Report and recommendations of the Environmental Protection Authority and the Waste Authority

Environmental and health performance of waste to energy technologies

Advice of the Environmental Protection Authority to the Minister for Environment under Section 16(e) of the *Environmental Protection Act 1986*

Report 1468

April 2013

Strategic Advice Timelines

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Foreword from the Chairmen

We are pleased to transmit this advice to the Minister for Environment on behalf of the Environmental Protection Authority and the Waste Authority on the environmental and health impacts associated with waste to energy technologies. This advice is provided under section 16(e) of the *Environmental Protection Act 1986.*

To assist in the development of this advice, a technical report was commissioned focussing on different regulatory regimes across jurisdictions, profiling operating state-of-the-art waste to energy plants and presenting a review of environmental and health literature. The key findings identified in this technical report supported the Authorities in formulating this advice to the Minister for Environment.

Waste to energy is a recognised recovery option in the waste hierarchy and is likely to play an important role alongside other waste management options in contributing to Western Australia's resource recovery targets.

The EPA and Waste Authority are confident that, subject to conditions and matching suitable technologies to types of waste input and appropriate plant scale, waste to energy plants employing best practice can be operated with acceptable impacts to our community. Nevertheless, engagement with the community through the full planning, design, environmental approvals and commissioning process for waste to energy plants is essential to build community confidence and acceptability. This advice identifies six principles that the EPA and Waste Authority see as key to the successful operation of waste to energy plants in Western Australia:

- Only proven technology components should be accepted for commercially operating waste to energy plants.
- The expected waste input should be the main consideration for the technology and processes selected.
- Proposals must demonstrate best practice that, at a minimum, meets the European Union's Waste Incineration Directive standards for emissions at all times.
- The waste sourced as input must target genuine residual waste that cannot feasibly be reused or recycled.
- Continuous emissions monitoring must occur where feasible, and non-continuous emissions monitoring must be required for all other emissions of concern.

- Residual by-products must be properly treated and disposed of to an appropriate landfill, except where it is demonstrated that they can be safely used elsewhere with acceptable impacts to the environment or human health.

This advice is provided to guide the emerging waste to energy industry in Western Australia. It recommends a precautionary approach, which could be revised once the industry develops and demonstrates it can successfully operate under Western Australian conditions.

The Waste Authority has a role in promoting the most efficient use of resources, including resource recovery. While beyond the scope of this advice, the Waste Authority notes the importance of developing appropriate contracting and governance models within a suitable planning framework to ensure the long term outlook for this industry aligns with the waste strategy for the State.

Dr Paul Vogel

Chairman, Environmental Protection Authority

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Chairman, Waste Authority

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Recommendation 1 Given the likely community perception and concern about waste to energy plants, a highly precautionary approach to the introduction of waste to energy plants is recommended.

Recommendation 2 As part of the environmental assessment and approval, proposals must address the full waste to energy cycle - from accepting and handling waste to disposing of by-products, not just the processing of waste into energy.

Recommendation 3 Waste to energy proposals must demonstrate that the waste to energy and pollution control technologies chosen are capable of handling and processing the expected waste feedstock and its variability on the scale being proposed. This should be demonstrated through reference to other plants using the same technologies and treating the same waste streams on a similar scale, which have been operating for more than twelve months.

Recommendation 4 Waste to energy proposals must characterise the expected waste feedstock and consideration made to its likely variability over the life of the proposal.

Recommendation 5 The waste hierarchy should be applied and only waste that does not have a viable recycling or reuse alternative should be used as feedstock. Conditions should be set to require monitoring and reporting of the waste material accepted over the life of a plant.

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Recommendation 7 Regulatory controls should be set on the profile of waste that can be treated at a waste to energy plant. Plants must not process hazardous waste.

Recommendation 8 In order to minimise the discharge of pollutants, and risks to human health and the environment, waste to energy plants should be required to use best practice technologies and processes. Best practice technologies should, as a minimum and under both steady state and non-steady state operating conditions, meet the equivalent of the emissions standards set in the European Union's Waste Incineration Directive (2000/76/EC).

Recommendation 9 Pollution control equipment must be capable of meeting emissions standards during non-standard operations.

Recommendation 10 Continuous Emissions Monitoring must be applied where the technology is feasible to do so (e.g. particulates, TOC, HCl, HF, SO_2, NOx, CO). Non-continuous air emission monitoring shall occur for other pollutants (e.g. heavy metals, dioxins and furans) and should be more frequent during the initial operation of the plant (minimum of two years after receipt of Certificate of Practical Completion). This monitoring should capture seasonal variability in waste feedstock and characteristics. Monitoring frequency of non-continuously monitored parameters may be reduced once there is evidence that emissions standards are being consistently met.

Recommendation 11 Background levels of pollutants at sensitive receptors should be determined for the Environmental Impact Assessment process and used in air dispersion modelling. This modelling should include an assessment of the worst, best and most likely case air emissions using appropriate air dispersion modelling techniques to enable comparison of the predicted air quality against the appropriate air quality standards. Background monitoring should continue periodically after commencement of operation.

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Recommendation 16 Any proposed use of process bottom ash must demonstrate the health and environmental safety and integrity of a proposed use, through characterisation of the ash and leachate testing of the by-product. This should include consideration of manufactured nanoparticles.

Recommendation 17 Long term use and disposal of any by-product must be considered in determining the acceptability of the proposed use.

Recommendation 18 Standards should be set which specify the permitted composition of ash for further use.

Recommendation 19 Regular composition testing of the by-products must occur to ensure that the waste is treated appropriately. Waste by-products must be tested whenever a new waste input is introduced.

Recommendation 20 Waste to energy plants must be sited in appropriate current or future industrial zoned areas with adequate buffer distances to sensitive receptors. Buffer integrity should be maintained over the life of the plant.

Recommendation 21 For a waste to energy plant to be considered an energy recovery facility, a proposal must demonstrate that it can meet the R1 Efficiency Indicator as defined in WID.

1 Introduction

Background

On 16 November 2011, the Minister for Environment wrote to the Chairman of the Environmental Protection Authority (EPA) and the Chairman of the Waste Authority, requesting that the two Authorities investigate the environmental and health performance of waste to energy technologies internationally.

This request sought information on:

- legislation for the establishment and operation of waste to energy facilities, focussed on emissions, in jurisdictions where these facilities currently exist;
- current emissions from established and operating best practice facilities; and
- current and historical level of compliance of these facilities.

The Minister requested that the information gathered be from full-scale, commercial plants that process municipal solid waste (MSW) and from a variety of technology types.

To assist with this investigation, WSP Environment and Energy Ltd were engaged to undertake a technical review of waste to energy plants around the world. These technical reports are attached. The reports provide detailed information to address the issues identified by the Minister for Environment. This advice from the EPA and Waste Authority draws on the technical advice to make recommendations that are relevant to the Western Australian situation.

What is waste to energy?

Waste to energy is the process of converting waste products into some form of energy. This energy could be heat, steam or synthetic gas (syngas). These primary energy sources can either be used directly or further converted into products such as electricity or synthetic fuels. Waste to energy technologies transform the calorific energy in waste products into usable energy. For example, unrecoverable items in residual solid waste such as scrap timber, textiles, nappies, organic waste mixed with packaging, soiled paper and unrecovered packaging still contain energy bound within them. The waste to energy process frees this energy.

Waste incinerators have existed since the 19th century, with renewed interest across the United States, Europe and Asia since the 1970s. These incinerators were designed to reduce the volume of waste going to landfill (as the resulting ashes would normally be less than 30% of the original mass of the input waste). Most plants built up until the 1990s were basic mass burn incineration plants. A number of these incineration plants were only later retrofitted to also produce energy.

In the 1990s, major regulatory reform occurred across the world to reduce the environmental and health impacts of mass burn incinerators and waste to energy plants. As opposed to older plants, modern plants have been designed to produce energy as the primary objective, and dispose of waste as a secondary objective. For example, in Europe there are set energy recovery levels that must be reached if a plant is to be classed as a legitimate waste to energy resource recovery operation rather than a disposal operation. The energy recovery level varies depending on the age of a plant.

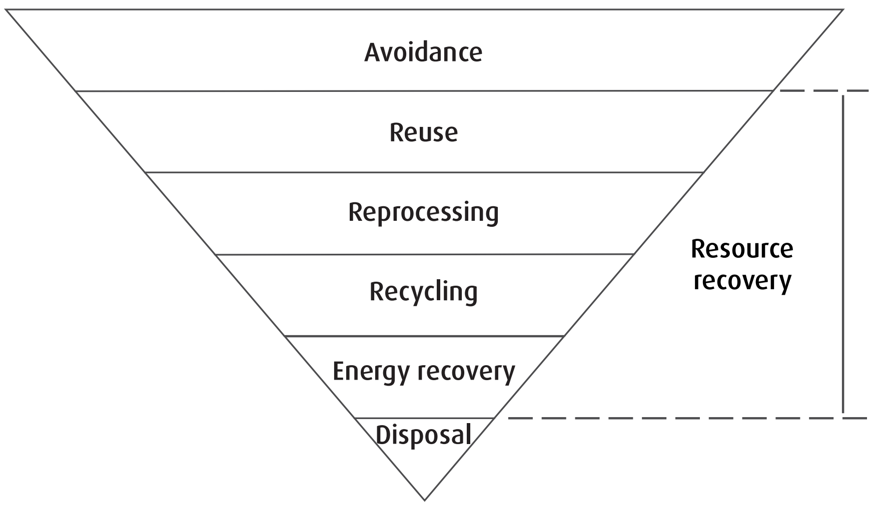
Waste to energy processes generally include combustion, gasification and pyrolysis. These are discussed in Section 2.

Waste to energy in the Western Australian context

Waste generation in Western Australia is growing. This is largely the result of population and economic growth. It is estimated that in 2011-12 total solid waste generation in the Perth and Peel regions was 5.23 million tonnes, and will increase to 5.6 million tonnes in 2014-15 and 6.1 million tonnes in 2019-20. When the population of the Perth and Peel regions reaches 3.5 million people, waste generation could be approximately 9.7 million tonnes per year or more.

The Waste Authority has identified that, not only is the current rate of disposal to landfill a poor use of resources, the current waste and recycling infrastructure is not sufficient to meet the population's needs in the medium to long term.

In 2012, the Western Australian Government released the State Waste Strategy, *Creating the Right Environment*, which aims to move Western Australia to a low waste society. The strategy supports the management of waste consistent with the waste hierarchy which aims to maximise the value of waste and minimise its environmental impact. The waste hierarchy is set out in the *Waste Avoidance and Resource Recovery Act 2007* (WARR Act).



The strategy contains landfill diversion targets for the three main waste streams:

- Municipal Solid Waste: 65% diversion of metropolitan waste by 2019-20 (50% diversion from major regional centres)
- Construction and Demolition Waste: 75% diversion by 2019-20
- Commercial and Industrial Waste: 70% diversion by 2019-20

The growth in waste generation and the preference to divert waste from landfill has significant implications for waste management infrastructure planning and investment into the future. In order to meet policy objectives and strategy targets, a range of waste management options will need to be pursued along different points of the waste hierarchy.

Energy recovery is a recognised option at the lower end of the hierarchy. It is generally considered more favourable than landfill, but less favourable than options such as recycling, re-use and avoidance.

Waste to energy technologies should not replace management options higher up the waste hierarchy. However, where no viable alternatives exist, waste to energy could play an important role in diverting residual waste from landfill and contribute to policy objectives and strategy targets.

Conclusion 1 Waste to energy plants have the potential to offer an alternative to landfill for the disposal of non-recyclable wastes, with the additional benefit of the immediate capture of stored energy.

Regulatory regime in Western Australia

The *Environmental Protection Act 1986* (the EP Act) provides the primary mechanisms to regulate environmental and health aspects of waste to energy plants in Western Australia.

Part IV of the EP Act provides for environmental impact assessment of proposals which are likely, if implemented, to have a significant impact on the environment. Under Part IV, the EPA provides advice to the Minister for Environment, and the Minister may set conditions on a proposal.

Part V of the EP Act requires prescribed premises (including waste to energy plants) to hold a works approval prior to commencing any works on site, and to hold a licence prior to the commencement of any operation of the facility. Works approvals and licences can include conditions relating to the design and construction of facilities, the installation of pollution prevention equipment, the emissions criteria or limits that must be complied with, monitoring requirements, waste disposal, and regular reporting.

The EPA's preference is that proponents present proposals when they are in the detailed design stage so that the EPA can assess the fully designed proposal. However, the EPA accepts that in some instances it may be asked to assess proposed waste to energy plants while they are at the preliminary design stage. In such circumstances, the environmental assessment and regulatory approval process will need to proceed cautiously through the preliminary design, detailed design, engineering procurement and construction phase and, importantly, commissioning phase. In these circumstances, there will be an increased reliance on the Part V process of the EP Act, i.e. Works Approval and Licensing, to assess the detailed design, including the final combination and configuration of technologies chosen for the plant, to ensure environmental criteria are met.

The EPA and the Waste Authority are confident that the regulatory regime provided under the EP Act is well equipped to minimise and manage the environmental and health risks associated with waste to energy plants in Western Australia. Some of the recommendations made in this advice focus on how the regulatory regime should be applied in Western Australia, for example through the application of emission standards. These recommendations are consistent with the approach taken in the European Union, United States and Japan, and are based on the establishment and operation of waste to energy plants in existence in these jurisdictions.

Current situation

The EPA is currently assessing four waste to energy proposals and has set the level of assessment at Public Environmental Review. This means that there is an opportunity for the community to provide comments on each of the proposals. This is the most in-depth level of assessment.

In the past, there has been deep community concern in Western Australia about the health impacts of waste incinerators. Although waste to energy plants have improved significantly on these older incinerators, this concern is likely to continue. There is mixed community opinion about waste to energy plants across the jurisdictions investigated in the WSP Report (see Stage Two Report). However the common opinion and comments put forward by the community appear to relate primarily to older incinerators. Modern state-of-the-art plants are often located in densely populated areas, and operate successfully to meet stringent emission standards.

As stated in the WSP report (Stage Two Report – page 18):

> *Modern waste to energy plants are required to meet among the most stringent emissions requirements of any industrial process. Concerns around airborne pollutants, in particular dioxins, have led to a considerable tightening in the environmental regulation of such facilities over the last few decades, and as a result the emissions to air from modern plants are very low. Some plants even claim to produce flue*

gases that are cleaner than the surrounding air.

In some cases, other non-technical aspects have been used by proponents to gain community acceptance of a plant. This has included both architectural design to make the plants more aesthetically pleasing and having real time monitoring displays at the entrance to the plant to provide transparency and demonstrate compliance with emissions standards and build community confidence.

Recommendation 1 Given the likely community perception and concern about waste to energy plants, a highly precautionary approach to the introduction of waste to energy plants is recommended.

Effective community engagement will be paramount for the successful establishment of a waste to energy industry in Western Australia.

It is essential that proponents of waste to energy proposals engage fully with stakeholders, especially local communities, as early as possible in the planning of their proposals. Consultation should be ongoing through the design, environmental approvals, commissioning and operating phases. The history of waste to energy in Australia and internationally suggests that working with the community through the process leads to better community acceptance of a facility.

Scope of advice

This advice focuses on waste to energy using thermal treatment technologies only. Biological treatment of waste using technologies such as composting or anaerobic digestion to obtain heat or methane gas is not included. The scope of the advice is limited to the environmental and health impacts of thermal treatment plants. While economic, waste availability, landfill availability and other factors play a significant role in the feasibility of waste to energy plants, they are not the focus of this advice. These factors however are important drivers of the need to consider waste to energy facilities in the broader waste management hierarchy.

How this advice will be used

This advice discusses the potential environmental and health impacts and risks of waste to energy plants around the world, and offers recommendations to minimise and manage these.

This advice provides useful context for proponents developing waste to energy plants to understand the key issues that the EPA will consider in undertaking its environmental impact assessment. The advice and attached technical report also provides information for the community to support open and informed public discussion about waste to energy.

The recommendations relate to the six key principles outlined in the foreword. These recommendations will provide the basis for the EPA's assessment of the current and future proposals. It will assist the Minister in making a decision on whether to approve a proposal under Part IV of the EP Act). It will also provide guidance on decisions made under Part V of the EP Act for Works Approval and Licensing of prescribed premises. The recommendations emphasise the importance of integration of Part IV and Part V processes of the EP Act to allow a life cycle approach to the assessment and approval of these plants. This allows the assessment of different components of the proposal to occur at the most appropriate time, including during commissioning. This will ensure that before a plant is licenced to operate, it has demonstrated its environmental acceptability.

2 Waste to energy process

Components of waste to energy

In simple terms, the waste to energy process generally has the following five components:

1. Waste arrival and storage
2. Core reactor (i.e. where the waste is converted to energy)
3. Energy recovery
4. Air pollution control
5. Residual product processing.

Component 1 is comparable to a waste transfer station where waste is brought in by truck and deposited on the tipping floor. It is then processed, sorted and stored.

Component 2 is the main unique component of waste to energy plants. This is where the actual conversion of waste into energy occurs. The types of modern waste to energy technologies include direct combustion, gasification and pyrolysis and other more novel technologies. Direct combustion technologies include moving grate mass burn facilities, rotary kiln facilities and fluidised bed facilities. Combustion is the dominant technology for processing solid waste through thermal treatment globally.

A range of approaches are taken to gasification or pyrolysis. Many gasification or pyrolysis technologies need to manage the characteristics of input waste and may use one or more of the following techniques: mechanical separation, bio-drying, particle size reduction, co-processing with more suitable materials and increased residence time in process.

Process	Description
Combustion	This is the dominant waste to energy approach taken globally. Combustion uses excess air or oxygen to drive the reaction in combusting waste into heat, ash and a flue gas. The heat is often then used to produce steam to drive a steam turbine to generate electricity. The specific reaction conditions and the systems for extracting useful energy from the process are critical factors that determine the efficiency of a facility.
Gasification	Involves the conversion of waste into synthetic gas (syngas) using a limited amount of oxygen. The process is more efficient than direct combustion and converts about 80 per cent of the energy in the waste into syngas. Most gasification plants use air in the process rather than pure oxygen as it is cheaper, however it produces a lower quality syngas. Most gasification is undertaken at high temperature (at least 900°C), although certain technologies run at lower temperatures where the waste is treated for a longer period of time. Gasification can be undertaken in combination with combustion in modular plants.
Slagging gasification	Some gasification plants operate at a higher temperature and are known as slagging gasification. These higher process temperatures are produced using oxygen injections or plasma, which melt the by-products (ash or char) into an inert vitrified glass-like product. In some jurisdictions this vitrified material is recycled into construction materials such as road base, as extensive testing has shown the material has very low leaching characteristics and is considered to be safe for use. Globally, the majority of commercially-sized operating slagging gasification plants are located in Japan.
Plasma gasification	Plasma gasification is a new technology currently being tested, but as yet has not been commercially proven. This type of gasification involves no air or oxygen. Plasma gasification is carried out by exposing waste to intense temperature conditions (4,000 – 7000°C) from a plasma arc which results in the production of syngas, a vitrified slag and molten metal. The proportions and composition of the products will depend on the composition of the input waste. Emissions of pollutants such as nitrogen oxides and sulphur dioxide are effectively avoided, but other contaminants such as hydrogen sulphide, ammonia and carbonyl sulphide may have to be abated.
Pyrolysis	Pyrolysis does not involve any oxygen or air. In this case

	waste is placed into an air-free reactor and heated using an external source of energy. The waste is then converted into solid char, pyrolysis oil and syngas through physical and chemical processes. True pyrolysis is undertaken at a low temperature (around 400°C), however, pyrolysis undertaken at a higher temperature (around 800°C) changes the amount of each product produced – at higher temperatures more syngas is produced. For waste to energy purposes, syngas is the currently preferred energy product as it is easier to convert into electricity.

Within each of these processes, there are various designs such as fluidised bed, rotary kiln, updraft and downdraft reactors, each of which is tailored to give certain benefits when processing various types of wastes. Further details are available in the attached report (see Stage Two Report – Overview section).

Component 3 involves the recovery of energy from the process. This may be heat, steam, syngas or oil, which can be used directly or converted into electricity.

Component 4 controls the emissions from the process and uses technologies already in existence for other industries. This includes flue gas cleaning systems such as fabric filters, electrostatic precipitators, cyclones, selective non-catalytic reduction, selective catalytic reduction, wet, semi-dry and dry scrubbers, activated carbon injectors, etc. These are used to remove or capture air emissions.

Component 5 involves dealing with the residual products from the process. These are generally bottom ash (char), fly ash (the major hazardous waste collected through air pollution control systems) and recovered metals. In some jurisdictions, some of these by-products are marketable products for use in, for example, road base. Others, particularly fly ash, are generally hazardous and need to be disposed of to an appropriately licensed landfill. Disposal of residual products are discussed further in Section 3.

Recommendation 2 As part of the environmental assessment and approval, proposals must address the full waste to energy cycle - from accepting and handling waste to disposing of by-products, not just the processing of waste into energy.

Technology and operation

There are many waste to energy technologies available around the world, but not all of them are proven technologies in jurisdictions that set strict emissions standards, or have been demonstrated across the full spectrum of waste streams. Many of the emissions related to waste to energy plants occur during start-up, shutdown and non-standard operation. To minimise the risk to humans and the environment, commercially operating plants should only use proven technology.

In assessing waste to energy proposals, the EPA will seek for proponents to demonstrate that:

- The technology for each component in the proposed configuration of the plant has operated reliably elsewhere;
- The combination of technologies for the components can operate well within emissions standards equal to the European Union's Waste Incineration Directive (WID);
- The technology for each component has a successful track record in treating the same waste streams as those proposed;
- If possible, the technology for each component has been operated at a similar scale or have a track record at a lower scale that can be reasonably upscaled; and
- If possible, the configuration of components of the plant has also been previously demonstrated elsewhere.

Recommendation 3 Waste to energy proposals must demonstrate that the waste to energy and pollution control technologies chosen are capable of handling and processing the expected waste feedstock and its variability on the scale being proposed. This should be demonstrated through reference to other plants using the same technologies and treating the same waste streams on a similar scale, which have been operating for more than twelve months.

Variation in waste streams poses one of the greatest risks to the ability of waste to energy plants to meet emissions standards. It is important that the intended waste stream is carefully characterised to ensure that it can meet the specifications of the plant. When considering the life of a waste to energy plant, it is likely that the waste stream will vary in line with population growth, uptake of recycling and re-use of materials, change in markets for recycling, change in waste streams, availability of new waste streams, introduction of other waste processing facilities, etc. Variation will not only occur over these longer timeframes, but variation in municipal solid waste is also known to occur seasonally. Therefore, the type of technology and processes should be chosen to best align with the expected waste stream.

Recommendation 4 Waste to energy proposals must characterise the expected waste feedstock and consideration made to its likely variability over the life of the proposal.

Waste to energy plants should only process residual waste. Residual waste generally refers to material that is left over after processing, and which would otherwise be sent to landfill. Residual waste streams may vary from region to region depending on availability of recycling and recovery options. Ultimately, residual waste should have no viable higher value use.

The viability of higher value waste management options (such as source separated collection and processing) will change over time as population, technologies, markets for materials and other factors change. Waste to energy plant operators should not adversely affect future higher value recovery options by relying on a single residual waste stream over the longer term.

As sources of waste are removed when other high order uses become available, new waste streams may need to be introduced to enable plants to continue operating at capacity. The likely sources of these new waste streams need to be considered in plant design to ensure that the plant technology is adequate to treat these wastes.

Recommendation 5 The waste hierarchy should be applied and only waste that does not have a viable recycling or reuse alternative should be used as feedstock. Conditions should be set to require monitoring and reporting of the waste material accepted over the life of a plant.

Recommendation 6 Waste to energy operators should not rely on a single residual waste stream over the longer term because it may undermine future recovery options.

The waste stream put into the waste to energy process will determine the characteristics of the process residues and emissions. Certain types of waste will increase the amount of certain emissions (e.g. within MSW there may be plasterboard offcuts which will result in higher sulphur dioxide emissions) and the content of process residue (e.g. batteries will increase the amount of heavy metals). While some of these are inevitable with the collection of MSW, it is important that large quantities of identified hazardous waste are not processed together with MSW. This will prevent large amounts of process residue potentially being classified as hazardous. The reference to hazardous waste here refers to any waste which could not be landfilled without prior treatment and includes dangerous goods, biomedical waste, pharmaceutical waste, poisons, quarantine waste, radioactive waste, significantly contaminated soils and asbestos waste.

Recommendation 7 Regulatory controls should be set on the profile of waste that can be treated at a waste to energy plant. Plants must not process hazardous waste.

The attached Stage Two Report discusses thirteen case studies of operating plants to demonstrate the wide variety of technology types and processes in existence, as well as two reviews of slagging and plasma gasification plants. Generally the report shows that these modern plants can operate well within acceptable standards. The table at the end of this advice summarises these plants and full details on the operation of these plants are available in the attached report. By allowing the operation of state-of-the-art plants, waste to energy can contribute to meeting Western Australia's resource recovery targets while building community confidence in the waste to energy industry.

Conclusion 2 It has been demonstrated internationally that modern waste to energy plants can operate within strict emissions standards with acceptable environmental and health impacts to the community when a plant is well designed and operated using best practice technologies and processes.

3 Environmental and health impacts

The two main environmental and health issues associated with waste to energy plants are emissions from the process and handling the process residues. Air emissions can be controlled through technology and process similar to that in other industries. Process residues can be managed through controlling the waste input and disposing of waste in accordance with regulatory guidelines.

Air emissions

The EPA's objective for air is to maintain air quality for the protection of the environment and human health and amenity. In order to achieve this, waste to energy plants should be designed to meet best practice, both in terms of technology and process. Best practice is defined by the EPA as:

- All relevant environmental quality standards must be met.
- Common pollutants should be controlled by proponents adopting Best Practicable Measures (BPM) to protect the environment.
- Hazardous pollutants (like dioxins) should be controlled to the Maximum Extent Achievable (MEA), which involves the most stringent

measures available. For a small number of very hazardous and toxic pollutants, costs are not taken into account.

- There is a responsibility for proponents not only to minimise adverse impacts, but also to consider improving the environment through rehabilitation and offsets where applicable and practicable.

The technical review by WSP provides a comparison of air emissions standards from three jurisdictions being the European Union, the United States and Japan. The European Union's Waste Incineration Directive (WID) standards are generally the strictest across the range of typical emissions. Individual States or local authorities may have stricter emissions limits on certain emissions of concern where appropriate to the local context (e.g. the plant is located within an urban setting). The EPA and the Waste Authority agree that the WID standards should be the minimum accepted in Western Australia.

Recommendation 8 In order to minimise the discharge of pollutants, and risks to human health and the environment, waste to energy plants should be required to use best practice technologies and processes. Best practice technologies should, as a minimum and under both steady state and non-steady state operating conditions, meet the equivalent of the emissions standards set in the European Union's Waste Incineration Directive (2000/76/EC)[1].

The figure on the next page shows the air emissions from all the European and United States case studies considered in the attached technical report (see Stage Two Report). All European case studies are within WID limits. In many cases the emissions are more than an order of magnitude below the regulatory limit.

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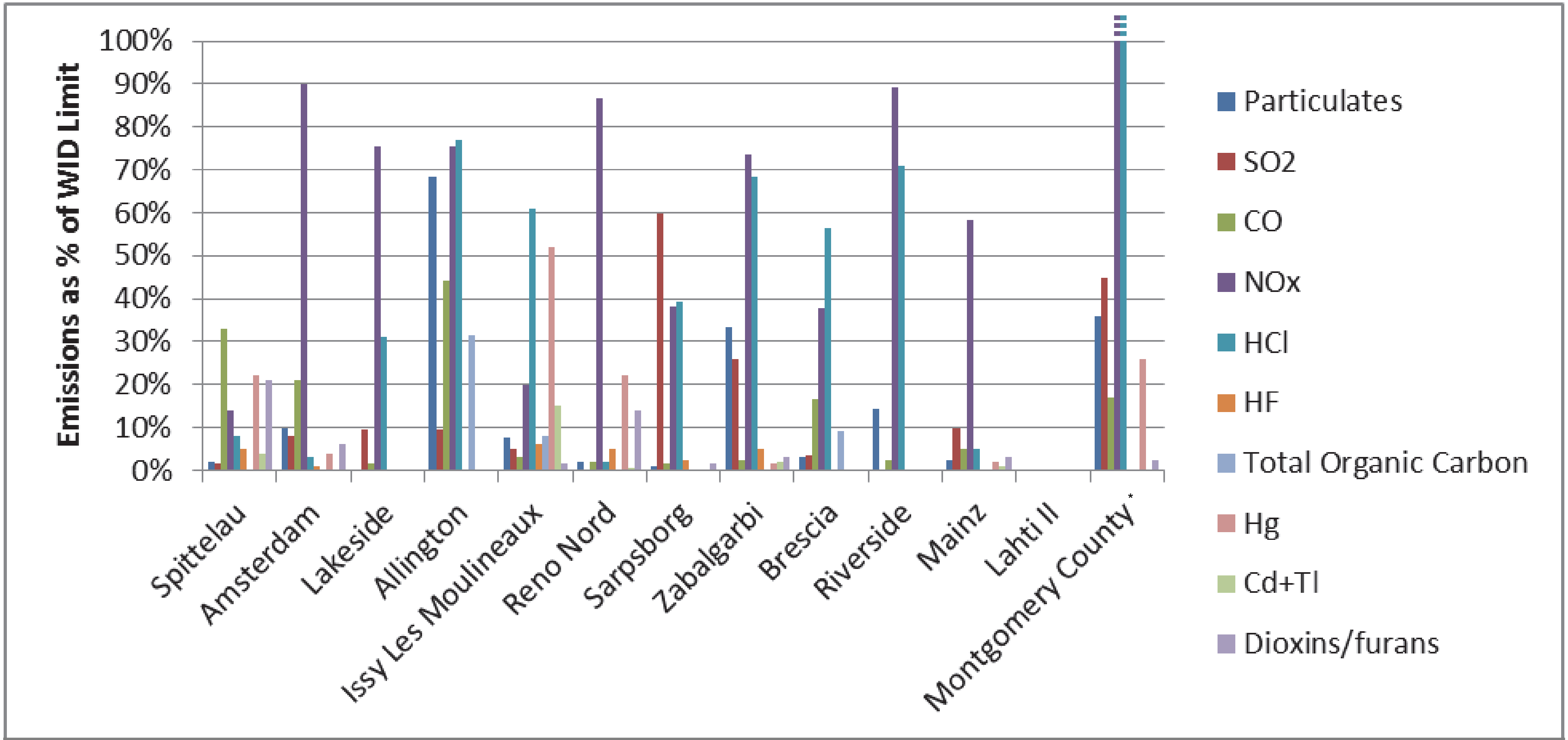
1 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0076:EN:NOT



* Montgomery County (United States) exceeds the WID standards for NOx (approx. 120%) and HCl (approx. 180%) however it complies with the local limit.

Figure 1: Summary emissions performance for plants reviewed in case studies (Note: Lahti II yet to release emissions data)

Of those jurisdictions investigated, most specify minimum pollutant emission standards which must be met. However, there is a trend internationally to also require best available technologies to prevent or minimise pollution, in addition to specifying minimum standards.

It has been demonstrated that plants employing best practice technologies operating under steady state conditions can readily meet the strictest emissions standards set by the European Union's WID.

Peak emissions generally occur during start up, shut down and non-standard operation (e.g. when the temperature of the furnace is too low). Any waste to energy proposal should demonstrate how it will minimise emissions during non-standard operation, start up and shut down. Generally, for start up and shut down, this is managed by excluding waste from the combustor. Waste to energy plants will be required to meet emission standards during non-standard operations.

Recommendation 9 Pollution control equipment must be capable of meeting emissions standards during non-standard operations.

To demonstrate that a waste to energy plant is in full compliance with emissions limits, continuous emissions monitoring of emissions of concern should be undertaken where the technology to do so is available. Where this is not available, non-continuous emissions monitoring should be undertaken. The emissions monitored should include all those relevant to the waste feedstock and air pollution control techniques. The main emissions of concern generally include particulates, heavy metals, dioxins and furans.

The extent of non-continuous monitoring required will initially be set more frequently, particularly during the commissioning phase of the plant. This phase is most likely to have emissions closer to the limits and so is a key point to closely monitor emissions. Once the plant is fully commissioned and has demonstrated continuous operation within the limits, the non-continuous emissions monitoring frequency may be reduced. These monitoring requirements will form part of the Works Approval and Licence issued for a prescribed premises under Part V of the EP Act.

Recommendation 10 Continuous Emissions Monitoring must be applied where the technology is feasible to do so (e.g. particulates, TOC, HCl, HF, SO_2, NOx, CO). Non-continuous air emission monitoring shall occur for other pollutants (e.g. heavy metals, dioxins and furans) and should be more frequent during the initial operation of the plant (minimum of two years after receipt of Certificate of Practical Completion). This monitoring should capture seasonal variability in waste feedstock and characteristics. Monitoring frequency of non-continuously monitored parameters may be reduced once there is evidence that emissions standards are being consistently met.

Measuring background levels of emissions of concern is important to set the baseline for comparison. These background levels must be obtained far enough in advance so that they can be used in air dispersion models as part of the assessment of a plant.

Recommendation 11 Background levels of pollutants at sensitive receptors should be determined for the Environmental Impact Assessment process and used in air dispersion modelling. This modelling should include an assessment of the worst, best and most likely case air emissions using appropriate air dispersion modelling techniques to enable comparison of the predicted air quality against the appropriate air quality standards. Background monitoring should continue periodically after commencement of operation.

Dioxins and furans

The emission of dioxins and furans has been one of the community's greatest concerns with waste incinerators and is likely to continue with waste to energy plants. However, since the 1990s reform of the regulations, the emission of dioxins and furans has decreased significantly. In the United States, between 1987 and 2002, emissions of dioxins reduced by 99.9% with the introduction of Maximum Achievable Control Technology regulations, while in Germany, emissions were reduced by three orders of magnitude. Air pollution control technologies, waste acceptance criteria and appropriate process controls (e.g. maintaining a high temperature) are able to limit the amount of dioxins emitted.

The majority of dioxin emissions occur during start-up, shutdown and non-standard operation. These spikes in emissions can relate to waste not being fully established on the combustion grate during start-up and shutdown.

Where there are increases in emissions during non-standard operation, these should be investigated to determine the cause and changes made to prevent this issue occurring again.

Recommendation 12 To address community concerns, proponents should document in detail how dioxin and furan emissions will be minimised through process controls, air pollution control equipment and during non-standard operating conditions.

Particulates (dust)

The main concern relating to particulate emissions is the impact of ultrafine and nanoparticles on human health. While it is accepted that ultrafine particles do have an impact on human health, there is still uncertainty as to the mechanism. There has been some debate about whether the mass of particles should only be assessed in relation to health impacts or if the total number of particles needs to be considered as well. There are still significant questions about the feasibility of obtaining robust data to make inferences relating to health risks from fine and ultrafine particle counts.

Waste to energy plants will have both nanoparticles already contained within the input waste feedstock as well as new nanoparticles created during combustion.

The potential impact of nanoparticles in the waste industry will increase in the future as the use of nanoparticles in manufactured goods becomes more common. Nanoparticles do not appear to be changed by combustion or by adhering to larger particles. The literature suggests that manufactured nanomaterials in the waste stream may be efficiently filtered during combustion by filter systems designed to capture small particles. This occurs because nanoparticles bind loosely to each other and other particles and to solid residues which are in turn captured during filtration. As a consequence, the bulk of the nanoparticles are found in the fly ash and bottom ash. This suggests potential exposure to nanoparticles could occur predominantly during disposal and deposition of the ash.

At this stage, products containing manufactured nanoparticles should be treated with caution. Large quantities of known manufactured nanoparticles should not be accepted by waste to energy plants.

The fate and behaviour of nanoparticles formed during combustion is also not known. Neither nanoparticle numbers nor concentrations have been routinely monitored. The health effects of nanoparticles cannot be separated from those associated with fine particles although the evidence strongly suggests ultrafine particles present a real risk in the development of chronic diseases. The absence of any evidence of harm directly attributable to nanoparticles should not be taken as evidence of no harm.

However, it is important to remember that waste to energy plants are only one source of nanoparticles and would only contribute a small amount when compared with other sources, including industrial, transport and natural.

Waste to energy plants will have three potential exposure pathways – the handling of process residues (ash) by workers, emissions to air and potential leaching from re-use of process residues.

In order to increase the knowledge of the effects of nanoparticles, better data is required and consideration should be given to monitoring nanoparticles from newly established industrial facilities. This increased knowledge should feed back into the development of appropriate management of nanoparticles. Emissions monitoring data should be made available so that this can occur.

Odour

Odour has the potential to significantly disrupt community comfort and amenity. Odour is generally one of the most complained about environmental pollution issues. Waste to energy plants can be designed to minimise odours as the entire process is generally contained within a building. Doors are designed to close behind vehicles to reduce the chance of odours escaping the plant. Typical installations keep the building under negative pressure by extracting air from the waste tipping hall and feeding it into the combustion process.

Other potential sources of odour are emissions from vehicles and emissions during downtime of the combustion process. Appropriate siting of waste to energy plants will reduce the impact of fugitive odours from garbage trucks. Siting is discussed further in section 4. During extended downtime this odour can be managed through either air pollution technology such as biofilters or process controls such as diverting incoming waste.

It is essential that odour management is adequately planned to ensure that control systems are built into the design of the plant.

Recommendation 13 Proposals must demonstrate that odour emissions can be effectively managed during both operation and shut-down of the plant.

Process residues

There are two main types of process residue from a waste to energy plant – bottom ash and air pollution control (APC) residue (APC residues mostly consist of a material known as fly ash). Depending on the type of air pollution control technology used, waste water may also require disposal. In some cases overseas these residues have been used as products in the construction industry rather than being disposed of to landfill. This advice deals with the bottom ash and air pollution control residue separately as the content of each of these varies.

Air pollution control residue

The residues captured in air pollution control equipment can be highly toxic. It is essential that this material is characterised and disposed of in accordance with waste guidelines. This includes appropriate transport to a licensed landfill.

Overseas, particularly in Japan, vitrification of process residues including APC residue has been used to treat the waste. Vitrification means heating the waste to a very high temperature and adding silicon dioxide to melt the waste into a glass-like product. This product can then be used in the construction industry replacing aggregate material. This process occurs using slagging gasification or plasma technology.

While vitrification of APC residues has been found to limit leaching of toxins into the environment, there is likely to be higher level of risk associated with any lesser treatment of air pollution control residues. In the European Union, most APC residue does not meet waste acceptance criteria for disposal in hazardous landfill unless it has been pre-treated.

The EPA and the Waste Authority recommend that a precautionary approach must be taken in relation to the use of any APC residue. At this stage, it is recommended that all APC residue be disposed of to an appropriate landfill.

Recommendation 14 All air pollution control residues must be characterised and disposed of to an appropriate waste facility according to that characterisation.

Bottom ash

Bottom ash is the generally inert non-combustible residue that remains after treatment of waste in the plant. It also contains ferrous and non-ferrous metals which are usually extracted and recycled. Bottom ash is increasingly being processed into new materials for the construction industry rather than being disposed of to landfill. Bottom ash is typically used as a bound material in asphalt or cement. When bound, the potential for leaching is greatly reduced.

The content of dioxins in bottom ash is considered to be very low and no greater than alternative materials already used in the construction industry. The content of the bottom ash is a direct result of the waste input. It is important to regularly test both the waste input characteristics and bottom ash composition to ensure that any use of bottom ash will be within contaminant limits. Nanoparticles are a known component of bottom ash and need to be considered in the handling and use of any product.

The end product can be processed further to reduce any potential for contaminant leaching. This could be through weathering of the bottom ash before use to stabilise most of the pollutants. The use of the product can also be controlled.

Before any re-use is proposed, issues need to be considered beyond the creation of a stable product to the whole life cycle of the product. This includes both leaching while the product is in use and the potential impacts when the product is disposed of.

If used appropriately the risks of these products to human health and the environment are likely to be minimal. Until it can be demonstrated that the material used in specific applications can meet acceptable contaminant release thresholds, the EPA and the Waste Authority recommend that bottom ash be disposed of to landfill. In the future, re-use of the bottom ash may be acceptable once proponents can demonstrate that the product does not pose unacceptable risks to the community or the environment.

Recommendation 15 Bottom ash must be disposed of at an appropriate landfill unless approval has been granted to reuse this product.

Recommendation 16 Any proposed use of process bottom ash must demonstrate the health and environmental safety and integrity of a proposed use, through characterisation of the ash and leachate testing of the by-product. This should include consideration of manufactured nanoparticles.

Recommendation 17 Long term use and disposal of any by-product must be considered in determining the acceptability of the proposed use.

Recommendation 18 Standards should be set which specify the permitted composition of ash for further use.

The waste input will change over the life of a waste to energy plant. There will be both gradual changes to the composition of the MSW mix as well as immediate changes where a new waste input stream is accepted. By-products should be tested regularly and every time there is a major change, such as a new waste input source, to ensure they still fit within the standards.

Recommendation 19 Regular composition testing of the by-products must occur to ensure that the waste is treated appropriately. Waste by-products must be tested whenever a new waste input is introduced.

Waste water

Waste water discharge, like air emissions, will be regulated under Part V of the EP Act. However, not all plants will discharge water, and some will only discharge water from independent cooling systems, where temperature will be the main emission of concern. Others will discharge water after treatment from air pollution control equipment used (e.g. wet scrubbers). Contaminant levels for water discharge will be set through Part V licence conditions in the local context.

4 Planning and efficiency

Siting

Appropriate siting of waste to energy plants is essential to minimise community concerns and health and environmental risks. While internationally many waste to energy plants exist within densely populated and urban areas, this is unlikely to be acceptable to the Western Australian community at this point.

Planning controls in Western Australia require waste to energy plants to be located in industrial zoned land. Generally, these industrial estates are separated by a buffer from other sensitive land uses. Modelling of noise, odour and air pollution will need to demonstrate that adequate buffers exist. Furthermore, to ensure the separation of incompatible land uses, the integrity of the buffer must be maintained over the life of the plant.

Appropriate siting can also ensure that ancillary impacts, such as noise, odour and greenhouse gas emissions from the transport of waste, are minimised.

Recommendation 20 Waste to energy plants must be sited in appropriate current or future industrial zoned areas with adequate buffer distances to sensitive receptors. Buffer integrity should be maintained over the life of the plant.

Energy efficiency

In the Western Australian context, it is understood that the current waste to energy proposals have the dual primary purpose of generating energy and reducing the amount of waste going to landfill. Proponents should select a technology that, while being appropriate for the expected waste stream, also maximises the efficiency of energy recovery. Waste to energy plants should meet the efficiency criteria as defined by the European Union, which separates incineration facilities from genuine energy recovery facilities. This is known as the R1 Efficiency Indicator and is explained further in the attached technical report (see Stage Two Report – Section 3).

Recommendation 21 For a waste to energy plant to be considered an energy recovery facility, a proposal must demonstrate that it can meet the R1 Efficiency Indicator as defined in WID.

Greenhouse gases

The greenhouse gas emissions from each individual waste to energy plant will vary depending on a number of factors including the composition of its waste input, the efficiency of the technology used, the source of any energy inputs and the substituted energy mix. However, because waste to energy plants produce energy that displaces emissions from the use of conventional emissions intensive fossil energy sources, they are considered beneficial in minimising greenhouse gas emissions.

Waste to energy plants can also produce heat which can be exported to other commercial users. This could reduce other's greenhouse gas emissions and should be considered as part of the siting of a plant.

It should be noted that waste to energy facilities that emit over 25,000 tonnes of carbon dioxide equivalent are liable under the Australian Government's Carbon Pricing Mechanism and have reporting obligations under the *National Greenhouse and Energy Reporting Act 2007*. Waste to energy facilities may be eligible to create large-scale generation certificates under the Renewable Energy Target depending on their feedstock[2].

5 Conclusions

While there is still uncertainty about the impacts of nanoparticles on human health, overall, the international waste to energy plants studied in the WSP Report have performed well within emissions limits at levels acceptable to the community. The distinction between modern state-of-the-art plants and older incinerators is significant and an important factor in the recommendations contained in this advice. Western Australia should be focussed on ensuring application of best practice for any waste to energy proposals and continually improving the standards of this industry as further knowledge is gained. This precautionary approach will provide the opportunity for a successful, long term contribution of waste to energy plants to the management of waste in Western Australia, without unacceptable environmental consequences.

[2] Biomass-based components of municipal solid waste are considered an eligible renewable energy source under the *Renewable Energy (Electricity) Act 2000.* http://ret.cleanenergyregulator.gov.au/For-Industry/Renewable-Energy-Power-Stations/LGC-Eligibility-Formula/lgc-eligibility-formula

6 Case studies

Facility	Commenced Operations	Throughput Capacity	Process Type	Boiler Type	Steam Pressure (bar)	Steam Temp (°C)	Gross Power	Overall Efficiency	Gas Cleaning System	Waste Processed	Plant Residues	Fate of Residues
AEB, Netherlands	1969, upgraded 1993 & 2007	1,370,000t	Moving grate	Horizontal	130	440	66MWe	30.6%	SNCR, ESP and wet and dry scrubbers	Household, C&I	Bottom ash Fly ash	Sand-lime bricks, concrete Asphalt concrete
Lakeside, UK	2010	410,000t	Mass burn	Horizontal	45	400	37MWe	Not available	FGR, SNCR and semi-dry scrubbing	MSW, non-hazardous C&I	Bottom ash APC residues	Construction Landfill after treatment
Spittelau, Austria	Original 1969, 2nd generation 1986	250,000t	Reverse-acting grate	Vertical	34	245	6MWe 60MWt	Not available	ESP, scrubber (wet), SCR and EDV	Municipal; non-hazardous commercial	Bottom ash APC residues	Landfill Engineering Deep mine disposal
Allington, UK	2008	500,000t	Rotating fluidised bed	Horizontal	65	420	43MWe	Not available	ESP and dry scrubbing	Non- hazardous MSW, C&I	Bottom ash APC residues	Construction industry Landfill after treatment
ISSEANE, France	2007	460,000t	Water-cooled grate	Horizontal	50	400	52MWe	30% electrical (theoretical) See Note 1	ESP and SCR DeNOX system	Residual MSW	Bottom ash Fly ash	Recycled Landfill after treatment
Reno Nord, Denmark (Line 4)	2005	160,000t	Moving grate	Horizontal	50	425	18MWe 43MWt	27% electrical See Note 2	Three-field electro-static filter, wet and dry scrubbers and AFMs	MSW	Bottom ash Fly ash	Construction industry Not specified
Energos, Norway	Sarpsborg II 2010	78000t	Staged combustion	Horizontal	23	217	32MWt	Not available	Semi dry cleaning system	Residual C&I waste	Bottom ash APC residues	Landfill Landfill
Zabalgarbi, Spain	2004	250,000t	Moving grate	Horizontal	100	330	99.5MWe	42% See Note 2	SNCR and wet scrubber	MSW	Bottom ash Fly ash	Construction industry Storage
Brescia, Italy	1998 (household waste) 2004 (biomass)	800,000t	Moving reverse thrust grate	Vertical	72	450	Up to 100MWe 150MWt	>27% electrical	SNCR, activated carbon and dry lime scrubbing	2 lines MSW, 1 line biomass	Bottom ash APC residues	Construction material Deep mine disposal
Riverside, UK	2012	670,000t	Moving grate	Horizontal	72	427	66MWe	27%	Semi dry cleaning system	MSW	Bottom ash APC residues	Construction Landfill
Mainz, Germany (Line 3)	2008	110,000t	Reverse-acting grate	Vertical	42	420	See Note 4	See Note 4	SNCR and wet (pre) and dry scrubbers	Residual MSW	Bottom ash APC residues	Used in landfill and road construction as substitute materials for virgin aggregates Infilling old salt mines
Lahti II, Finland	2012	250,000t	Circulating fluidised bed	Vertical	121	540	50MWe and 90MWt	31% thermal efficiency based on waste NCV	Gas cooling and filtration by ceramic filter; dry APC system and NOx control using SCR	SRF	Bed ash Filter (Fly) ash	Landfill Treated as hazardous

Facility	Commenced Operations	Throughput Capacity	Process Type	Boiler Type	Steam Pressure (bar)	Steam Temp (°C)	Gross Power	Overall Efficiency	Gas Cleaning System	Waste Processed	Plant Residues	Fate of Residues
Montgomery County, USA	1995	573,000t	Reverse-reciprocating stoker	Not known	59.6	443	63MWe	Not Available	LoNOx system, semi-dry scrubbers and thermal DeNOx	MSW	Bottom ash	Landfill engineering
											Fly ash	Landfill
Shin-Moji, South Korea	2005	216,000t	Fixed Bed	Vertical	39.2	400	23.5MWe	23%	Dry scrubber and SCR	Industrial waste	Vitrified slag	Re-used
											Fly ash	Recycled
Sagamihara, Japan	2010	160,000t	Fluidised bed gasifier and melting furnace	Vertical	40	400	10MWe	Not available	Dry scrubber and SCR	MSW	Vitrified slag	Re-used
Fukuyama, Japan	2004	92,400t	Slagging updraft gasifier	Vertical	60	450	20MWe	30%	Dry scrubber and SNCR	Pelletised RDF	Melted slag	Recycled
											Metal	Recycled

MWe – Megawatt electrical

MWt – Megawatt thermal

SCNR – Selective Non-Catalytic Reduction

SCR – Selective Catalytic Reduction

ESP- Electrostatic Precipitator

FGR – Flue Gas Recirculation

EDV – Electrodynamic Venturi

AFM – Agglomeration Filtration Modules

C&I – Construction and Industrial waste

RDF – Refuse Derived Fuel

Note 1: Annual average gross electrical efficiency estimated at around 10% due to high level of heat export - thermal efficiency of around 40%

Note 2: High level of heat export means electrical efficiency lower in practice, but overall efficiency high (actual figure unknown), estimated >40%

Note 3: The efficiency achieved is only possible because the waste to energy plant provides steam to an on-site natural gas fired combined cycle plant

Note 4: The conversion of the steam to electrical energy is carried out in the neighbouring 400MW combined cycle power plant owned by Mainz-Wiesbaden AG