Partnership i.e. that the Partnership continues to landfill residual waste with no changes to future source segregation performance, for example, with no improvements to kerbside collections. This is used as a baseline against which technology options can be evaluated.

The table below shows the current destination of residual municipal waste from the Partnership authorities.

Authority	Transfer Stations	Destination Landfill Sites	Anticipated site closure date at estimated rate of filling
B&NES	• Bath (railhead) • North Radstock	• Calvert, Buckinghamshire • Dimmer, Somerset • Calne, Wiltshire	• 2015 • 2021 • 2031
BCC	• St Philips (railhead) • Avonmouth	• Calvert, Buckinghamshire • Hempsted, Gloucestershire	• 2015 • 2016
NS	• Western-Super-Mare	• Yanley, Somerset • Broadpath, Devon	• 2008 • 2010
SG	• Yate • Mangotsfield	• Calne, Wiltshire • Chapel Farm, Swindon • Hempsted, Gloucestershire	• 2031 • Unknown • 2013

For a variety of reasons, including conducive geology and extensive mineral extraction activity; the UK has a long history and considerable experience in designing, constructing and operating landfill sites. There are nearly 800 licensed operating landfill sites in England and Wales in 2006[1].

[1] http://www.defra.gov.uk/environment/waste/wip/data/pdf/waste-facilities.pdf

Option 1: Energy from Waste

Energy from Waste (EfW) is the application of sound proven combustion engineering principles to a variety of technologies which greatly reduce the volume of the residual municipal waste fraction. This process occurs after recycling and composting has taken place, in order to recover energy released during the combustion process [2].

The residual municipal waste in this option is received in a reception hall, where a small percentage of oversized and inappropriate fractions of waste are removed and disposed to landfill, for example, mattresses, bicycles, engine parts. The remaining waste is deposited in a deep concrete bunker, mixed with older wastes and allowed to dry out before being fed by a grab hook via a hopper into the furnace. Some new EfW facilities have fully computerised and automated (laser guided) grab hooks.

There are a number of different types of grate and furnace in EfW plants such as moving grate, rotary, drum kiln, a combined oscillating grate and rotary kiln, and a fluidised bed furnace. The process described here is the traditional moving grate technology, but the key combustion process is similar for all variant processes.

The waste moves down the grate by moving bars or rockers. The moving grate allows waste to be fed continuously into the furnace, initially either by gravity or by mechanical means. As well as moving waste down the grate in a controlled manner, this motion mixes the waste to help ensure complete combustion.

The waste gradually passes through the furnace, which runs at a temperature of approximately 900°C. It must reach a minimum of 850°C for at least two seconds in the presence of air (with at least 6% oxygen) to comply with the European Union Waste Incineration Direction (WID) (2000/76/EC)[3].

Typical grate speeds allow for approximately 12 tonnes per hour to be combusted, which equates to the material travelling along the grate over a period of upwards of 40 minutes. During combustion, the organic component of the waste is oxidised to carbon dioxide (CO_2) and water (H_2O) whilst the solid residues are transformed into a mineralised form (called bottom ash). The volume of the waste is reduced by around 90% and the weight by around 75%.

To meet the widely varying combustion characteristics of residual municipal waste, the grate system must be capable of:

- Conveying waste and ash in a controlled manner from the feed chute to the grate end;
- Efficiently turning and mixing the waste to ensure complete combustion;
- Controlling primary air admission to meet the combustion requirements of the WID; and
- Adapting to the variable properties of the waste.

The heat from the furnace is transferred from the hot combustion gases to water in the boiler tubes, generating steam whilst cooling the combustion gases. This steam is used to turn a turbine and generate electricity, and/or can be used as a heat source for space heating and powering industrial processes, which is called combined heat and power (CHP).

After passing through the boiler tubes, the cooled gases pass through a gas cleaning plant, typically consisting of scrubbers (for acid gas removal) and bag-house filters (for fine particulate removal). The cleaned gas outputs from the gas cleaning plant

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[2] Professor Andrew Porteous, Department of Environmental and Mechanical Engineering, The Open University, Chairman of the Chartered Institution of Wastes Management Thermal Treatment Special Interest Group which authored The Chartered Institution of Wastes Management (2003), Energy from Waste: A Good Practice Guide.

[3] Defra: Pollution Prevention and Control: The Waste Incineration Directive http://www.defra.gov.uk/Environment/ppc/wasteincin/index.htm

are dispersed into the atmosphere via an exhaust stack (also called a chimney). There are strict levels of gas cleaning performance that must be adhered to, which are outlined in the WID and the operating permit issued by the Environment Agency.

In addition to this complex pollution control, urea or ammonia is injected into the furnace to reduce nitrogen oxides to nitrogen (known as selective non-catalytic reduction). Dioxins and heavy metals are adsorbed onto a surface of activated carbon, which is then removed by the scrubbers and bag-house filters. All residues and outputs from this gas cleaning process are typically disposed of at a licensed hazardous waste landfill site.

A non-combustible fraction and the bottom ash is discharged from the end of the grate into a water quench pit from where it is removed for further treatment and recovery, for example, as an aggregate in construction, or disposal to landfill. The WID states that this bottom ash must have less than 3% unburned carbon by weight. In addition, the majority of UK operating facilities typically recover both ferrous (magnetic) and non-ferrous (non-magnetic) metals from the bottom ash after the thermal treatment; however, they may also be removed (though generally the quality of the material is poor) at the start of the process when the waste enters the reception hall.

EfW is based on combustion and therefore relies on waste inputs with sufficient calorific value (CV) to burn (approximately greater than nine Mega Joules per kilogram). CV is the thermal units contained in one unit of a substance and released when the substance is burned. EfW facilities also rely on a constant input of waste with a sufficient CV to be treated. Other materials with high calorific values such as wood and card are also beneficial to the EfW process whereas ‘wetter’ materials such as food and garden waste have a lower CV that is less suitable for maximising the efficiency of this technology. An EfW can accept a variety of different residual waste streams, not just municipal, but also commercial and industrial wastes. This is because the combustion process can accept a wide range of calorific values of input material.

A typical EFW plant generates electricity from waste with an efficiency of around 22-25% (compared with a coal-fired plant at approximately 35%). Taking into account the energy required to operate the plant itself, a typical rule of thumb is that approximately 500 kilowatts per hour of electricity can be generated (net) from one tonne of waste. However, if district heating/CHP systems are incorporated into the plant design, energy generation efficiencies of >85% may be possible.

EfW facilities operating in the UK

“There are over 1,000 grate and furnace based incineration of EfW plants in operation worldwide,”[4] in the UK there are more than 20 treating residual municipal waste. The UK has a long history and considerable experience in building and operating EfW facilities, some of which are described in the table below.

Site	Type	Start-up year (approx)	Approximate throughput (tonnes per annum)
Edmonton, North London	EfW (45MW_e)	1970	550,000
Bernard Road, Sheffield	EfW CHP	1970	80,000

[4] The Chartered Institution of Wastes Management (2003), Energy from Waste: A Good Practice Guide.

Site	Type	Start-up year (approx)	Approximate throughput (tonnes per annum)
Eastcroft, Nottingham	EfW CHP	1974	150,000
Coventry & Solihull	EfW (17.7MW_e) CHP (9MW_e)	1974	270,000
Raikes Lane, Bolton	EfW	2000 (refurb)	130,000
SELCHP, Lewisham	EfW (30MW_e)	1994	420,000
Tyseley, Birmingham	EfW (25MW_e)	1996	350,000
Stoke Sideway, Stoke on Trent	EfW (13MW_e)	1997	200,000
Lerwick, Shetland	Heat	1998	26,000
Baldovie plant, Dundee	EfW Solid Recovery Fuel - Fluidised bed (8MW_e)	1999	120,000
Haverton Hill, Billingham, Cleveland	EfW (20MW_e)	1998	245,000
Dudley	EfW (6MW_e)	1998	90,000
Wolverhampton	EfW (8MW_e)	1998	110,000
Kirklees	EfW (11MW_e) with future CHP	2002	136,000
Slough Trading Estate	Solid Recovery Fuel CHP	2003	110,000
Chineham, Basingstoke	EfW (8MW_e)	2003	90,000
Grimsby, North East Lincolnshire	EfW (3MW_e) CHP (3MW_e) Rotary kiln	2004	56,000
Isle of Man	EfW	2005	65,000
Marchwood, Southampton	EfW (14MW_e)	2006	165,000
Havant, Portsmouth	EfW (14MW_e)	2006	165,000
Allington, Kent	EfW (40MW_e)	2007	500,000
Lakeside, Colnbrook, Slough	EfW (36MW_e)	2008	400,000

Please note that this is not an exhaustive list. This list has been developed from publicly available reports, and from industry sources. This list may not reflect the precise current information.

Further Sources of Information

Department of Environment, Food and Rural Affairs (2005). Introductory Guide: Options for the Diversion of Biodegradable Municipal Waste from Landfill
http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/introductoryguide_bmw.pdf

Department of Environment, Food and Rural Affairs (2005). Advanced Thermal Treatment of Municipal Solid Waste
http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/advancedthermaltreat.pdf

The Chartered Institution of Wastes Management (2003), Energy from Waste: A Good Practice Guide
http://www.ciwm.co.uk/iwm-pubs/itm01805.htm

The Environment Agency's Waste Technology Data Centre
www.environment-agency.gov.uk/wtd

Chartered Institution of Wastes Management
http://www.ciwm.co.uk

European Commission Directorate General; Joint Research Centre on Performance, Reliability and Emissions Reduction in Waste Incinerators (PREWIN).
http://prewin.jrc.nl/index.htm

Pollution Prevention and Control: The Waste Incineration Directive
http://www.defra.gov.uk/Environment/ppc/wasteincin/index.htm

Option 2: Biological Mechanical Treatment with 3rd Party Thermal Treatment of SRF (Solid Recovery Fuel) and In-Vessel Composting of waste derived compost

Biological Mechanical Treatment

BMT refers to an arrangement of biological and mechanical processes used to treat waste.

The incoming residual municipal waste is tipped into a reception hall, from where cranes feed the waste into shredders. The shredded fraction is then stored in a storage pit from which cranes load the waste in continuous windrows (piled into rows), which can be up to 5m high. The biological drying stage takes place in an environmentally controlled enclosed hall that has underflow air vents.

Air is passed through the waste, which draws moisture away, before being fed through a bio-filter to remove odours before discharging to the atmosphere. This flow of air increases the fermentation (the breakdown of organic matter) of the waste and temperatures of 50-60°C can be reached. Computer systems are used to control the airflow to maintain this temperature. Typically this bio-drying process takes 12-15 days. At the end of this period, the mass of the windrows will be reduced by approximately 25% and the waste will be more stabilised than in the reception hall and emit significantly less odour.

The next step in the process is to refine the biologically treated material. The material is separated into five fractions by using a combination of mechanical processes such as sieving; weight separation and metal extraction.

The largest fraction (by volume) that is recovered is a Solid Recovery Fuel (SRF), which can be utilised as a fuel in a third party facility, for example, cement kiln. A waste derived organic fraction can be sent to an in-vessel composting facility for further processing and stabilisation. A glass and grit residue fraction is typically disposed of to landfill; and ferrous (magnetic) metals and non-ferrous (non-magnetic) metals are recovered with an overband magnet and an eddy current separator for reprocessing.

In-Vessel Composting

IVC is a process that speeds up the natural degradation of organic material in an enclosed environment, but with oxygen present where both temperature and moisture are controlled to improve the efficiency of the composting process.

The waste derived organic fraction from the biological process is pre-screened before the in-vessel composting (IVC) process takes place. A small quantity of pre-screening residue is disposed to landfill, for example, stones and plastic bags.

The remaining fraction is wetted to create a more homogeneous, moist material that will improve the efficiency of the composting process.

An IVC facility can be constructed in a variety of shapes and sizes, for example, tunnels, clamps, silos, pods[5].

The particular technology modelled was based on a clamp system, with a three-sided steel clamp and entry door, enclosed by retractable roofing. The waste derived organic fraction is mechanically loaded into the composting clamp. Once the clamp is full, the door is closed and the roofing is bought into place to enclose the material in the clamp.

Temperature probes are then inserted to allow the monitoring of the composting process. Fresh air is passed upwards through the composting material. Exhaust fans

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[5] The Composting Association http://www.compost.org.uk/

suck the air out of the clamps and pass it through a biological filter to reduce odour emissions.

To ensure compliance with the Animal Bi-Product Regulations[6] the organic fraction must be maintained at a temperature of at least 60°C for a minimum of two days. It must also undergo a two stage barrier process, where the material is completely removed from one clamp and placed in a second clamp for a further period of composting, again reaching at least 60°C for a minimum of two days. In total the material will reside within the clamps for approximately 10 to 14 days.

Depending on the market outlet the composted product is removed from the clamps, screened (or graded) to reduce size and to remove any contaminants like plastic, glass and stones, which are landfilled. Any oversized or poorly composted material can be fed back into the start of the process for further composting. The product can then be moved to an outdoor area of hard standing for further degradation and stabilisation, this is called maturation.

After testing for pathogen content the compost product can then be used for a variety of purposes, for example, directly as landfill cover, for landscaping, or if from a source segregated collection for use as an agricultural product or soil improver.

3rd Party Thermal Treatment

The SRF that is mechanically separated following the biological process can be sent to a third party thermal treatment facility to utilise or recover the energy content. The circulation of air during the biological process draws away the moisture from the waste. During this aerobic fermentation process the most easily decomposed portion of the organic waste is completely oxidised. The remaining organic fractions, which are strongly dehydrated, contribute to the increased calorific value (CV) of the processed fraction. The CV is essentially a measure of how much energy a material contains, which is typically between 15 Mega Joules per kilogram (MJ/kg) and 18 MJ/kg of SRF. This represents an increase in energy content of between 50% and 100% when compared to the wetter residual municipal waste that enters the reception hall, hence the benefits for thermally treating the SRF to recover its energy.

[6] Defra: Animal By-Products http://www.defra.gov.uk/animalh/by-prods/default.htm

The UK has limited track record in constructing and operating BMT facilities. The technology has long been operated in Europe, notably in Italy, Germany and Austria.

Biological Mechanical Treatment facilities operating in the UK

Authority	Start-up year (approx)	Approximate throughput (tonnes per annum)
East London	2006	Two facilities (one still under construction); each 180,000
Dumfries and Galloway	2006	60,000 (under construction)

In-Vessel Composting facilities operating in the UK

The UK has successfully constructed and operated IVC facilities. There are approximately 100 sites operating similar IVC type technologies across the UK, a selection of which are described in more detail in the table below.

Authority	Start-up year (approx)	Approximate throughput (tonnes per annum)
Isle of Wight	1999	20,000
Aberdeenshire	2001	32,000
Aberdeenshire	2001	20,000
Bromley	2001	1,500
Manchester	2003	8,500
East Cambridgeshire	2004	40,000
Buckinghamshire	2004	15,000
Merseyside	2005	11,000
Magherafelt	2005	8,000
Somerset	2005	25,000
North London	2006	50,000
Dimmer, Castle Cary	????	35,000

Please note that this is not an exhaustive list. This list has been developed from publicly available reports, and from industry sources. This list may not reflect the precise current information.

Further Sources of Information

Department of Environment, Food and Rural Affairs (2005). Introductory Guide: Options for the Diversion of Biodegradable Municipal Waste from Landfill
http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/introductoryguide_bmw.pdf

Department of Environment, Food and Rural Affairs (2005). Advanced Thermal Treatment of Municipal Solid Waste
http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/advancedthermaltreat.pdf

The Chartered Institution of Wastes Management (2003), Energy from Waste: A Good Practice Guide http://www.ciwm.co.uk/iwm-pubs/itm01805.htm

The Environment Agency's Waste Technology Data Centre
www.environment-agency.gov.uk/wtd

Mechanical Biological Treatment and Mechanical Heat Treatment of Municipal Solid Waste 2005
http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/mechbiotreat.pdf

Advanced Biological Treatment of Municipal Solid Waste 2005
http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/advancedbiotreat.pdf

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

WRAP Organics website http://www.wrap.org.uk/materials/organics/

Chartered Institution of Wastes Management http://www.ciwm.co.uk

Juniper Consultancy Ltd for Sita Environmental Trust (2005), Mechanical Biological Treatment: A Guide for Decision Makers, Processes, Policies and Markets http://www.sitaenvtrust.org.uk/research/overview

Option 3: Mechanical Biological Treatment with 3rd Party Thermal Treatment of SRF (Solid Recovery Fuel) and landfill of stabilised output

The MBT process is similar to the BMT process described in Option 2, but in this case the waste is mechanically treated first and then biologically treated.

Essentially any metals, plastics, paper are mechanically recovered with fine fractions going to a composting process. Any oversized rejects are also removed for disposal to landfill.

The delivered MSW residual waste will arrive in a reception hall where grab cranes load conveyors with waste which passes through a bag splitter and then on through to a 10m long rotating trommel screen which separates the waste into materials according to size and shape.

The trommel screen is a huge drum with holes in it, like a giant washing machine drum. The turning of the drum creates centrifugal force, which throws larger materials away from the centre. The trommel (drum) can have holes of different sizes to allow different materials to fall through at different points), which separates the waste into fractions. The less than 80mm fraction will fall through the trommel screen and is conveyed into a composting hall.

Ferrous (magnetic) metals such as steel cans are recovered from the fine fraction using an overband magnet, simply a huge continuous magnetic belt which hangs over the conveyor belt, lifting off the ferrous metals and dropping them into an open top container below. Non-ferrous (non-magnetic) metals, such as aluminium cans, are recovered by an eddy current separator which uses a special rotating magnet to fire non-ferrous metals off the conveyor belt into an open topped container below.

The larger material >80mm exits the back of the trommel screen and is conveyed to another separating machine called a ballistic separator, which further sorts the oversize material by size, shape and by density, producing a two more fractions; rolling heavy fraction and flat light fraction. Typical constituents for the two fractions are detailed below.

Rolling heavy fraction:

- Stones (natural, brick stone)
- Wooden pieces
- Pieces of plywood
- Steel profiles
- Massive pieces of plastic
- Sheet steel containers
- Solid plastic containers
- Partly electric scrap

Flat light fraction:

- Foils
- Textiles
- Tissue
- Paper
- Cardboard (flattened)
- Fibrous materials (mats, cords, carpets)

A ballistic separator comprises rotating paddles arranged parallel to each other and graduated one after the other in 120° steps. The inclination of the paddles is adjustable. According to the application, the surface of the paddles will be closed or perforated. The paddle length is also variable within a certain limit. Due to the range of adjustment possibilities the separator can be specifically adapted to the feed material and the requirements of the outputs.

Again ferrous and non-ferrous metals are recovered from the ballistic separator output. Some plastics, such as drinks and milk bottles can be recovered through an optical separation process, which uses light to identify plastics and air jets to blast off recoverable plastics into a container. A Solid Recovery Fuel (SRF) can be recovered, primarily formed of paper and plastic, which can be sent to a third party facility to be used as a fuel, for example, a cement kiln.

In the composting hall the less than 80mm fraction is loaded into parallel windrows through which air is sucked vertically down from top to bottom. This material is turned automatically by a system which is essentially a large overhead bucket wheel and conveyor system. This system incorporates a compost irrigation process utilising re-circulated leachate from within the composting hall to improve the efficiency of the composting process. The whole process takes about six weeks in the hall during which time the turning system will turn and process each bay of compost at least five times, moving the windrows progressively down the hall i.e. new waste enters the hall at one end and is progressively moved along the hall before finally being extracted at the other end of the hall. The hall could be 150m long and 50m wide.

The gases generated during the composting process are collected by a suction system and passed through a scrubber and bio-filter before being emitted to the atmosphere. The resulting output is a stabilised fraction which is disposed of to landfill or used for landfill restoration, although the material may still have approximately 25-40% biodegradable content. Achieving a more 'beneficial use' for the output material, for example, for land improvement, is subject to restrictions under the Waste Management Licensing Regulations[7].

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[7] Regulations can be accessed at: http://www.opsi.gov.uk/si/si1994/Uksi_19941056_en_1.htm and information on the 2006 consultation on the source segregation requirement in Paragraph 7A of Schedule 3 of the Regulations can be accessed at:http://www.defra.gov.uk/ENVIRONMENT/WASTE/management/index.htm

Mechanical Biological Treatment plants operating in the UK

The UK has limited track record in constructing and operating MBT facilities. The technology has long been operated in Europe, notably in Italy, Germany and Austria.

Authority	Start-up year (approx)	Approximate throughput (tonnes per annum)
Dorset	2006	~30,000
Byker, Newcastle and Ellington, Northumberland	2006	120,000 through the Byker mechanical separation process. The biological process takes place at Ellington.

In-Vessel Composting facilities operating in the UK

The UK has successfully constructed and operated IVC facilities. There are approximately 100 sites operating similar IVC type technologies across the UK, a selection of which are described in more detail in the table below.

Operational UK In-Vessel Composting Plants		
Authority	Start-up year (approx)	Approximate throughput (tonnes per annum)
Isle of Wight	1999	20,000
Aberdeenshire	2001	32,000
Aberdeenshire	2001	20,000
Bromley	2001	1,500
Manchester	2003	8,500
East Cambridgeshire	2004	40,000
Buckinghamshire	2004	15,000
Merseyside	2005	11,000
Magherafelt	2005	8,000
Somerset	2005	25,000
North London	2006	50,000
Dimmer, Castle Cary	????	35,000

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http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/introductoryguide_bmw.pdf

Department of Environment, Food and Rural Affairs (2005). Mechanical Biological Treatment and Mechanical Heat Treatment of Municipal Solid Waste
http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/mechbiotreat.pdf

Department of Environment, Food and Rural Affairs (2005). Advanced Biological Treatment of Municipal Solid Waste
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Juniper Consultancy Ltd for Sita Environmental Trust (2005), Mechanical Biological Treatment: A Guide for Decision Makers, Processes, Policies and Markets
http://www.sitaenvtrust.org.uk/research/overview

The Composting Association
www.compost.org.uk/

Option 4: Autoclave with Anaerobic Digestion of fibres

Autoclave

Autoclave is a technology that utilises steam injected into a sealed vessel under high pressure to 'clean' residual waste, soften plastics and to produce a fibrous organic rich material. This technology has been used for many years in hospitals to sterilise clinical materials and waste.

The residual municipal waste received in a reception hall is loaded into the autoclave unit, which is then sealed and rotation is started. An autoclave unit is generally a large metallic cylindrical vessel, which can look like a thermos flask. Typically, an autoclave, having a diameter of 2m to 2.5m and a length of 9m, would provide a processing capacity of approximately 5-8 tonnes of residual waste. Larger facilities with a length of 12m can provide a processing capacity in the region of 10-15 tonnes of residual waste at a time.

Steam, at around 160°C, is injected into the rotating vessel for a short period of time, approximately 30 minutes. This period may vary according to the composition of the residual municipal waste and the quantity/ density of waste present in the autoclave unit. The pressure is maintained to allow the process to fully sterilise the waste. After the treatment process has finished the steam flow is stopped and vented via a compressor, this allows atmospheric pressure to be reached inside the autoclave.

Following sterilisation the material is transferred to a 10m long rotating trommel screen (this is a huge drum with holes in it, like a giant washing machine drum). The turning of the drum creates centrifugal force, which throws mixed recyclable material away from the centre. The trommel (drum) can have holes of different sizes to allow different materials to fall through at different points), which separates the fine fibrous fraction and the residue glass and grit fraction from the bulk of the recoverable recyclable (plastics and metals) material. This fraction is separated further using an air classifier, which uses air to separate the lighter fibre fraction from the heavier glass and grit fraction. The fibres, which comprise approximately 70% by weight of the input waste, have a number of potential applications; in this option using anaerobic digestion to further treat it.

The metals from the oversized fraction from the trommel separation are recovered. Ferrous (magnetic) metals such as steel cans are recovered from the fine fraction using an overband magnet, simply a huge continuous magnetic belt which hangs over the conveyor belt, lifting off the ferrous metals and dropping them into an open top container below. Non-ferrous (non-magnetic) metals, such as aluminium cans, are recovered by an eddy current separator which uses a special rotating magnet to fire non-ferrous metals off the conveyor belt into an open topped container below.

Some plastics, such as drinks and milk bottles can be recovered through an optical separation process, which uses light to identify plastics and air jets to blast off recoverable plastics into a container.

All other remaining fine residual fractions and non-recoverable materials would be disposed to landfill.

Anaerobic Digestion of fibres

Anaerobic digestion is the biological breakdown of waste fractions in the absence of oxygen (anaerobic).

The fibre output from the autoclave where it is mixed with process water to produce slurry, which is placed into an anaerobic digester unit, which is a sealed, airless container.

The conditions are controlled for anything between 10-25 days in the digester (the typical retention time is 18 days in the anaerobic digestion tanks), where a mechanical stirrer ensures there is maximum contact between the microbes and the waste. The material in the digester heats up due to microbial activity, and temperatures are generally between 50°C and 60°C (the 2005 Animal-By Product Regulations state that the slurry must be pasteurised at 70°C for 1 hour[8]). The organic rich fibres then ferment and produce a methane rich biogas and an organic digestate by-product. This is the result of decomposition of the fibre by bacteria within the digester.

The biogas generated can be utilised to produce renewable energy to power the process and to export electricity to the national grid. The excess heat from the electricity generators is utilised to warm the process water. In addition to income from selling electricity to the National Grid, this renewable energy production also qualifies for additional Government grants in the form of Renewable Obligation Certificates (ROCs)[9].

The digestate by-product from the digestion process, which contains bio-solids and a liquid, can be used as a bio-fertiliser or alternatively the bio-solids can be dewatered and treated aerobically (in the presence oxygen). If so, the resultant solid digestate fraction can then be used as a soil conditioner or in agriculture. The filtrate resulting from any dewatering stages is rich in organic compounds and may be either recirculated through the process, or could be used as a fertiliser.

Autoclave facilities in the UK

The UK has limited track record in constructing and operating autoclave facilities for the processing of residual municipal waste. A small number of suppliers are marketing their technologies and three 100,000 tonnes per annum facilities are progressing through the planning process in Herefordshire and Worcestershire.

Anaerobic Digestion facilities operating in the UK, processing materials derived from residual municipal waste

The UK has limited experience in operating anaerobic digestion facilities for processing materials derived from residual municipal waste. The UK does, however, have a good track record in using anaerobic digestion, particularly in the sewerage and farming/ food industries.

Authority	Start-up year (approx)	Approximate throughput (tonnes per annum)
Leicester	2005	40,000
Shropshire *	2006	5,000
The Western Isles, Scotland **	2006	21,000

* This AD plant is a Defra New Technologies Demonstrator Programme pilot plant.[10]
** This AD plant is undergoing commissioning and testing (December 2006).

Please note that this is not an exhaustive list. This list has been developed from publicly available reports, and from industry sources. This list may not reflect the precise current information.

Further Sources of Information

[8] Defra: Animal By-Products http://www.defra.gov.uk/animalh/by-prods/default.htm
[9] DTI: The Renewables Obligation http://www.dti.gov.uk/energy/sources/renewables/policy/renewables-obligation/page15630.html
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The Environment Agency's Waste Technology Data Centre
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Department of Trade and Industry: The Renewables Obligation
http://www.dti.gov.uk/energy/sources/renewables/policy/renewables-obligation/page15630.html

Option 5: Mechanical Treatment with 3rd Party Thermal Treatment of SRF (Solid Recovery Fuel) and Anaerobic Digestion of waste derived compost with final maturation of digested compost product

Mechanical treatment of residual municipal waste is the mechanical separation of the waste into different fractions for further processing.

There are a variety of mechanical separation treatments in operation, for example, simple hand picking, trommel screen separation, magnetic separation, eddy current separation, air classification, density separators, and gravity separation. The ball mill method is another mechanical separation process which was modelled in this option.

The residual municipal waste is deposited in an enclosed waste reception hall by delivery vehicles. Waste is transferred from the reception hall to the ball mill by a conveyor and vibrating screen to ensure a continuous, even flow and spread of residual waste into the ball mill. A ball mill is a large rotating cylindrical mill that contains steel balls that crush the input residual municipal waste. The mill rotates at a relatively low speed of approximately 3m per second.

Steel balls with a diameter of 100-120mm are used as the grinding media in the ball mill, which rotates to impact maximum grinding/pulverising potential on the waste to break it down into easier to separate components so that downstream sorting and separation processes can work with higher efficiency. Interestingly, any large or heavy metal objects remain in the ball mill and act as additional grinding media.

A rotating trommel screen sorts the ball mill outputs into two fractions, a less than 40mm fraction and a greater than 40mm fraction.

A long rotating trommel screen is a huge drum with holes in it, like a giant washing machine drum. The turning of the drum creates centrifugal force, which throws mixed recyclable material away from the centre. The trommel (drum) can have holes of different sizes to allow different materials to fall through at different points), which separates the fine fibrous fraction and the residue glass and grit fraction from the bulk of the recoverable recyclable (plastics and metals) material. This fraction is separated further using an air classifier, which uses air to separate the lighter fibre fraction from the heavier glass and grit fraction. The fibres, which comprise approximately 70% by weight of the input waste, have a number of potential applications; in this option using anaerobic digestion to further treat it.

The undersize material from the trommel screen is further separated to produce two streams, a fine (<5mm) organic rich material stream, and an oversize material stream (5-40mm). The fine material will be fed into an anaerobic digestion process, and the oversize material can be processed further to produce an SRF using an air classifier and ballistic conveyor to separate the high calorific value material from residual matter (which will be landfilled).

The metals from the oversized fraction from the trommel separation are recovered. Ferrous (magnetic) metals such as steel cans are recovered from the fine fraction using an overband magnet, simply a huge continuous magnetic belt which hangs over the conveyor belt, lifting off the ferrous metals and dropping them into an open top container below. Non-ferrous (non-magnetic) metals, such as aluminium cans, are recovered by an eddy current separator which uses a special rotating magnet to fire non-ferrous metals off the conveyor belt into an open topped container below.

The trommel screen also sorts larger materials greater than 40mm, with a higher calorific value. The separation of these heavier fraction materials (40 to 80mm) uses a ballistic separator which further sorts the oversize material by size, shape and by density, producing a two more fractions; a rolling heavy fraction and flat light fraction. Typical constituents for the two fractions are detailed below.

Rolling heavy fraction:	Flat light fraction:
• Stones (natural, brick stone)	• Foils

- Wooden pieces
- Pieces of plywood
- Steel profiles
- Massive pieces of plastic
- Sheet steel containers
- Solid plastic containers
- Partly electric scrap
- Textiles
- Tissue
- Paper
- Cardboard (flattened)
- Fibrous materials (mats, cords, carpets)

A ballistic separator comprises rotating paddles arranged parallel to each other and graduated one after the other in 120° steps. The inclination of the paddles is adjustable. According to the application, the surface of the paddles will be closed or perforated. The paddle length is also variable within a certain limit. Due to the range of adjustment possibilities the separator can be specifically adapted to the feed material and the requirements of the outputs.

Anaerobic Digestion

Anaerobic digestion is the biological breakdown of waste fractions in the absence of oxygen (anaerobic).

The separated waste derived material (<5mm) mainly consists of an organic fraction, sand and other harmful material (such as glass and plastics). This material is mixed with process water to separate out the unwanted solids and to produce slurry, which is placed into an anaerobic digester unit, which is a sealed, airless container.

The conditions are controlled for anything between 10-25 days in the digester (the typical retention time is 18 days in the anaerobic digestion tanks), where a mechanical stirrer ensures there is maximum contact between the microbes and the waste. The material in the digester heats up due to microbial activity, and temperatures are generally between 50°C and 60°C (the 2005 Animal-By Product Regulations state that the slurry must be pasteurised at 70°C for 1 hour[11]). The organic rich fibres then ferment and produce a methane rich biogas and an organic digestate by-product. This is the result of decomposition of the fibre by bacteria within the digester.

The biogas generated can be utilised to produce renewable energy to power the process and to export electricity to the national grid. The excess heat from the electricity generators is utilised to warm the process water. In addition to income from selling electricity to the National Grid, this renewable energy production also qualifies for additional Government grants in the form of Renewable Obligation Certificates (ROCs)[12].

The digestate by-product from the digestion process, which contains bio-solids and a liquid, can be used as a bio-fertiliser or alternatively the bio-solids can be dewatered and treated aerobically (in the presence oxygen). If so, the resultant solid digestate fraction can then be used as a soil conditioner or in agriculture. The filtrate resulting from any dewatering stages is rich in organic compounds and may be either recirculated through the process, or could be used as a fertiliser.

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[11] Defra: Animal By-Products http://www.defra.gov.uk/animalh/by-prods/default.htm

[12] DTI: The Renewables Obligation http://www.dti.gov.uk/energy/sources/renewables/policy/renewables-obligation/page15630.html

Anaerobic Digestion facilities operating in the UK, processing materials derived from residual municipal waste

The UK has limited experience in operating anaerobic digestion facilities for processing materials derived from residual municipal waste. The UK does, however, have a good track record in using anaerobic digestion, particularly in the sewerage and farming/ food industries.

Authority	Start-up year (approx)	Approximate throughput (tonnes per annum)
Leicester	2005	40,000
Shropshire *	2006	5,000
The Western Isles, Scotland **	2006	21,000

* This AD plant is a Defra New Technologies Demonstrator Programme pilot plant.[13]
** This AD plant is undergoing commissioning and testing (December 2006).

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Further Sources of Information

Department of Environment, Food and Rural Affairs (2005). Introductory Guide: Options for the Diversion of Biodegradable Municipal Waste from Landfill
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http://www.wrap.org.uk/materials/organics/

Chartered Institution of Wastes Management

[13] http://www.defra.gov.uk/environment/waste/wip/newtech/index.htm

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Juniper Consultancy Ltd for Sita Environmental Trust (2005), Mechanical Biological Treatment: A Guide for Decision Makers, Processes, Policies and Markets http://www.sitaenvtrust.org.uk/research/overview

Option 6: Autoclave followed by Gasification of Fibres

Autoclave

Autoclave is a technology that utilises steam injected into a sealed vessel under high pressure to 'clean' residual waste, soften plastics and to produce a fibrous organic rich material. This technology has been used for many years in hospitals to sterilise clinical materials and waste.

The residual municipal waste received in a reception hall is loaded into the autoclave unit, which is then sealed and rotation is started. An autoclave unit is generally a large metallic cylindrical vessel, which can look like a thermos flask. Typically, an autoclave, having a diameter of 2m to 2.5m and a length of 9m, would provide a processing capacity of approximately 5-8 tonnes of residual waste. Larger facilities with a length of 12m can provide a processing capacity in the region of 10-15 tonnes of residual waste at a time.

Steam, at around 160°C, is injected into the rotating vessel for a short period of time, approximately 30 minutes. This period may vary according to the composition of the residual municipal waste and the quantity/ density of waste present in the autoclave unit. The pressure is maintained to allow the process to fully sterilise the waste. After the treatment process has finished the steam flow is stopped and vented via a compressor, this allows atmospheric pressure to be reached inside the autoclave.

Following sterilisation the material is transferred to a 10m long rotating trommel screen (this is a huge drum with holes in it, like a giant washing machine drum). The turning of the drum creates centrifugal force, which throws mixed recyclable material away from the centre. The trommel (drum) can have holes of different sizes to allow different materials to fall through at different points), which separates the fine fibrous fraction and the residue glass and grit fraction from the bulk of the recoverable recyclable (plastics and metals) material. This fraction is separated further using an air classifier, which uses air to separate the lighter fibre fraction from the heavier glass and grit fraction. The fibres, which comprise approximately 70% by weight of the input waste, have a number of potential applications; in this option using a thermal treatment gasification facility to further treat it.

The metals from the oversized fraction from the trommel separation are recovered. Ferrous (magnetic) metals such as steel cans are recovered from the fine fraction using an overband magnet, simply a huge continuous magnetic belt which hangs over the conveyor belt, lifting off the ferrous metals and dropping them into an open top container below. Non-ferrous (non-magnetic) metals, such as aluminium cans, are recovered by an eddy current separator which uses a special rotating magnet to fire non-ferrous metals off the conveyor belt into an open topped container below.

Some plastics, such as drinks and milk bottles can be recovered through an optical separation process, which uses light to identify plastics and air jets to blast off recoverable plastics into a container.

All other remaining fine residual fractions and non-recoverable materials would be disposed to landfill.

Gasification

Gasification is the thermal breakdown of hydrocarbons into a syngas by carefully controlling the amount of oxygen present.

Fibres from the autoclave process are fed into a gasification chamber, which is at a temperature of between 800°C and 1,200°C. This is an exothermic reaction, meaning that the temperature can be self-sustained by the reaction. Oxygen is added but the amount is not sufficient enough to allow the char to be completely oxidised and full combustion to occur.

The main product is a syngas, which contains carbon monoxide, hydrogen and methane. This syngas can be burnt to produce renewable electricity through a steam turbine to power the process and to export electricity to the national grid. In addition to income from selling electricity to the National Grid, this renewable energy production also qualifies for additional Government grants in the form of Renewable Obligation Certificates (ROCs)[14].

The other product is a solid, non-combustible fraction (an ash like residue) which is typically disposed to landfill.

Autoclave facilities in the UK
The UK has limited track record in constructing and operating autoclave facilities for the processing of residual municipal waste. A small number of suppliers are marketing their technologies and three 100,000 tonnes per annum facilities are progressing through the planning process in Herefordshire and Worcestershire.

Gasification facilities in the UK
The UK has limited track record in constructing and operating gasification facilities for the processing of residual municipal waste. The UK does have experience in applying this technology in other industries, notably in processing coal. There is, however, considerable experience in this type of technology in Japan, with a large number of facilities and operators processing residual municipal waste. To a lesser extent a small number of facilities operate in Scandinavia. A few facilities are being progressed in the UK and these are detailed below.

Authority	Anticipated Start-up year (approx)	Approximate throughput (tonnes per annum)
Dagenham	2008	90,000
Isle of Wight	2008	30,000
Seamer Carr, Scarborough	2008	unknown

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The Environment Agency's Waste Technology Data Centre www.environment-agency.gov.uk/wtd

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[14] DTI: The Renewables Obligation
http://www.dti.gov.uk/energy/sources/renewables/policy/renewables-obligation/page15630.html

Chartered Institution of Wastes Management http://www.ciwm.co.uk

Department of Trade and Industry: The Renewables Obligation
http://www.dti.gov.uk/energy/sources/renewables/policy/renewables-obligation/page15630.html

Option 7: Pyrolysis/Gasification (with fuel preparation)

The residual municipal waste in this option is firstly put through a mechanical treatment process, which prepares the waste for use as a fuel, typically producing a homogenous sized material to improve combustion efficiency. A small quantity of residues may result from this process, which are unsuitable for thermal treatment and would therefore be disposed of to landfill. The remaining prepared fuel fraction is the feedstock for the thermal treatment process.

The process modelled for the West of England Partnership is based on a two stage thermal treatment process where waste is first pyrolysed and then gasified. A description of both stages is presented below.

Pyrolysis

Pyrolysis is the thermal degradation of residual municipal waste in the absence of air to produce a solid fraction and syngas.

After the preparation of the residual municipal waste as a fuel, it is fed into the pyrolysis chamber, which is at a medium temperature between 400-700°C. This is an endothermic reaction, meaning that an external heat source is required to maintain the temperature. Here the thermal decomposition of the organic fraction of the waste results in the formation of a process gas (syngas) and a solid fraction (sometimes described as char). Char is a combination of non-combustible materials and carbon. The ferrous and non-ferrous metal components can be recovered for re-manufacture. The condensable fraction of the syngas can be collected by cooling, potentially for use as a liquid fuel. The remaining char residue can be further treated in the gasification process. The solid non-combustible fraction (an ash like residue) resulting from this process is typically disposed to landfill.

Gasification

Gasification is the thermal breakdown of hydrocarbons into a syngas by carefully controlling the amount of oxygen present.

The remaining char residue from the pyrolysis process is fed into a gasification chamber, which is at a temperature of between 800°C and 1,200°C. This is an exothermic reaction, meaning that the temperature can be self-sustained by the reaction. Oxygen is added but the amount is not sufficient enough to allow the char to be completely oxidised and full combustion to occur. The main product is syngas, which contains carbon monoxide, hydrogen and methane. This is burnt to produce renewable electricity through a steam turbine to power the process and to export to the national grid. In addition to income from selling energy to the National Grid, this renewable energy production also qualifies for additional Government grants in the form of Renewable Obligation Certificates (ROCs)[15].

The other product is a solid, non-combustible fraction (an ash like residue) which is typically disposed to landfill.

A pyrolysis plant is in development at Avonmouth, Bristol and should be operational by the third quarter of 2008. This will be a demonstration plant which will process 34,000 tonnes per annum of Bristol's residual waste. The plant received support from the Defra New Technologies Demonstrator Programme and Bristol City Council.

Pyrolysis/ Gasification facilities in the UK
The UK has limited track record in constructing and operating pyrolysis/ gasification facilities for the processing of residual municipal waste. The UK does have

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[15] DTI: The Renewables Obligation
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experience in applying these technologies in other industries, notably in processing coal. There is, however, considerable experience in this type of technology in Japan, with a large number of facilities and operators processing residual municipal waste. To a lesser extent a small number of facilities operate in Scandinavia. A few facilities are being progressed in the UK and these are detailed below.

Location	Anticipated Start-up year (approx)	Approximate throughput (tonnes per annum)
Bristol	2008	30,000
Dagenham	2008	90,000
Isle of Wight	2008	30,000
Seamer Carr, Scarborough	2008	unknown

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