7. Environmental Best Practice

7.1 Overview

This section is designed to demonstrate that the REA WtE facility meets environmental best practice taking into account the EPA Guidelines, Demonstrating Best Practice[65] and Application of the environment protection principles to EPA's approvals process[66]. The choice of gasification, the design specifications for operating equipment, the types and operation of emission control systems and equipment and the overall demonstrated cost effectiveness of the technology were evaluated considering the environmental, economic and social impacts of the project (Figure 1-2).

7.2 Legislative Requirements

Best Practice is defined in the EPA Guidelines as *"the best combination of techniques, methods, processes or technology used in an industry sector or activity that demonstrably minimises the environmental impact of that industry sector or activity[67]".* Best Practice is a requirement of statutory policy. This is detailed in the various SEPPs which set out process-related requirements for industry, including those for the management of emissions and discharges to air, land, surface and groundwater.

For new projects the Best Practice Assessment needs to consider:

- Best practice for site selection and management systems. An assessment of environmental impact needs to consider the sensitivity of the receiving environment and is therefore site-specific. The best practice assessment may also need to be applied to site selection, site layout, site operation (e.g. operating hours), and management systems to ensure that human health and amenity, and the environment, are protected;
- Best practice is preventative. Best practice contributes to ensuring that the proposed environmental impact is prevented, or minimised, as far as practicable;
- Best practice means undertaking all practicable measures. Decisions related to practicability, when assessing best practice, should have regard to technical, logistical and financial considerations;
- Best practice may be internationally demonstrated and locally available. Identifying best practice means identifying the combination of measures or practices that demonstrably prevent or minimise environmental impact. An assessment of best practice needs to give reasonable consideration to the availability of technology.

7.3 Best Practice Assessment Methodology

The methodology used generally follows that recommended in the EPA Guideline, Demonstrating Best Practice (2017)[67]. This Guideline outlines how EPA assesses best practice, and provides guidance on how to demonstrate compliance with best practice requirements and requires the following:

- Undertake a risk assessment to determine the potential environmental issues associated with the project. Such an assessment has been conducted which has identified the key environmental risks of the project and these have been the focus of the best practice assessment (Section 5.0, Appendix 4);
- Use the risk assessment to define the scope of the best practice assessment;

[65] EPA Victoria (October 2017) Guideline: Demonstrating Best Practice. EPA Publication 1517.1
[66] EPA Victoria (June 2014) Guideline: Application of the environment protection principles to EPA's approvals process EPA Publication 1565
[67] EPA Victoria (October 2017) Guideline: Demonstrating Best Practice. EPA Publication 1517.1

- Undertake a best practice analysis utilising available literature, provide information benchmarking the project and assess the Projects alignment with the 11 principles of environmental protection;
- Provide a broad summary outlining the range of options available for the proposed works (including the 'do nothing' option), and a brief indication of why they were considered or discarded.

7.3.1 Risk Assessment

A risk assessment was completed to highlight the most serious risks of harm to human health or the environment and thus define the scope the best practice evaluation.

The proposed facility has included a range of design and operation measures to reduce risks to the environment from the Project. Nevertheless, a review of the risks for potential environmental impacts indicates that there will be the potential for moderate impacts on the environment from air emissions, noise and surface water associated with equipment malfunctions or non-routine shut downs.

7.3.2 Scope of Best Practice Assessment

The risk assessment focused the best practice assessment on those risks identified as higher risk. Four moderate risks to air quality, one moderate risk of noise and one moderate risk to surface water were identified in the risk assessment. These particular risks provide the focus for the best practice evaluation.

7.4 Best Practice Analysis

7.4.1 Literature Review

All relevant EPA Environmental Management Guidelines have been reviewed. These included:

- Demonstrating Best Practice, Guideline 1517.1;
- Energy from Waste, Guideline 1559.1;
- Application of the Environment Protection Principles to the EPA's Approvals Process;
- Environmental Guidelines for Major Construction Sites: EPA Publication 480(1996).

In addition guidance on best practice has been obtained from reports of the European Commission-Integrated Pollution Prevention and control Reference Documents on Best Available Techniques (BAT) and a range of literature detailing projects in the WtE sector both in Australia and Internationally. The key documents utilised to benchmark the WTE facility design and reference plant operations have been the following:

- European Commission (2017) Draft *Best Available Techniques (BAT) Reference Document for Waste Treatment.* Industrial Emissions Directive 2010/75/EU, Integrated Pollution Prevention and Control.
- European Commission (2006) *Reference Document on Best Available Techniques for Waste Incineration.* Integrated Pollution Prevention and Control.
- European Commission (2016) Draft *Best Available Techniques (BAT) Reference Document for Large Combustion Plants.* Industrial Emissions Directive 2010/75/EU, Integrated Pollution Prevention and Control.
- European Commission (2017) Draft *Best Available Techniques (BAT) Reference Document for Waste Incineration.* Industrial Emissions Directive 2010/75/EU, Integrated Pollution Prevention and Control.
- European Commission (2006) *Reference Document on Best Available Techniques for Waste Treatments Industries.* Integrated Pollution Prevention and Control.

7.4.2 Benchmarking

The REA WtE facility incorporates a reactor (gasifier) which includes a drying zone (200°C – 400°C), a pyrolysis zone (500°C – 700°C) and a gasification zone (700°C – 900°C) within the same vessel to generate the syngas. This process efficiently converts the organic portion of the MSW to syngas in a controlled air, low oxygen environment which limits the generation of oxides of nitrogen and reduces the generation of particulates reducing the generation of fly ash. The syngas ignites in the direct coupled oxidation chamber at temperatures of 1100°C- 1200°C which ensures almost complete destruction of organic carbon and any residual tars that could otherwise present in the flue gas. In this WtE facility, the waste feeding system, the boiler system and the flue gas cleaning systems are all standard equipment used widely in best practice WtE facilities globally. Only the gasifier and the secondary oxidation chamber are unique to this process systems configuration of equipment.

The European Union has produced reference documents for Best Available Techniques for Waste Incineration (2006) (BAT)[68], Draft Best Available Techniques for Large Combustion Plants (2016)[69] and Draft Best Available Techniques for Waste Incineration (2017) which refer specifically to gasification technologies. While gasification and other similar technologies (pyrolysis) are reviewed there is no detail provided on the best practice design of this type of reactor. As with incinerators, process vessel design rests with the technology provider. The benchmarking documents concentrate on providing guidance on how wastes should be managed, how the operations should be managed and monitored to minimise emissions both to air and water and what methods are BAT for flue gas treatment.

These documents have been used to benchmark REA Proposal. Table 7-1 lists the various BAT relevant to the REA Project and evaluates compliance with the BAT. These tables show that the Eco-Waste gasification system for MSW is consistent with Best Available Technology.

BAT for Waste Treatment Gasification Facilities	Eco-Waste Gasifier System	Compliance
The storage of wastes according to a risk assessment of their properties, such that the risk of potentially pollution released is minimised. In general it is BAT to store waste in areas that have sealed and resistant surfaces, with controlled and separated drainage.	Residual MSW derived from the weekly collection bins is the focus of the planned process. This waste is source separated household waste which contains very little hazardous material. Random audits will be conducted at the waste supplier's premises. The waste arrives at the proposed site in sealed trucks and is tipped into a concrete refuse pit which has a specified resistant finish. Leachate is drained from the pit into a specifically designed leachate containment tank.	Yes
To use techniques and procedures to restrict and manage waste storage times, in order to generally reduce the risk of processing difficulties that may arise. In general it is BAT to: prevent the volumes of wastes stored from becoming too large for the storage provided in so far as is practicable, control and manage deliveries by communication with waste suppliers, etc	The waste storage pit will be sized to allow for 4 days storage to accommodate public holidays and other non-operational waste collection days. Gasifier maintenance will be scheduled for these days to minimise down time during peak collection periods and reduce process volumes required during longer holiday periods. Close communication with the waste collectors will be maintained to minimise the risk of oversupply of MSW. Facility access will be restricted to contracted volumes to	Yes

68 European Commission (2006) Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques for Waste Incineration
69 European Commission (2016) Reference Document on Best Available Techniques for Large Combustion Plants (Draft)

	optimise scheduled receivals according to processing capacity.	
To minimise the release of odour (and other potential fugitive releases) from bulk waste storage areas and waste pre-treatment areas by passing the extracted atmosphere to the Incinerator for combustion.	The entire processing facility is located within enclosed structures. The MSW receival area is compartmentalised and air for gasification and the syngas combustion chamber is drawn from the waste pit and arrivals hall to minimise the chance of odour moving outside the facility	Yes
As far as practicably and economically viable, remove ferrous and non-ferrous recyclable metals for their recovery after incineration from the bottom ash residues.	In theory recyclable materials should be separated at the household source into the provided recycling bins. In practice some recyclables will enter the residual MSW waste bin. Carbonaceous materials will be gasified and the inert material will pass through the gasifier and be discharged as a siliceous slag. The slag will include any ferrous and non-ferrous metal residues. These will be recycled through the contracted slag processor.	Yes
Use of flow modelling to provide information in order to: • Optimise furnace and boiler geometry so as to improve combustion performance; • Optimise combustion air injection so as to improve combustion performance; • Where SNCR or SCR is used, to optimise reagent injection points so as to improve the efficiency of NOX abatement whilst minimising the generation of nitrous oxide, ammonia and the consumption of reagent.	Eco-Waste have undertaken many years of research and have reviewed the numerous operational installations to optimise the performance of the gasifier and combustion chamber, the quantity and position of air injection and the injection points of the SNCR nitrogen abatement system.	Yes
To pre-treat the waste, in order to improve its homogeneity and therefore combustion characteristics and burn-out, by: • Mixing in the bunker • The use of shredding or crushing for bulky wastes e.g. furniture that is to be incinerated, to the extent that is beneficial according to the combustion system used.	MSW is continuously mixed in the bunker by the grab operator. While shredding or crushing is generally not required for the typical residual waste expected a shredder is incorporated over the pit area to process any oversized waste inadvertently dropped into the waste receival system. A double roller feed system applies compression to the waste that will result in crushing and sizing of solid components.	Yes
In order to reduce overall emissions, adopt operational regimes and implement procedures (e.g. preventative maintenance systems) in order to minimise as far as practicable planned and unplanned shutdown and start-up operations.	Eco-Waste has implemented preventative maintenance programs at the facilities visited overseas and this will be a key operational requirement in Victoria.	Yes
The identification of a combustion control philosophy, the use of key combustion criteria and a combustion control system to monitor and maintain these criteria within appropriate boundary conditions, in order to maintain effective combustion performance.	Combustion control is a key design criterion of the process which is a practical and physical determinant of the selection of operational equipment and its integration across the process. Operational control parameters are measured throughout the gasifier, syngas combustion chamber and off gas systems to manage temperature, combustion efficiency and flue gas emissions.	Yes
The optimisation and control of combustion conditions by a combination of: • The control of air (oxygen) supply, distribution and temperature, including gas and oxidant mixing;	Air to fuel ratio, temperature and syngas residence time are managed to ensure near complete destruction of residual organics across the gasifier and the syngas combustion chamber (LOI < 2%)	Yes

• The control of combustion temperature level and distribution, • The control of raw gas residence time.		
The preheating of primary combustion air for low calorific value wastes, by using heat recovered within the installation, in conditions where this may lead to improved combustion performance (e.g. where low LCV/high moisture wastes are burned).	A portion of the air flows through heat exchanges to heat it to 150ºC prior to entering the gasifier	Yes
The use of furnace (including secondary combustion chambers etc.) dimensions that is large enough to provide for an effective combination of gas residence time and temperature such that combustion reactions may approach completion and result in low and stable CO and VOC emissions.	The Eco-Waste syngas oxidation chamber operates at an average temperature in a range 1100ºC – 1200ºC) with a gas residence time of >2 seconds ensuring the combustion reactions are near complete resulting in low and stable CO and TOC levels.	Yes
When gasification or pyrolysis is used, in order to avoid the generation of waste, it is BAT to combine the gasification or pyrolysis stage with a subsequent combustion stage with energy recovery and flue-gas treatment that provides for operational emission levels to air within the BAT associated emission ranges.	The Eco-Waste system combines a syngas combustion chamber with gasification to achieve the IED operational emission levels (Section 6.3.1.4).	Yes
In order to avoid operational problems that may be caused by higher temperature sticky fly ashes, to use a boiler design that allows gas temperatures to reduce sufficiently before the convective heat exchange bundles (e.g. the provision of sufficient empty passes within the furnace/boiler and/or water walls or other techniques that aid cooling). The actual temperature above which fouling is significant is waste type and boiler steam parameter dependent. In general for MSW it is usually 600 – 750ºC. Radiative heat exchangers, such as platten type super heaters, may be used at higher flue-gas temperatures than other designs.	Syngas combustion chamber exit temperatures are controlled to 1100ºC with the flue gas directed through several empty passes in the boiler to reduce temperatures to ±650ºC prior to contact with the boiler heat exchanger bundles.	Yes
For gasification and pyrolysis processes that are combined with a subsequent combustion stage, the use of a boiler with a thermal conversion efficiency of at least 80%, or the use of a gas engine or other electrical generation technology.	Eco-Waste estimate the boiler efficiency at 82%	Yes
The use of an overall flue-gas treatment (FGT) system that, when combined with the Installation as a whole, generally provides for the operational emission levels listed for releases to air associated with the use of BAT.	The flue gas treatment system reduces contaminants to levels which comply with IED emission levels (Section 6.3.1.4)	Yes
The reduction of FGT reagent consumption and of FGT residue production in dry, semi-wet, and intermediate FGT systems by a suitable combination of: • Adjustment and control of the quantity of reagent(s) injected in order to meet the requirements for the treatment of the flue-gas such that the target final operational emission levels are met; • The use of the signal generated from fast response upstream and/or downstream monitors of raw HCl	The FGT systems in the Eco-Waste plants are operated with real time monitoring and feedback loops to allow adjustment of the alkali injection quantities to meet the required emission targets. A portion of the flue gas is recirculated into the secondary oxidation chamber for temperature control.	Yes

and/or SO_2 levels (or other parameters that may prove useful for this purpose) for the optimisation of FGT reagent dosing rates; • The re-circulation of a proportion of the FGT residues collected.		
The use of primary (combustion related) NOX reduction measures to reduce NOX production, together with either SCR or SNCR, according to the efficiency of flue-gas reduction required.	One of the unique features of the Eco-Waste Gasifier is that NOx levels remain low and generally do not require further treatment to meet emision standards. Gasification in a low oxygen environment minimises the formation of NOx compounds while operating the syngas combustion chamber at temperatures above 1100C° but lower than 1200°C minimises the production of NOx in the flue gas. In recognition of the higher nitrogen content of Melbourne residual MSW a SCNR NOx treatment system will be installed. In addition, provision in the design for the alkali scrubber to include caustic soda as well as lime is used to reduce NOx levels and other acid gases should operations require it. NOx is real time monitored and if levels are of concern the included SNCR system is managed to reduce emissions.	Yes
For the reduction of overall PCDD/F emissions to all environmental media, the use of: • Techniques for improving knowledge of and control of the waste, including in particular its combustion characteristics, using a suitable selection of techniques; • Primary (combustion related) techniques to destroy PCDD/F in the waste and possible PCDD/F precursors; • The use of installation designs and operational controls that avoid those conditions that may give rise to PCDD/F reformation or generation, in particular to avoid the abatement of dust in the temperature range of 250 – 400°C. • The use of a suitable combination of one or more of the following additional PCDD/F abatement measures: i. adsorption by the injection of activated carbon or other reagents at a suitable reagent dose rate, with bag filtration; ii. adsorption using fixed beds with a suitable adsorbent replenishment rate; iii. multi layer SCR, adequately sized to provide for PCDD/F control; iv. the use of catalytic bag filters (but only where other provision is made for effective metallic and elemental Hg control).	The Eco-Waste syngas combustion chamber maximises hydrocarbon/carbon combustion/destruction by operating at high temperatures (average 1150C°), ensuring high turbulence during combustion through the specific design of the air injection system and ensuring the syngas spends >2seconds in the hot combustion zone. While the high destruction efficiencies achieved in the Eco-Waste process minimise PCDD/PCDF formation, in practice it is impossible to achieve 100% burnout of carbon contained in the syngas and fly ash. Consequently, the system incorporates injection of powdered activated carbon into the flue gas stream with recovery of the particulates in a bag house filter to recover any potential *de novo synthesis* PCDD/PCDF formed in the gas cooling zone of the process.	Yes
The use of a suitable combination of the techniques and principles for improving waste burnout to the extent that is required so as to achieve a TOC value in the ash residues of below 3 wt % and typically between 1 and 2 wt %.	TOC values for the gasifier bottom slag is consistently <3wt%. Recent data from new operational plants is <1%.	Yes
The separate management of bottom ash from fly ash and other FGT residues, so as to avoid contamination of the bottom ash and thereby improve the potential for bottom ash recovery.	Fly ash is kept separate from gasifier slag and boiler bottom ash.	Yes
The treatment of bottom ash (either on or off-site) to the extent that is required to meet the specifications set for its use or at the receiving treatment or disposal site e.g. to achieve a	The gasifier bottom slag has been tested and appears suitable for recycling to clean fill or road base.	Yes

leaching level for metals and salts that is in compliance with the local environmental conditions at the place of use.		
The treatment of FGT residues (on or off-site) to the extent required to meet the acceptance requirements for the waste management option selected for them, including consideration of the use of the FGT residue treatment techniques.	Testing of the FGT residues suggest that it is likely to be classified as a prescribed waste and the process design currently incorporates on-site stabilisation prior to disposal in an appropriately licensed landfill. Once the specific characteristics of the fly ash generated from processing Melbourne's residual waste is verified REA will seek confirmation of its classification and determine whether other options being investigated warrant implementation.	Yes
The implementation of noise reduction measures to meet local noise requirements	The entire facility is located inside buildings to minimise noise output. Equipment is chosen with noise attenuation in mind. Building is compartmentalised and sound proofed around the more noisy equipment.	Yes

Table 7-1: Comparison of REA Gasifier System with Best Available Techniques

7.4.3 Alignment with the Environment Protection Principles

The Demonstrating Best Practice Guideline indicates that "EPA's powers, duties and functions – including decisions relating to works approvals and licences – all need to be discharged in accordance with the environment protection principles set out in the EP Act[70]". The EP Act details 11 Environmental Principles and any one or more of the principles may be important for the proposed project. For works approval assessments the most frequently relevant principles include:

- The principle of integration of economic, social and environmental considerations;
- The principle of shared responsibility;
- The principle of the waste hierarchy;
- The principle of integrated environmental management.

This section shows how the proposed WtE facility aligns with the principles particularly relevant to the proposal.

7.4.3.1 The principle of integration of economic, social and environmental considerations

Economic, social and environmental considerations have been evaluated in the development of this proposed Project. The benefits of the Project in this context are outlined below:

- Only residual waste will be processed in the facility. This will be sourced primarily from the Council operated kerbside residual bin (red bin) which is source separated at the household. Additional sorted wastes may be obtained from Council transfer stations and from MRF's. The Melbourne metropolitan waste system was designed to maximise recycling and recognises the effectiveness of recyclable separation at the source. The WtE facility focus is on the residual household bin from a 3 bin system to ensure it does not undermine current and future recycling strategies and as such does not interfere with any efforts to increase recycling from the householder or from industry;
- Reduced dependence on landfill, particularly for putrescible organic wastes, by diverting 195,000 tonnes per annum. Burying waste in landfill constitutes a poor outcome for resources and landfills consume valuable land, require significant buffers and represent an environmental and social risk through odour, generation of contaminated leachate, methane

[70] EPA Victoria (October 2017) Guideline: Demonstrating Best Practice. EPA Publication 1517.1

emissions and vermin. The proposed process will recover considerably more energy than a landfill operated on best practice principles. Importantly, landfills present as "legacy" infrastructure requiring care and maintenance to manage leachate and fugitive emissions so environmental performance is ensured for a period, generally accepted to be at least 30 years, post closure. Diversions from landfill, whether to WtE or other reuse options, is an important consideration in evaluating intergenerational equity;

- Plant design and flue gas scrubbing techniques are best practice and will ensure that emissions from the Project meet State Environment Protection Policy (Air Quality Management) and European Union Industrial Emissions Directive (IED), 2010/75/EU;
- Generation of base load electricity supplying 120,800 MWh into the grid each year which is sufficient to power around 24,000 homes;
- Increased employment opportunities with a projected construction workforce of 400 and long term direct operational workforce of around 40;
- Net reduction in greenhouse gas emissions of approximately 237,007 tonnes per year compared to disposal to landfill which is approximately equivalent of removing 100,000 cars from the road.

7.4.3.2 The principle of shared responsibility

The REA facility has been sized to only accommodate the residual household waste generated by local municipalities under the principal that the facility provides a local solution to a local problem. Localised distributed waste processing solutions such as proposed by REA provide greater capacity for the sharing of the waste disposal burden across Melbourne than do large centralised facilities, such as is currently the case with large landfills in Melbourne.

The REA WtE proposal will produce energy from residual waste. Initially this will be electricity but provision for converting to a combined heat and power output has been included in the design as it is the intention of REA to supply steam and/or heating to industry as it develops and is required in the surrounding industrial subdivisions. This WtE facility will provide a competitively priced service to reprocess residual waste to recover its inherent energy while at the same time reducing greenhouse gas and will:

- Be cost comparative with the prevailing landfill gate fees;
- Be relatively small scale providing a localised operation that will reduce waste haulage distances;
- Improve environmental waste management outcomes by diverting >97% of residual waste from landfill;
- Maintain the existing receival system that requires no change to current council bin collection, waste aggregation or transport practices;

7.4.3.3 The principle of the waste hierarchy

EPA Guideline, Energy from Waste (publication 1559.1) states with reference to the Environmental Protection Principles the "*EPA encourages EfW options where energy recovery provides the best practicable environmental outcome for the management of the waste having regard to economic, social and environmental considerations, and when the waste has a gross calorific value that can be recovered. It should be considered where generation of the waste cannot be avoided or the waste cannot be recovered for productive purposes through reuse and recycling. EfW should be considered for 'residual waste' and other wastes for which energy recovery represents the most feasible option, due to the absence of a market for the waste"*

The REA Project proposes to primarily source MSW from the household residual bin source separated municipal waste collection system (separation of recyclables and green waste by householder) operated by Councils. Currently the residual bin waste is wholly disposed to landfill.

Section 6.2.4 evaluated the potential for further separation of recyclables from residual waste kerbside collection at the WtE facility. This high level evaluation showed that while some value could be recovered from recyclables in the residual bin waste, the level of contamination, the cost of operating a "dirty" MRF, the sale price of the separated recyclables and the capital cost of setting up a "dirty" MRF showed that increased separation at the WtE facility was unlikely to be economically viable in the foreseeable future.

Most commentary on increasing the separation of recyclables from kerbside collections agrees that increasing the separation at the source (i.e. the household)[71,72,73] is the most effective method of recovering recyclable materials. Reduction of misdirected recyclables in the residual bin will be directly related to the ongoing education of the community and businesses which is a shared responsibility of Governments, commercial and waste industry participants.

Under the current waste management system operating in Melbourne all residual waste is disposed to landfill. The wastes hierarchy (Figure 7-1) indicates that landfilling is the least preferable option and redirecting this waste for energy production will result in a higher order use of wastes and the consequent diversion rate of MSW from landfill for waste processed by the REA facility of greater than 97%. Furthermore, the metals, glass and other inert materials will be recovered from the gasifier slag and recycled.

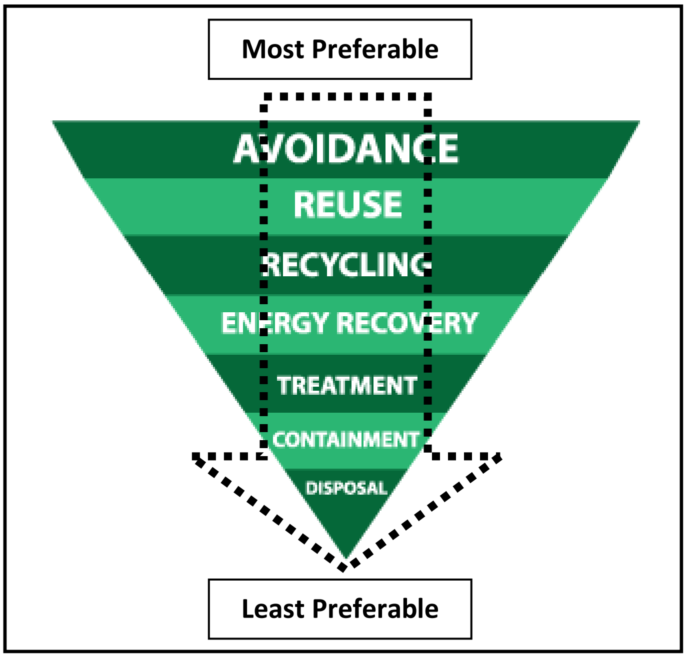

Figure 7-1: The Wastes Hierarchy

Moving up the hierarchy and reducing MSW directed to landfill will have a significant impact on greenhouse gas generation (GHG). While the operation of the plant will generate 59,493 tonnes of CO_2e per annum there will be a net reduction in emissions of GHG emissions of 237,007 tonnes of CO2e per year (Section 8.2.1) when compared with the current "business as usual" disposal to best practice landfill (which would incorporate optimised methane gas collection systems).

[71] Department of Environment and Energy (2016) *Australian National Waste Report*
[72]Sustainability Victoria (2018) *Statewide Waste and Resource Recovery Infrastructure Plan*
[73] MWRRG (September 2018) *Advanced Waste and Resource Recovery Technologies. Metropolitan Regional Business Case and Procurement Strategy*

Processing MSW through the gasifier system does generate several by-products. Up to 19.3% (depending on the extent of FOGO adoption) of the residual MSW is composed of non-organic materials and these will report to the gasifier bottom slag. This by-product will contain ferrous and non-ferrous metals, silica from glass and the residues from other inert materials such bricks and soil which find their way into the residual bin. Preliminary testing indicates that the gasifier bottom slag is likely to be suitable for recycling and in-principal agreements with a third parties[74] for further resource recovery and reuse in road base or similar earth-based products have been negotiated.

The REA system has been designed to be flexible specifically to accommodate changes in calorific value and composition of the MSW feed that will occur as waste types and recycling programs (such as FOGO and landfill bag bans) evolve over time. Focusing on the residual household waste bin, making allowances for FOGO and recycling of non-organic by-products provides Melbourne with an alternative to landfill disposal which promotes the higher order outcomes of resource recovery intrinsic to the intent of the waste hierarchy. The REA WtE proposal will supplement existing waste disposal and diversion infrastructure in Victoria.

7.4.3.4 The principle of integrated environmental management

In 2015-16 approximately 12.7 million tonnes of materials entered the waste management system in Victoria. This is projected to reach 20 million tonnes by 2046. At present, recovery and recycling rates are around 67% which indicates that around 4.2 million tonnes of waste is disposed to landfill[75]. While significant effort is being expended to improve the resource recovery sector it is likely that waste directed to landfill will continue to grow (Figure 7-2) at least in line with population growth. This is likely to be a conservative assessment as in a recent publication on the circular economy it states that "*in Australia, the waste we produce is growing at double the rate of our population— with 52 mega tonnes generated each year*"[76].

[74] REA have negotiated an in-principle Agreements with a third Parties who will accept all gasifier slag as is, provided it meets industrial waste Guidelines. This Third Party will process any metals and resize product to ensure compatibility for road base.
[75] Sustainability Victoria (2018) *Statewide Waste and Resource Recovery Infrastructure Plan*
[76] Otter C. (2018) The Circular Economy Research Note No. 10, Department of Parliamentary Services, Parliament of Victoria. http://apo.org.au/sites/default/files/resource-files/2018/10/apo-nid198946-1179331.pdf

Figure 7-2: Projected Quantity of Waste Directed to Landfill in Victoria[77]

Even the most efficient "best practice" landfills adversely impact on the environment and the amenity of nearby residents. Landfills impact by:

- Generating significant quantities of methane, carbon dioxide and other noxious gases which cause odour and contribute to climate change both while operating and after closure;
- Generating leachate which needs ongoing management while operational and post closure to prevent contamination of groundwater, surface water and storm water;
- Loose waste and/or inappropriate capping attracts disease carrying vermin and "fly away" dust and plastics causing issues for nearby residents.

Diverting materials away from landfill for viable recovery is intrinsic to the SWIRRP as it creates opportunities to reduce potential risks, capture value from our wastes and generate jobs. Figure 7-3 shows an analysis of carbon dioxide equivalent emissions per household using various waste management strategies for MSW. This data was supplied by MRA Consulting and was modelled on a typical Melbourne Metropolitan Council (Appendix 15). It is clear that continuing the existing management system where residual waste ends up in landfill has the worst outcome from a greenhouse gas perspective. Combining FOGO and composting with source separated recycling to MRF's and energy recovery from the residual waste is a significantly better option for reducing the CO_2 footprint than the other modelled scenarios.

The REA WtE facility will be based on recovering the energy from the residual waste stream. It has been designed to accommodate the impacts of wider FOGO implementation which, based of best outcome uptake, is expected to divert up to 50% of food waste from the current residual MSW composition.

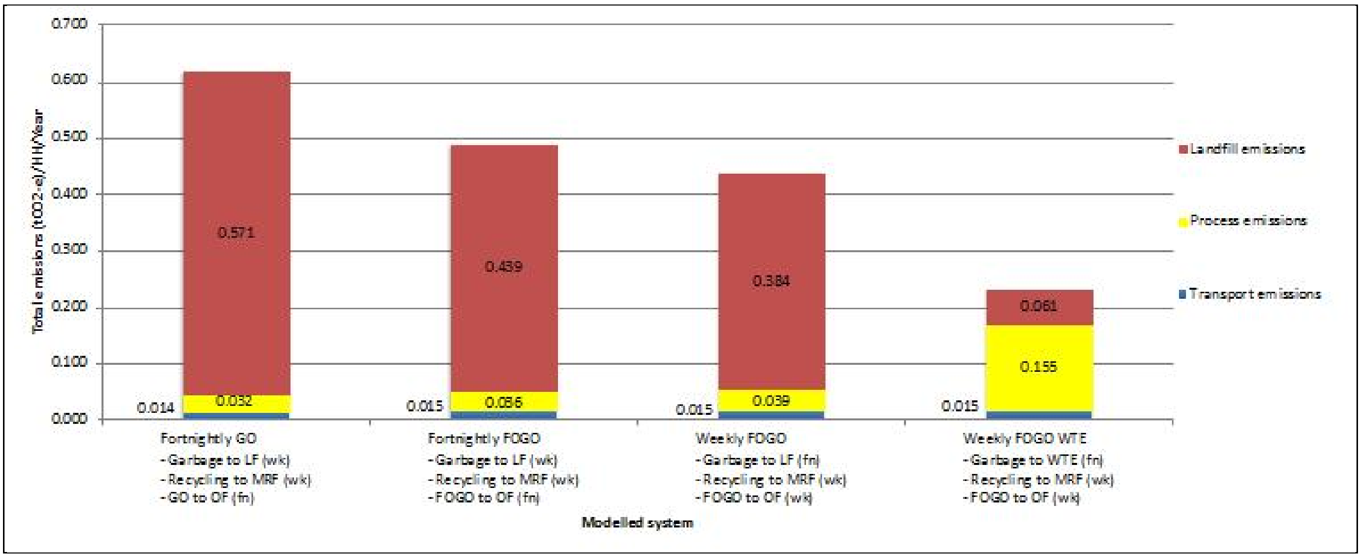

Figure 7-3: Prediction of CO2-e generation per household per annum with various strategies for MSW Management[78].

[77] www.sustainability.vic.gov.au/Government/Victorian-Waste-data-portal/Interactive-waste-data-mapping/Waste-projection-model

[78] Analysis and graph supplied by MRA Consulting modelled on a typical Metropolitan Council

7.5 Best Practice Assessment

The documents European Commission (2006) *Reference Document on Best Available Techniques for Waste Incineration,* Draft *Best Available Techniques (BAT) Reference Document for Large Combustion Plants* (2016) and Draft *Best Available Techniques (BAT) Reference Document for Waste Incineration* and Industrial Emissions Directive 2010/75/EU (2017) have been used as the best practice benchmark for the REA Proposal. Section 7.4.2 details best practice and shows how the REA plant complies with these guidelines. This section provides an overview of those best practices which specifically relate to flue gas emissions, odour and noise as these aspects were highlighted in the risk analysis.

7.5.1 Air Quality

7.5.1.1 Emissions from the Stack

The WtE facility will comply with the IED emissions limits and will also comply with the limits set out in the SEPP (AQM) where the SEPP introduces more stringent limits than those defined by the IED. The air quality impact assessment (Section 10, Appendix 14) concluded that the impact of the emissions is minimal with modelling demonstrating no predicted exceedances of any parameter at the sensitive receptors. The State Environment Protection Policy (SEPP Air Quality Management) *Schedule A* primary pollutants (i.e. NOx, SO_2, CO, PM_{10}, $PM_{2.5}$, F, Pb, HCl, Hg, Dioxins & Furans) were compliant with maximum concentrations only reaching up to 6% of the SEPP limits under normal operating conditions at the nearest sensitive receptor (i.e. 6% being for modelled NO_x when conservatively compared against the NO_2 criterion). The balance of the *Scheduled* parameters were modelled with the highest concentration at the sensitive receptor of 8.4% of the SEPP limit for arsenic.

The IED specify an emissions monitoring protocol for best practice WtE facilities. This protocol will be adopted by REA and the necessary monitoring equipment incorporated in the design. Pollutants such as Nitrogen Oxides (including N_2O), Ammonia, Carbon Monoxide, Sulphur Dioxide, Hydrogen Chloride, Hydrogen Fluoride, dust, Volatile Organic Carbon will all be monitored on a continuous basis. Metals and metalloids except mercury will be sampled and analysed on a time sequence to be negotiated but are normally every six months and Dioxin and Furan will be sampled and analysed normally monthly. The volatile metal, mercury will be monitored on a continuous basis.

The REA design takes the cleaned gases from each gasification line and feeds these through an induced draft fan prior to release to the atmosphere via an appropriately sized triple flue stack. The CEMS system collects stack emissions data on a real time continuous basis from each flue for those parameters detailed in the IED emissions monitoring protocol which are fed back to operations to facilitate automated adjustments of parameters such as the alkali injection to the acid gas control system. The CEMS will report time averaged emissions corrected for concentration of the gases in the stack in accordance with the IED Directive. On a regular basis the on-line data will be validated against stack sampling and NATA registered analysis. A summary of the environmental data and environmental compliance reports will be regularly uploaded to the REA web site.

A backup CEMS will be maintained in a ready condition which can be utilised when the duty CEMS is non-operational due to maintenance, calibration or other instrument faults.

7.5.1.1.1 Emission Control Strategies

The emissions control strategies are best practice based on a literature review of international WtE facilities and includes the BREF documents listed above.

The main factors requiring emission control in the process are; the levels of acid gases (SO_2, HCl, NOx), particulates ($PM_{10,}$ $PM_{2.5)}$, Carbon Monoxide (CO), volatile metals (eg. mercury (Hg), Cadmium

(Cd)) and post combustion synthesis products of hydrocarbons such as dioxins and furans. Detail on the flue gas treatment systems are found in Sections 6.3.7 and 6.3.8 and the emission dispersion modelling is detailed in Section 10. A summary of the multiple discrete processes and systems management strategies that are best practice and in combination, serve to control and ensure emissions are minimised is provided below:

- Maintaining gasifier temperatures above ≥850°C and syngas combustion chamber temperatures between 1100°C – 1200°C to induce near complete destruction of all hydrocarbons including the char generated in gasification;
- Controlled air flow through the gasifier maintains a low oxygen environment which minimises the potential for the generation of precursor organic molecules and the relative low air volumes in the gasifier minimise the generation of particulates;
- Gasification in a low oxygen environment minimises the formation of NOx compounds with the syngas combustion chamber operating temperatures above 1100C° but lower than 1200 C° also ensures the production of NOx in the flue gas is minimised;
- The risk of NOx levels spikes are alleviated by the availability of the SNCR nitrogen reduction system in the syngas combustion chamber that will activate if required;
- On-line measurement of flue gas parameters including flow rate, oxygen, carbon monoxide, hydrogen chloride, sulphur dioxide and nitrogen oxides allows effective management of the operation of the gasifier and the secondary oxidation chamber where the syngas is combusted;
- Installation of a semi dry operating acid scrubber to remove acid gases such as sulphur dioxide, hydrogen chloride and hydrogen fluoride and intermediate base metals such as arsenic through the introduction of atomised alkali;
- Installation of a powdered activated carbon injection system that dispatches activated carbon into the flue gas to capture and remove volatilised base metals and reformed hydrocarbons such as dioxins and furans;
- Installation of a baghouse flue gas filtering system to capture the products of acid neutralisation, the activated carbon and any particulates prior to reaching the stack.
- Certified CEMS monitoring system for measuring flue gas characteristics to enable real time feed back to automated and partially automated control systems to allow appropriate management of gasifier train conditions to minimise emissions.

7.5.1.2 Odour Emissions

The primary potential source of odour generation from the facility is the arrivals hall and the waste pit. Odour generation from these areas is primarily managed by drawing air from this area into the gasifiers and the secondary oxidation chamber where odour causing molecules are destroyed. This is best practice in WtE facilities.

Drawing air from the waste pit results in the creation of a negative pressure in both the arrival hall and the waste pit which effectively negates odour and dust emission from the facility. The potential for odour emissions emanating from the WtE facility have been modelled and reported in Section 10 and Appendix 14.

During steady state operations the waste pit will be operated with less than 2 days (<1200 tonnes) accumulation of MSW. Operating in this manner provides at a minimum 2 days additional capacity (1200 tonnes) during routine maintenance or upset or emergency events. The 1200 tonnes additional capacity in the waste pit can provide operational space for 3 days - 12 days depending on what components are isolated from the system. In this context, the design of this WtE facility has a number of advantages over a single furnace line typical of many other thermal WtE projects. Deploying a modular multi-gasifier design and multiple processing lines maximises availability by providing the ability to isolate and shut down individual gasifiers or processing trains while maintaining production capabilities during maintenance or upset conditions. This also ensures negative air pressure can be maintained in the arrivals hall and waste pit thus minimising the potential for the escape of odour.

Given the inherent redundancy integral to this modular system it is therefore unlikely that all gasifiers and all processing lines will suffer outages at the same time. However, in the extreme case where this could occur, contracted waste will immediately be diverted to landfill. Odour generation in these circumstances will be controlled by keeping the waste pit doors closed, continue to operate the draft fans maintaining negative pressure in the arrivals hall and waste pit and by atomising a deodorant into the air space of the waste pit. A backup diesel powered generator is available for management of important operating and monitoring systems should complete power loss occur.

7.5.1.3 Noise Emissions

A noise impact assessment is presented in Section 11 which shows compliance with SEPP-N1 limits in all circumstances.

Noise management derived from vehicular movements will be managed by ensuring that all vehicles delivering MSW, equipment and reagents to site comply with the noise limits specified in the Vehicle Standard (Australian Design Rule 28/01 (ADR 28/01) – External Noise of Motor Vehicles) 2006. Speed limits will be strictly enforced on the arrival ramp and reversing of vehicles will occur within the enclosed MSW receival building where noise from reversing beacons will be mitigated by fast acting roller doors and the sound insulated building structure.

The noise associated with the power plant is derived from a number of sources. Gas dynamic noise is generated by the draft fans, blowers, steam turbine and high pressure pipeline and boiler exhaust steam. Mechanical noise is generated from a variety of pumps and air cooling fans while electromagnetic associated noise is derived from electrical equipment (generator, transformer etc.).

Enclosure of the entire processing area inside buildings reduces noise into the surrounding area considerably. Noise control is achieved by specifying that equipment suppliers meet noise control standards, isolation of noisier components of the plant behind sound proofed walls and doors, installation of specific sound insulation covers on the steam turbine, installation of mufflers on the air blowers and silencers on the boiler safety valves, installation of anti-vibration engine mounts, sound proofing of central control room and provision of appropriate PPE for operations personnel when working within the processing areas. Inspections of operating facilities demonstrate extremely low noise levels generated within or outside of the processing plant.

7.5.1.4 Energy Efficiency

Greater energy efficiencies from WtE facilities can be obtained by utilising the steam for heating rather than for the generation of electricity. However, using steam for heating requires a sizable and relatively constant demand for steam. The proposed location of the WtE facility is within a developing Industrial estate. Discussions have been conducted with the owners of the estate and in-principle agreements have been reached allowing REA to access easements to provision any steam and/or low grade heat requirements to new tenancies as they develop within the surrounding estate and adjacent industrial zone.

Firm commitments are unlikely to eventuate until the Works Approval process is complete and final design has been accepted. REA has instructed the engineering team to ensure that the options for combined heat and power (CHP) are included in the design to facilitate the potential provision of steam or heat to third parties as demand is identified.

At this time REA have determined that steam to electricity for distribution to the grid to be the default option for energy dispatch from the facility.

The EPA require an assessment of thermal efficiency based on the calculation of the R1 Efficiency Indicator as defined in European Union's Waste Framework Directive 2008/98/EC . For a plant to be considered a genuine energy recovery facility, R1 will be expected to be equal or above 0.65.

The R1 factor has been calculated for this project based on the characteristics of the MSW assessed by HRL and using 3 scenarios. The scenarios are:

- The projected composition of residual MSW in 2021 with partial adoption of FOGO and a calorific value of 11.3MJ/kg;
- The composition of residual MSW as it exists at present;
- The composition of residual MSW assuming the adoption of FOGO (50% reduction in food waste entering the residual bin).

The details of these calculations are presented in Appendix 6. These calculation estimates R1 factors of 0.745, 0.752 and 0.738 respectively which comfortably exceed the levels for the plant to be considered a genuine energy recovery facility. It is noteworthy to point out that REA have opted to sacrifice some energy efficiency by specifying air cooled chiller condensers which are relatively high energy consumers when compared with water fed cooling towers in order to minimise mains water requirements. Air cooled condensers are considerably more water efficient than water cooled alternatives.

7.6 Conclusion

The REA WtE facility complies with the wide range of best practice guides and processes. These include:

- Premising the project on the treatment of residual waste which may divert more than 97% from landfill securing significant greenhouse gas savings and elevating the residual waste stream to a higher value outcome within the waste hierarchy;
- Compliance with the EU IED emission levels and monitoring requirements;
- Installation of a certified CEMS for continuous monitoring flue gas characteristics;
- The use of negative pressure in the arrival hall and waste pit as the major mechanism for odour control;
- Installation of best practice flue gas treatment systems and equipment including alkali injection, activated carbon injection and baghouse filtration;

7.7 Choice of Process and Technology

REA directors have spent many years evaluating the technical and commercial viability of a wide variety of thermal, biological and hybrid technologies for their suitability to process various and evolving waste compositions at a scale and to the criteria necessary to be commercially, environmentally and socially acceptable in the Melbourne waste context. The range of pathways investigated has included conventional incineration, gasification, steam reformation, pyrolysis, mechanical biological treatment (waste sorting with anaerobic digestion), anaerobic digestion, and combinations of these processes. The evaluation process highlighted that thermal treatment of residual wastes utilising the Advanced Thermal Treatment (ATT) technology selected (gasification) offers the best opportunity to generate energy from waste while meeting the environmental and social expectations of the community at a scale and price point necessary to be acceptable and practical in the Melbourne context (Section 1.3.4).

The REA gasification technology was selected specifically for its demonstrated capability and history of processing mixed residual waste of a nature and composition typical of that now going to landfill in Melbourne. REA is committed to maintaining the integrity of Victorian recycling objectives. The modular nature of the gasification technology provides for relatively small-scale facilities that are less demanding on local waste systems for supply and consequently, offer less chance of waste volume demands potentially undermining recycling programs.

REA will predominantly use the waste derived from the residual bin system and have allowed in their design for the wider acceptance of FOGO in the source separation process. The proposal is intended to supplement rather than undermine recycling programs.

Any assumption that the inclusion of waste to energy in the mix of treatment options for MSW will reduce recycling is not borne out by international experience. A study conducted in 2013 by EEC "*Disposition of MSW in various countries*"[79] (Figure 7-4) shows the percentages of MSW recycled, landfilled and used in energy production. While Australia has a moderate recycling rate of slightly more than 40% and a high landfill rate, countries in Western Europe, United Kingdom, Taiwan, Korea and Singapore where waste to energy represents greater than 20% of the mix have significantly higher recycling rates than Australia. Adoption of WtE for MSW does not necessarily correlate with a reduction in recycling.

[79] Worrel W.A. et al (2013) Solid Waste Engineering: A Global Perspective. Ch2, Municipal Solid Waste Characteristics and Quantities

Figure 7-4: Percentages of MSW Recycled, Landfilled and Used in WtE

7.7.1 Merits of the Selected Technology

Gasification was originally used as a higher end technology for treatment of hazardous waste and has historically been more expensive to build and operate. In more recently times, costs of construction and operation have decreased and this ATT technology is increasingly being selected for smaller scale municipal and industrial waste treatment.

The key consideration for the selection of gasification was to obtain a commercially viable technology which could operate at relatively small scale, processing MSW that would provide a distributed disposal option suited to servicing the local requirements of a minimal number of Council areas. This objective supports the premise of community equity by offering “a local solution for a local problem”. REA will provide councils the option to secure a local solution for their own waste and giving them the opportunity to meet their (and State) carbon reduction targets through the reduced emissions they will derive by reducing the waste transport distances, the emissions generated from landfilling their waste and from the generation of renewable base load energy. At a high level, the choice of an ATT process (gasification) was deemed optimum and preferable to typical thermal combustion processes on the basis that:

- The modular nature of the installation provides for greater process control and availability due to the inherent manageability of multiple units integrated across multiple lines. This flexible layout allows for the distribution of the load and provides for more discrete management, monitoring and immediate fault response than typical of larger combustion processes;
- Conceptually and practically, the controlled air environment prevents combustion of the waste which presents as a socially superior process than incineration;
- The very high temperatures of the process provide for almost complete destruction of organic compounds in the waste minimising the potential for the formation of dioxins and furans;
- The combination of high temperatures and low air in the gasifiers causes the molecules in the waste to separate and form a gas which is effectively a concentration of the energy embedded in the waste. As there is limited air in the gasifier the low availability of oxygen results in limited potential to form oxides of Nitrogen and other contaminants requiring oxygen in their formation. The consequence of this is that the gasifier produces a gas which, without additional energy input, can be combusted further at temperatures, which unlike other processes, is sufficiently high that there is very low risk of toxins passing through the process.
- This gasifier design provides considerable flexibility to process variations in the waste composition as it evolves over time;
- The process generates a very small relative amount of residual fly ash and, consequently achieves high percentage diversion from landfill;
- It can be cost comparative with prevailing landfill gate fees at relatively small scale;
- Community consultation in the west of Melbourne has indicated that having “mega” waste sites (either landfills or otherwise) is not appropriate. The modular vertical design of the gasifier provides for a relatively compact site layout more suited to urban location;
- Residual MSW generated in individual Council areas is generally less than 40,000 tonnes per annum. REA considers a local solution would typically encapsulate no more than 5 municipalities. Therefore, an appropriately sized and located facility should be sized accordingly.

Incinerators in operation processing MSW are generally of large scale in the range 300,000 – 1,800,000 tonnes per annum with the relative gate fees and energy prices ultimately dictating their minimum economic scale. Operating Gasification systems range in size from 3,000 – 300,000 tonnes per annum. While there is some overlap in processing size, gasifier technology is typically modular providing better scope to be deployed for smaller volumes of waste or where staged capacity is required.

Further considerations were related to capital cost, operating cost, pre-treatment requirements, input energy, operating temperature, air emissions and solid waste generation. These considerations are summarised in Table 7-2.

Comparison of Gasification and Incineration			
Aspects	**Gasification**	**Moving Grate Incineration**	**Circulating Bed Incineration**
Pre-treatment Requirements	Low Requirement	Low Requirement	Higher Requirement – separation and shredding usually needed
Additional Fuel	No	Potentially	Yes

Mechanism	The waste gasified to generate syngas and then the syngas is combusted	Waste combusted directly on the grate	Mixed with additional fuel in a fluidized bed
Internal Material Requirements	Grate works in relatively low temperature environment and does not need specialized metal	Complex grate which requires specialized metal for operation in high temperature environment	Requires specialized material for air distribution and a high requirement for refractory materials
Operation	Relatively easy to start up and shut down and change adjustments. Can have managed shutdown across modular component increasing availability	Needs relatively longer period for start up, shut down and adjustments	More difficult to start up, shut down and operate but relatively easy to adjust
Energy Consumption	Low	Low	Higher
Operating Temperature	Gasifier 850º -1050ºC Secondary Combustion Chamber 1100º – 1250ºC	Furnace 850º – 1000ºC	Furnace 650º – 950ºC
Dioxin/Furan Generation	Low	Low	Low
Furnace turbulence	Minor turbulence caused by rotating grate, low air turbulence resulting particulate generation ≤3000mg/Nm³	Moderate level of turbulence resulting from air input. Particulates 6000 – 8000mg/Nm³	High pressure in furnace, high level of turbulence. Particulates 15000 – 20000mg/Nm³
Fly Ash	< 1% of feed, with alkali and activated carbon <2% of feed	5% – 8% of feed	8% - 12% of feed
Requirement for Acid Gas Scrubbing	Low - concentrations of SO_2, NOx low.	Moderate – higher concentrations of SO_2, NOx	Highest – highest concentrations of SO_2, NOx
Bottom ash/slag, LOI	Up to 15% of feed. LOI <3%, new plants <1%	Up to 15% of feed. LOI <3%, new plants 1% - 2%.	Lowest slag creation. LOI <1%
Project Scale	25t/d – 900t/d	>600t/d	>400t/d
Electricity Output	Low internal consumption, good electricity output	Low internal consumption, good electricity output	High internal consumption Poorer electricity output
Relative Operating Cost	Moderate	Moderate	High
Relative Capital Cost	Low	Moderate	High

Table 7-2: General Comparison of Gasification and Incineration

A recent study published by the City of Port Philip considered various thermal pathways and highlighted its preference for gasification over traditional incineration[80] (Figure 7-5). This table is included as a current reflection of a typical metropolitan community's perception of thermal waste processing options.

[80] City of Port Philip (2017) Don't Waste It. Draft Waste Management Strategy 2018 - 2028

COMPARISON: ADVANCED WASTE TREATMENT PROCESSES

	Our Current Process	Biological Process		Thermal Process			
Initial Assessment	Landfill	Mechanical Biological Treatment	Anaerobic Digestion	Grate Incineration	Gasification (two stage)	Pyrolysis	Plasma Arc Gasification
Significantly reduces GHG* emissions	✗	✓	✓	✗	✓	✓	✓
Generates renewable/non-fossil fuel gas for end use energy supply	✓	✓	✓	✗	✓	✓	✓
Waste diversion target	✗	✓	✓	✗	✓	✓	✓

*GHG = Green House Gas *(Source: Improved Resource Recovery within Fishermans Bend (Feasibility Analysis September 2017)*

Figure 7-5: Comparison of Advanced Waste Treatment Processes

7.7.2 Technology Supplier Considerations

REA have chosen the Eco-Waste gasification technology as this technology includes:

- The vertical rotating gasifier which has a demonstrated history of successful operation on a variety of waste particularly mixed low calorific waste similar to that comprising Melbourne residual MSW.
- The unique rotating grate and gasifier are proven to minimise the risk of slag and ash blockages characteristic of mixed waste gasifiers. The rotating gasifier also ensures the waste is continually mixed to maintain thermal integrity and exposure necessary to facilitate maximum destruction of carbon in the waste and conversion to energy;
- Surpasses the required emissions outcomes;
- Proven technology with commercial plant operational experience of 14 years;
- Constructed in gasifier modules of 25t/d – 175t/d and therefore offers flexible sizing suited to the residual waste processing requirements of small groups of Councils;
- Supported by a global scale reputable EPC contractor;
- Cost competitive capital and operational costs;
- Meets the criteria for investor, regulator and community endorsement based on prevailing Melbourne waste market conditions;
- Consistent in scope with the intent of the Melbourne SWRRIP.