Annex E: Summary guidance on energy from waste (EfW) technology

1. The various EfW technologies, their different feedstocks, carbon emissions performance, and outputs are described in Table E.1 below.

2. This is intended to act as a guide to local authorities and others who are considering procurement options. As Chapter 5 of the Strategy states, **the Government wishes to encourage more consideration of the use of anaerobic digestion (AD) both by local authorities and businesses**. Such use would complement strong measures which are being taken to promote AD in farming, where it has benefits for manure and slurry management. In suitable circumstances, spare capacity may be available in on-farm AD plant to manage biowaste from the locality, as is common practice in Denmark. Our recent research[1] has suggested that AD has significant environmental benefits over other options for food waste and may be particularly cost effective for food waste[2] if separately collected. Although AD is currently a commonly used technology in some other European countries this is not the case here.

3. Apart from AD, the Government does not generally think it appropriate to express a preference for one technology over another, since local circumstances differ so much. Those making investment decisions should consider the information in this document and other information such as that which the Waste Infrastructure Delivery Programme (WIDP) can supply – and make their own decisions. It is not helpful to rule out a particular technology – such as incineration – in advance, since this unnecessarily restricts options and threatens to raise costs.

4. Although the Government is not generally expressing a preference for one type of technology over another for EfW, it does believe that any given technology is (where applicable) more beneficial if both heat and electricity can be recovered. Particular attention should therefore be given to the siting of plant to maximise opportunities for combined heat and power (CHP).

5. The table below attempts to assess the net greenhouse gas impacts of various energy from waste technologies. The carbon dioxide impacts are based on recent work by ERM[1] and WRAP[2]. In line with IPCC guidelines biogenic carbon dioxide emissions are not included in these calculations. The figures also include the impact of avoiding landfilling – i.e. they are the net carbon dioxide equivalent emissions that result from shifting waste from landfill into energy from waste technologies. They include the carbon dioxide impacts of transporting waste to the facility. They also count the carbon dioxide impacts offset through avoiding alternative generation electricity or heat. It is assumed the marginal alternative generation that would have been used is combined cycle gas turbine (CCGT).

6. Recycling is also very important to the numbers inthis table, with different treatments assumed to capture different amounts of recyclable material either prior to energy recovery or during the process (metals). This has a large impact on carbon benefits, as the carbon benefits of recycling metal in particular can be very large.

7. It should also be noted that impact estimates for mixed waste treatments are based on estimated average bundles of municipal waste. The composition of waste is very important to the carbon impact; of particular interest given the assumption on biogenic carbon dioxide is the balance of fossil carbon materials and biogenic material. Seperately collecting recyclables befor mixed waste is sent for energy recovery could heavily influence these results as shown in the MBT analysis.

8. Whilst the estimates presented below are therefore the best figures available to Defra at the time of publication they are only indicative and likely to require further refinement before more concrete recommendations can be made

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1 *Carbon Balances and Energy Impacts of the Management of UK Wastes*, ERM for Defra 2007 () and Impact of Energy from Waste and Recycling Policy on UK Greenhouse Gas Emissions, ERM for Defra 2006 (http://www.defra.gov.uk/environment/waste/strategy/pdf/ermreport.pdf)

2 *Dealing with Food Waste in the UK*, Eunomia for WRAP 2007 (http://www.wrap.org.uk/downloads/Dealing_with_Food_Waste_-_Final_-_2_March_07.c0ae9c0a.pdf)

3 *Environmental Benefits of Recycling: An international review of life cycle comparisons for key materials in the UK recycling sector* is available at www.wrap.org.uk/applications/publications

Table E.1: Energy from waste (EfW) technology matrix

Technology type	Process characteristics	Outputs	Typical carbon dioxide (CO_2)[a] and cost data[b]	Other considerations
Direct combustion (incineration) Typical scale is 100–500 kilo tonnes per annum (ktpa)	• Capable of handling a wide range of unsorted, mixed residual wastes • Range of technologies in use. Moving grate or rotary kiln designs are very flexible on waste input composition. Fluidised bed units are less so, typically needing to be fed with a refuse derived fuel (RDF) • Depending on the process, energy conversion efficiencies for residual municipal waste tend to be in the range of 20-28%, or up to 70% with combined heat and power (CHP) • Certain waste streams with high calorific value are also well suited for combustion with energy recovery, including waste wood, tyres and solvents	• Electricity, with potential for CHP • Metals and some bottom ash for recycling. Initial mechanical sorting of waste input can increase recovery of recyclables • **Residues** include non-recyclable bottom ash and fly ash, which is classed as hazardous waste	• The CO_2 impact of mixed incineration (with electricity generation) depends very heavily on the composition of waste put into the burner • In the current accounting framework, biogenic CO_2 is not counted because biodegradable wastes, in effect, act like a biofuel when incinerated – the carbon benefits occur as a result of offsetting fossil CO_2 energy elsewhere in the economy, and the avoidance of methane from landfilling • Where fossil fuel based products are incinerated (e.g. plastics) they tend to generate energy less efficiently than using fossil fuel directly, hence are associated with an overall carbon cost • Given estimates of the composition of municipal waste, incineration rsults in carbon savings of 232 kg CO_2 equivalent which is essentially the savings from diverting mixed MSW away from landfill • CHP, there will be greater fossil fuel displacement and hence there should be a net carbon benefit Costs: Plant size/capital/gate fees (2006/07) 1. 100 ktpa/£64.7 million/ £78.4 per tonne 2. 200 ktpa/£104.7 million/ £58.5 per tonne 3. 400 ktpa/£149.1 million/ £37.8 per tonne	• Proven, bankable technology but significant public perception issues can affect delivery • Needs to be part of a wider waste strategy to ensure that it does not limit more beneficial activities, such as waste prevention, re-use, recycling and composting • Emission controls must comply with the Waste Incineration Directive • CHP offers potential for greater energy efficiency (and associated CO_2 savings) and benefits to the local area through heat and energy provided. Reliable markets for heat are needed to maximise heat off take and thermal efficiency. Construction of the necessary heat distribution infrastructure will also increase capital costs Number operating in England:[c] • 18 municipal waste incinerators, 3 of which operate with CHP • There are also numerous small-scale incinerators dealing with specific waste streams and several larger merchant incinerators Support: • Electricity generated from the biomass fraction of mixed wastes in CHP plants is eligible for Renewables Obligation support, as is that generated from fuels over 90% biomass content

Table E.1: Energy from waste (EfW) technology matrix *(continued)*

Technology type	Process characteristics	Outputs	Typical carbon dioxide (CO_2)[a] and cost data[b]	Other considerations
Refuse derived fuel (RDF) or solid recovered fuel (SRF) derived from mechanical biological treatment (MBT) processes Typical scale for MBT input is 50–250 ktpa	• MBT processes pre-treat mixed residual wastes and can be configured to produce RDF as one of several possible outputs. RDF can also be produced by mechanical heat treatment (MHT) processes such as autoclave • RDF is a suitable input for a number of thermal treatment processes (e.g. fluidised bed incinerators, pyrolysis or gasification), and a potential fuel for a range of uses, including industrial processes and co-firing with biomass fuels or coal • RDF can give a greater energy yield per tonne than mixed wastes, although conversion efficiency will depend on the waste input, how it is processed and the energy recovery technology used. Energy use incurred in the separation of waste typically involves around 15–20% of the energy value of the waste	• RDF can be thermally treated to recover electricity, with potential for CHP. Other outputs and residues will depend on the technology used • MBT processes can increase the initial separation of materials for recycling, although these are likely to be of lower quality than source separated recyclables	• As with incineration, the composition of waste is highly influential on the net benefit of MBT–RDF • Including the benefit of recycling and using a standard mix of municipal waste MBT–RDF could reduce CO_2 emissions by up to 570 kg per tonne of waste diverted from landfill • If dry recyclables or biodegradable wastes are removed prior to the MBT–RDF treatment the benefits of this process are reduced, as there are fewer recycling benefits or a lower biodegradable element in the remaining fuel **Costs:** Plant size/capital/gate fees (2006/07) 1. 50 ktpa/£29.4 million/ £98.8 per tonne 2. 100 ktpa/£44.4 million/ £79.3 per tonne 3. 200 ktpa/£67.1 million/ £65.3 per tonne	• Emission controls for plant recovering energy from RDF must comply with the Waste Incineration Directive • MBT is a modular technology, offering flexibility in terms of scale, waste input and output streams – which can include RDF • The market for RDF in England is at an early stage of development. A European Standard for SRF is being developed, which should improve consistency and quality of this fuel and confidence among potential users **Number operating in England:**[c] • 4 MBT plants operating, one of which currently produces RDF • 6 more facilities opening by 2007/08, of which 4 may produce RDF **Support:** • Waste Implementation Programme (WIP) New Technologies Demonstrator Programme **Further information:** • WIP Guide: *Mechanical Biological Treatment and Mechanical Heat Treatment of Municipal Solid Waste*

Table E.1: Energy from waste (EfW) technology matrix *(continued)*

Technology type	Process characteristics	Outputs	Typical carbon dioxide (CO_2)[a] and cost data[b]	Other considerations
Anaerobic digestion Typical scale up to 250 ktpa	• Ideally suited to treating a variety of source-separated high moisture content biodegradable wastes, such as food and agricultural wastes. • Conversion efficiencies are typically 30–35% (electricity only), depending on feedstock, and up to 80% with CHP[d] • AD can also provide the biological stage of an MBT plant to treat the organic fraction from a mixed waste stream	• Electricity and/or heat from combustion of biogas produced • Potential to produce alternative energy sources, e.g. in the form of biofuel or hydrogen • Produces a solid and a liquid digestate. • **Residues** include any solid or liquid digestate that cannot be applied to land	• Using the mix of biodegradable wastes in the municipal waste stream, and assuming electricity generation only, the carbon benefits of anaerobic digestion (through offsetting fossil fuel electricity production) are calculated at 430 kg CO_2 per tonne of waste transferred from landfill to anaerobic digestion. Note that the estimates of the benefits of anaerobic digestion used are comparatively low by international standards so this may be a conservative estimate. Nb. There are also no additional benefits from recycling (e.g. metals from mixed wastes) as exist with other technologies **Costs:** Plant size/capital/gate fees (2006/07) 1. 20 ktpa/£7.3 million/ £65.4 per tonne 2. 50 ktpa/£14.7 million/ £52.5 per tonne 3. 150 ktpa/£28.8 million/ £37.9 per tonne	• Plant treating food wastes will need to meet Animal By-Products Regulation requirements • AD is a modular technology, offering flexibility of scale • Digestate from source-separated AD processes could be spread to land as a soil improver, subject to regulatory controls • Markets for digestate from MBT–AD processes are limited • AD can be used to stabilise organic waste prior to landfill. The degree of stabilisation will depend on feedstock composition and residence time **Number operating in England:**[c] • 3 AD plant treating source-separated biodegradable wastes, with 6 to be opened 2007/08 • No AD plant currently operate as the biological stage of MBT plant **Support:** • Household waste treated at an AD plant can count towards composting BVPI 82b • Electricity generated is eligible for Renewables Obligation support • WIP New Technologies Demonstrator Programme **Further information:** • WIP Guide: *Advanced Biological Treatment of Municipal Solid Waste*[e]

Table E.1: Energy from waste (EfW) technology matrix *(continued)*

Technology type	Process characteristics	Outputs	Typical carbon dioxide (CO_2)[a] and cost data[b]	Other considerations
Pyrolysis Typical scale is <10–225 ktpa Gasification Typical scale is 10–150 ktpa	• Mixed residual wastes, which may require some pre-treatment, e.g. to remove non-combustibles and/or excess moisture, or to reduce size by shredding • Conversion efficiencies of the processes are up to 30% (electricity only) and 70% with CHP	• Electricity and/or heat from combustion of syngas produced • Potential to produce alternative energy sources, e.g. in the form of biofuel or hydrogen • Metals and other materials for recycling • **Residues** include char (from pyrolysis), which can have further energy recovered from it, bottom ash (from gasification) and fly ash, which is classed as hazardous waste	• No data is held on carbon benefit of waste pyrolysis • Gasification is expected to save around 524 kg CO_2 per tonne waste diverted from landfill for an average bundle of municipal waste, which again includes the benefits of recycling, for example, metal contents **Costs:** Plant size/capital/gate fees (2006/07) 1. 30 ktpa/£21.7 million/ £93.6 per tonne 2. 100 ktpa/£27.9 million/ £69.2 per tonne 3. 150 ktpa/£67.2 million/ £51.56 per tonne	• Emission controls must comply with the Waste Incineration Directive • Pyrolysis and gasification are modular technologies, offering flexibility in scale **Number operating in England:**[c] • 1 plant operating with both technologies **Support:** • Electricity generated is eligible for Renewables Obligation support • WIP New Technologies Demonstrator Programme **Further information:** • WIP Guide: *Advanced Thermal Treatment of Municipal Solid Waste*[f]

Table E.1: Energy from waste (EfW) technology matrix *(continued)*

Technology type	Process characteristics	Outputs	Typical carbon dioxide (CO_2)[a] and cost data[b]	Other considerations
Plasma arc heating	This novel thermal treatment technology heats waste to temperatures between 3,000 and 10,000 centigrade, converting organic material to a hydrogen-rich gas and non-combustibles to an inert, glassy residue. It is most suitable for treatment of hazardous wastes, including clinical waste and fly ash from waste combustion processes.			

a Impact of treatment which is assumed to divert waste away from landfill bringing additional CO_2 equivalent benefits due to avoided (uncaptured) methane emissions. Data for MBT/gasification taken from *Impact of Energy from Waste and Recycling Policy on UK Greenhouse Gas Emissions,* ERM, (January 2006), data for landfill, incineration and anaerobic digestion estimated based on *Carbon balances and energy impacts of the management of UK wastes*, ERM, (March 2007) and a comparison with *Environmental Benefits of Recycling: An international review of life cycle comparisons for key materials in the UK recycling sector* (WRAP, 2006).

b Figures taken from Local Authority Waste Recycling Recovery and Disposal (LAWRRD) Model.

c Data supplied by Environment Agency, March 2007.

d The Biomass Taskforce Report to Government (October 2005) is available at www.defra.gov.uk/forum/crops/industrial/energy/biomass_taskforce/index.htm

e WIP guide to Advanced Biological Treatment of Municipal Solid Waste is available at http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/advancedbiotreat.pdf

f WIP guide to Advanced Thermal Treatment of Municipal Solid Waste is available at http://www.defra.gov.uk/environment/waste/wip/newtech/pdf/advancedthermaltreat.pdf