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Process and technology options for treatment of Municipal Solid Waste

NSW Environment Protection Authority

Final Report

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Process and technology options for treatment of Municipal Solid Waste

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Definitions

Term	Definition
Alternative Waste Treatment (AWT)	An umbrella term for sophisticated technologies that accept residual waste as an alternative to landfill. (Blue Environment and Randell Consulting, 2018). In international literature Alternative Waste Treatment refers to the use of technologies that convert MSW into energy (refuse derived fuel), or other useful by-products, including biogas, and organic outputs derived from separating and treating the organic fraction of MSW using Mechanical Biological Treatment (MBT). In NSW, and for this report; Alternative Waste Treatment will explicitly refer to the Mechanical Biological Treatment process which produces an organic output referred to as 'mixed waste organic output' or MWOO.
Anaerobic Digestion	Anaerobic digestion in this report refers to a controlled biological degradation of organic wastes by microbial activity in the absence of oxygen (see Report into Alternative Waste Management technologies and Practices Inquiry, April 2000).
BAU	Business as Usual
Beneficial Re-use	The NSW EPA states, "To be considered beneficial, the properties of a waste derived fertilizer or soil amendment must be comparable to a commercially available fertilizer or soil amendment" and that "The NSW EPA's policy includes a requirement that waste to land activities cause no net accumulation and irreversible/long term adverse effects on the environment." (Technical Advisory Committee, 2018)
Bioaccumulation	The process of the accumulation of a contaminant in an individual organism's tissues.
Biomagnification	The process of the transfer of a contaminant in an organism to another organism via consumption. The contaminant increases in concentration as it moves up the trophic levels.
Biowaste	Biodegradable garden and park waste, food and kitchen waste from households, offices, restaurants, wholesale, canteens, caterers and retail premises and comparable waste from food processing plants. (Arcadis, 2010). In NSW this is called source separated garden and organic waste.
Calorific Value	Calorific Value or heating value is the amount of energy contained in a substance measured by the amount of heat released during the complete combustion of a specific amount of the substance, typically expressed in Megajoule per kilogram (MJ/kg).
Composting	Composting is the biological decomposition and stabilisation of organic substrates, under conditions that allow development of thermophilic temperatures as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land. (Haug, 1993). Compost produced and land-applied in NSW must meet the Compost Order 2016, and only contain the inputs specified in the order.
Energy from Waste Facility	A facility that thermally treats a waste or waste derived material, which is not an eligible fuel and which has as one of its primary purposes to create energy, typically as heat or electricity.

Term	Definition
Hazardous Waste	The following waste types (other than special waste or liquid waste) have been pre-classified by the EPA as ‘hazardous waste’ under the *Waste Classification Guidelines* (NSW Environmental Protection Authority, 2014): Containers, having previously contained a substance of Class 1, 3, 4, 5 or 8 within the Transport of Dangerous Goods Code, or a substance to which Division 6.1 of the Transport of Dangerous Goods Code applies, from which residues have not been removed by washing or vacuuming, Coal tar or coal tar pitch waste (being the tarry residue from heating, processing or burning of coal or coke) comprising of more than 1% (by weight) of coal tar or coal tar pitch waste Lead acid or Nickel-cadmium batteries (being waste generated or separately collected by activities carried out for business, commercial or community service purposes) Lead paint waste arising otherwise than from residential premises or education or child care institutions Any mixture of the wastes referred to above.
Human Health and Ecological Risk Assessment (HHERA)	A risk assessment matrix used to assess the impact an action or development may have on human or ecological health in the present and future.
Inorganic Fraction	The fraction of a waste stream, which is not biodegradable. In this report inorganic is refers to materials such as plastic, metal and glass in the MSW stream.
Mechanical Biological Treatment (MBT)	An internationally used term for treatment that processes municipal solid waste to extract recyclables through mechanical treatment and process the organic fraction through a biological process step (such as composting or anaerobic digestion) to create a stabilised organic-rich fraction for land application, landfilling and/or energy recovery.
Mixed Waste Organic Outputs (MWOO)	‘Mixed waste organic outputs’ is the NSW term for the pasteurised and biologically stabilised organic outputs produced from the mechanical biological treatment of mixed waste at an alternative waste treatment facility.
NSW EPA Resource Recovery Orders and Exemptions (RRO/E)	Resource recovery orders are orders made under clause 93 of the *Protection of the Environment Operations (Waste) Regulation 2014*, which involve conditions that suppliers of waste must meet in order to supply waste to which a resource recovery exemption applies. Resource recovery exemptions are exemptions made under clauses 91 and 92 of the *Protection of the Environment Operations (Waste) Regulation 2014,* which involve conditions that consumers of waste products must meet in order to use waste outputs for land application, fuel or thermal treatment.
Organic Fraction	The organic fraction of a waste stream in this report is the food and plant matter, which is biodegradable, and also includes wood.
Persistent Organic Pollutants	Carbon-based pollutants which are long lasting in the environment and are capable of bioaccumulation and biomagnification. The pollutants are often severely damaging to human and ecological health. (World Health Organisation, 2010)

Term	Definition
Precautionary Principle	The *Protection of the Environment Administration Act 1991* defines the Precautionary Principle as: If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. Decision making should be guided by: (i) a careful evaluation to avoid serious or irreversible damage to the environment wherever practicable; and (ii) an assessment of the risk-weighted consequences of various options.
Refuse Derived Fuel	Refuse Derived Fuel (RDF) is the combustible portion of a waste stream that has undergone processing in order to either eliminate non-combustible materials from the fuel or produce a fuel with certain agreed specifications. RDF is sometimes also called PEF (Process Engineered Fuel) or SRF (Solid Recovered Fuel). Only SRF is an internationally defined term in the sense that has an EU standard, which classifies SRF into 5 different classifications mostly on their difference in calorific value (CV) and Chlorine content (see also CEN/TC343).
Sewage Sludge Directive 86/278/EEC	A European Union directive aimed at regulating the use of sewage sludge in agriculture as to encourage it's use while preventing harmful effects on soil, vegetation, animals and people. (European Union, 1986)
Source Separated Compost	Compost produced from organic waste that is collected as a separate waste stream at the point of waste generation (usually by consumer or manufacturer). This process allows for a cleaner target material type where contamination is minimised.

Executive Summary

The NSW Environment Protection Authority (EPA) is seeking guidance on the process and technology options commercially available to further remove physical and chemical contaminants from Mixed Waste Organic Output (MWOO) produced at alternative waste treatment (AWT) facilities in NSW. The EPA is also seeking information on alternative pathways for the use of AWT facilities in NSW. This includes assessing how existing AWT facilities can be modified to produce a refuse derived fuel (RDF) as a new output, or treat source separated Food and Garden Organics (FOGO) as a new input. To further understand the context of AWT use globally, the EPA also sought information on municipal solid waste (MSW) processing across Europe including the destination of the processed outputs. This feasibility study report details the methodology, analysis and findings for each alternative pathway for use of AWT facilities, including an assessment of AWT use in a European context.

Summary of Key Findings

- The alternative process options reviewed as part of this study broadly align with Business as Usual (BAU) AWT operations, with some options requiring higher capital investment and longer implementation timeframes where re-engineering and installation of new technology is required.

- There are no known technical barriers to producing RDF as an output or accepting FOGO as an input. The barriers for these options are related to securing sustainable market supply and demand as well as renegotiating contractual obligations. These barriers impact the timeline on when these alternative options could be feasibly implemented.

- A key recommendation from the 2018 Technical Advisory Committee (TAC) Report to the EPA titled *Alternative Waste Treatment – Mixed Waste Derived Organics* was *that 'A limit for physical contaminants having a diameter < 2mm should be set'.* This project did not identify any commercially available sorting technologies that have proven to successfully detect and sort out physical contaminants below the 2mm fraction in a mixed organic waste stream. Technology suppliers have indicated that the smallest particle size that can be removed with confidence is between 6 to 5mm. This may impact the extent to which AWT operators can achieve acceptable physical contaminant levels required for an improved MWOO, dependent on what those acceptable levels are. All of the AWT operators interviewed were confident in their opinion that they can significantly reduce physical contamination of metals, plastics and glass to create an improved MWOO. The level of investment into new processes and technologies is dependent on the contamination limits set for the output but is estimated to be in the order of up to $20-30 million per facility or process change.

- Commercially available sorting technologies target the removal of physical contamination and are not designed to address chemical contamination. It is acknowledged that a proportion of chemical contamination can be successfully removed by removing the associated sources of contamination, for example removing lead acid batteries to reduce lead contamination. There is no readily available data to support the notion that the removal of certain physical contaminants will have an impact on the concentration of the series of chemical contaminants identified as a concern in the TAC Report. Literature and stakeholder engagement support that the most effective way to address chemical contamination is at the source, where education campaigns or alternative hazardous waste services could be implemented.

- The majority of European countries have established, or are in the process of establishing, mandated source separation of household organics as a key initiative to meet the European Union target of recycling 65% of municipal waste by 2030. Generally, European countries use AWT or Mechanical Biological Treatment (MBT) facilities to treat residual household waste for use as an alternative fuel source to fossil fuels and as a source of thermal energy for district heating, not for land application. By 1

January 2027 stabilised organic outputs from MBT facilities will no longer count towards recycling targets. The market for RDF is dependent on the type of offtake facility, as well as the quality and the calorific value of the output.

Project Background

In October 2018, NSW EPA made a regulatory decision to stop the application of MWOO to agricultural land and to cease its use on plantation forest and mining rehabilitation land until further controls have been considered. This decision was prompted by environmental and human health risks associated with MWOO that were identified during a comprehensive scientific research program commissioned by the EPA, conducted over seven years (2010-2017). These findings were summarised in the TAC report.

In November 2018, Jacobs in partnership with Jackson Environment and Planning (J&JEP) were commissioned by the NSW EPA to perform an alternative market options analysis for MWOO application. The key finding of this report was that all market options assessed have barriers that need to be overcome. The following two market options were concluded to have fewer constraints and could be considered further:

- Option 1.2: Revised RRO/E or alternative legal instrument for mine site rehabilitation including revised limits for chemical and physical properties. This option will require investment in new sorting/processing equipment to meet lower physical contamination thresholds.
- Option 2.1: Use as daily landfill cover in NSW in compliance with landfill guidelines.

A key management recommendation made in the TAC report was that '*better engineering/technology is needed to reduce sources of metals/plastics/glass during processing of waste if MWOO is to be applied to land'.* The EPA sought further guidance on the applications and limitations of commercially available technologies to adequately address contamination.

Study Overview

Jacobs in partnership with Full Circle Advisory (Jacobs) were commissioned by the EPA to review the process and technology options to further remove physical and chemical contaminants from MWOO, and comment on the technical feasibility of the alternative pathways for the future use of AWT facilities in NSW.

The alternative pathways for AWT facilities have been identified as:

Pathway One: Continue to process Municipal Solid Waste (MSW) as an input under the following three process options:

1) *BAU*: Maintain current technical processing to recover recyclable material and sending pre-treated organic waste to market[1].
2) *Improved MWOO*: Increase technical processing to reduce physical and chemical contamination of MWOO.
3) *RDF Output*: Change technical processing to produce alternative output of refuse derived fuel (RDF).

Pathway Two: Accept source separated food and garden organics (FOGO) as an input to produce compost quality to meet the *Compost Order 2016* (the Compost Order).

Pathway Three: Accept an organics-depleted MSW as an input under the following two process options

[1] The pre-treated organic waste is currently being sent to landfill, following the revocation of the Resource Recovery Orders and Exemptions for land application of MWOO. From November 2018 the application of MWOO to landfill has been given a 12-month waste levy exemption as published in the NSW Government Gazette (NSW Government , 2018).

1) *Do Nothing*: Continue to process MSW to sort out recyclables and create a stabilised organic output, with a reduced organics content.
2) *RDF Output*: Change technical processing to produce alternative output of refuse derived fuel.

Jacobs undertook the following steps in the development of this report:

1) **Perform Stakeholder Consultation**: To understand local market capabilities and technologies currently available through consulting with technology/equipment suppliers, and to gain access to intelligence AWT operators may have on technologies and processes based on internal research conducted.
2) **Conduct Literature Review**: To further understand the ability of selected technologies and processes to address chemical and physical contamination in MWOO or provide a feasible alternative pathway for the AWT facilities in NSW. To review current European practice for treatment of MSW, specifically focussed on the use and penetration of AWT facilities.
3) **Provide Overview of Alternative Pathways for AWT facilities in NSW**: To develop representative process flow charts for each of the alternative pathways such that their technical feasibility as a future pathway can be assessed.
4) **Assess the Technical Feasibility of Alternative Pathways:** Answer a series of research questions regarding the feasibility of commercially available technologies and/or processes that could potentially be implemented by NSW AWT operators.
5) **Deliver Technology and Process Review Report**: To provide options for the available technologies and processes to address physical and chemical contamination of MWOO for AWT facilities and assess the technical feasibility of alternative pathways for AWT facilities in NSW.

Limitations of the Analysis

It is recognised that there are limitations in this feasibility assessment. These have been identified as:

- The time frame in which literature review was conducted has limited the breadth of the review under some pathways.
- The project team relied on information provided in the TAC report, as the HHERA commissioned by the NSW EPA was not yet completed. The results of the trials conducted under the seven-year research program were not provided to inform this report.
- The sampling data behind all of the claims made throughout this report regarding the sorting capabilities of suggested technology have not been sighted by the project team.
- Each site in NSW has unique circumstances that could not be directly addressed in this report. Whilst some of the AWT operators have made available very generalised flow charts about how they think an improved MWOO could be achieved, a much more detailed technical and engineering discussion would be required to determine the technical feasibility and the costing of an improved MWOO for each site.
- The costs provided for technologies are not always in Australian dollars, as these have been informed by overseas sources. Some costings are dated and will be subject to increases in annual Consumer Price Index (CPI).
- This report has been developed as follow on work from the Alterative Market Options Feasibility Study performed by J&JEP (2019). It is assumed that this report is read in conjunction with the previous report.

Overview of an AWT process in NSW

AWT facilities in NSW process municipal solid waste (MSW) to extract recyclables and create a stabilised organic-rich fraction through a composting process originally destined for land application. As of October 2018, each NSW AWT facility has continued to process MSW under the same processing operations despite the regulatory changes regarding land application. From November 2018, the processed MWOO has been sent to landfill under a waste levy exemption for a 12-month period (NSW Government , 2018). For the purposes of this report, this process is identified as *Pathway One: BAU*.

In terms of technical processes, all of the NSW AWT facilities include the following generic process steps:

- Material receival.
- Material stream preparation.
- Material stream separation.
- Biological treatment.
- Material refinement.

A generic process flow chart has been developed by Jacobs to reflect the operations of NSW AWT facilities, see Figure 1.

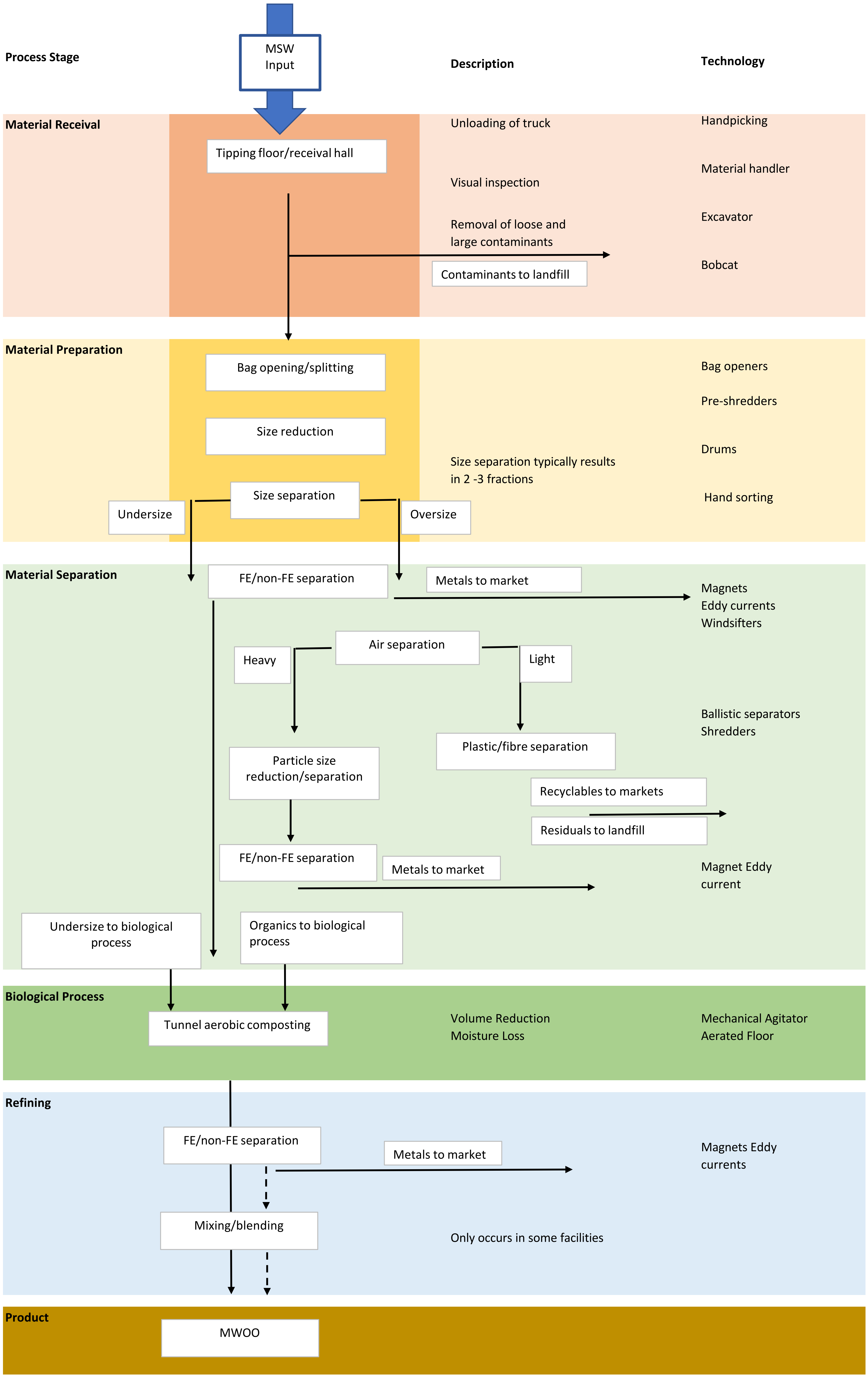

Figure 1 Overview of generic AWT processing

Stakeholder Engagement

AWT Operators

A questionnaire was sent to NSW AWT operators prior to follow up stakeholder meetings. The questions focused on gaining an understanding of the level of investigation AWT operators have undertaken to assess the feasibility of the identified alternative pathways and associated process options. Figure 2 shows an overview of the feedback provided by the AWT operators for the process options under Pathway One. All operators noted that there are no technical constraints to accepting FOGO under Pathway Two, constraints are related to contractual and market barriers. The responses to Pathway One were used to inform the outcomes of Pathway Three.

Pathway One: BAU

- Not sustainable practice due to contractual breaches of not meeting diversion targets

Pathway One: Improved MWOO

- **Addressing Physical Contamination**
  - Processes and technology can be installed to increase the removal of glass, paper and metal contamination.
  - The level of investment into additional technologies or processes is determined by the specifications of the product.
  - Increased equipment sensitivity and new optical sorting technologies have been proposed as feasible options for reducing physical contaminants.
  - There are no known commercially available technologies that can sort out plastic of particle sizes <2mm.
- **Addressing Chemical Contamination**
  - Separation at kerbside is the most effective way to reduce chemical contamination.
  - It is proposed that the removal of physical contaminants identified as the sources of chemical contamination early in the sorting process will reduce the level of chemical contamination in the final product.

Pathway One: RDF Output

- Current technology and equipment can be utilised for producing RDF, although re-engineering and some additional purchases may be required.
- The key barrier to producing RDF is the lack of local demand. Some smaller scale opportunities for cogeneration may offer a shorter term solution.
- There are generally two markets for RDF
  - Cement kilns, ceramic and brick processing require RDF of a high calorific value (CV).
  - Coal fired plants or Energy from Waste facilities require RDF of a lower CV.
- The NSW EPA Energy from Waste Policy Statement (2015) as it stands may limit the market accessibility of RDF produced from MSW

Figure 2 Overview of AWT operator engagement

Waste Treatment Technology Suppliers

Individual interviews were conducted with selected waste solutions technology suppliers (Waste Treatment Technologies (WTT), Cemac Technologies (Cemac) and Steinert). Technology suppliers were selected based on the expert knowledge of the project team and input provided by the AWT operators during the engagement process. A questionnaire was sent to each supplier prior to a follow up phone interview to gain an understanding of the technical feasibility of the identified alternative pathways and associated process options. Figure 3 shows an overview of the feedback provided by the suppliers.

Pathway One: BAU

- There are no technical barriers for an existing operation.
- Globally, the stabilised organic fraction is destined for landfill as a long term, feasible process option.

Pathway One: Improved MWOO

- Sorting investment is dependent on the level of contamination of the input and the accepted purity level of the product.
- **Addressing Physical Contamination**
  - Optical Sorting: The sensors most used in the context of sorting contaminants from organics or compost are NIR, laser or x-ray sensors.
  - A key limiting factor of these sensors is particle size, with the smallest particle size that can be removed with confidence is between 6 to 5mm.
- **Addressing Chemical Contamination**
  - Commercially available sorting technologies do not have chemical sorting capabilities.
  - Reducing physical contamination, may however reduce the presence of certain chemical contaminants.

Pathway One: RDF Output

- RDF production is widely carried out in Europe and the US, and there are no technical limitations as to why this process could not be achieved in NSW.
- The key barrier to producing RDF is the lack of local demand.
- As identified by operators, AWTs typically produce either a high calorific value (CV) or low CV RDF, or both destined for separate markets.
- Producing a low CV RDF follows a similar process to AWT BAU, where the organic and combustible fraction can remain together.
- Producing a higher CV RDF means removing materials with a low CV such as organics, as well as materials containing chlorine (Cl) such as Polyvinyl Chloride (PVC) plastic to meet required standards.
- The organic fraction in an MBT producing high CV RDF can be treated via anaerobic digestion to produce biogas for energy generation and a digestate that can be sent to landfill, land reclamation or highway projects.

Figure 3 Overview of Waste technology supplier engagement

Literature Review

The purpose of the literature review was to:

- Provide an overview of which processes and technology options are in use in Northern/Southern Europe, including best practice options for AWT outputs.
- List example AWT facilities and their associated processes, including the quality and destination of the outputs and processing technologies used.
- Outline where there are differences in the reference facilities to the NSW AWT BAU process.
- Summarise the literature responses addressing physical and chemical contamination in MSW.

Overview of AWT Processes in Europe

Within the European Union (EU) landfilling is less than 10% in countries such as Belgium, the Netherlands, Denmark, Sweden, Germany, Austria and Finland. This is achieved through high rates of recycling, separate biowaste collection (green waste and food waste) and utilisation of Energy from Waste facilities; where non-recyclable waste is processed (RDF) and incinerated for heat and energy generation. Notably, as of 2010 some of the EU countries with the highest percent of waste to landfill also have some of the higher MBT capacities, see Figure 4. Although not at the same diversion rates yet, Southern European countries such as Italy and Spain are generally mandating source separated organics collection, implementing landfill taxes and extended producer responsibility schemes (European Commission, 2019)[1]. Countries that are at risk of not meeting their EU landfill directives, such as Greece have been advised by the European Commission to reallocate funding from MBT facilities towards initiatives that achieve outcomes higher up the waste hierarchy (European Commission, 2019)[2].

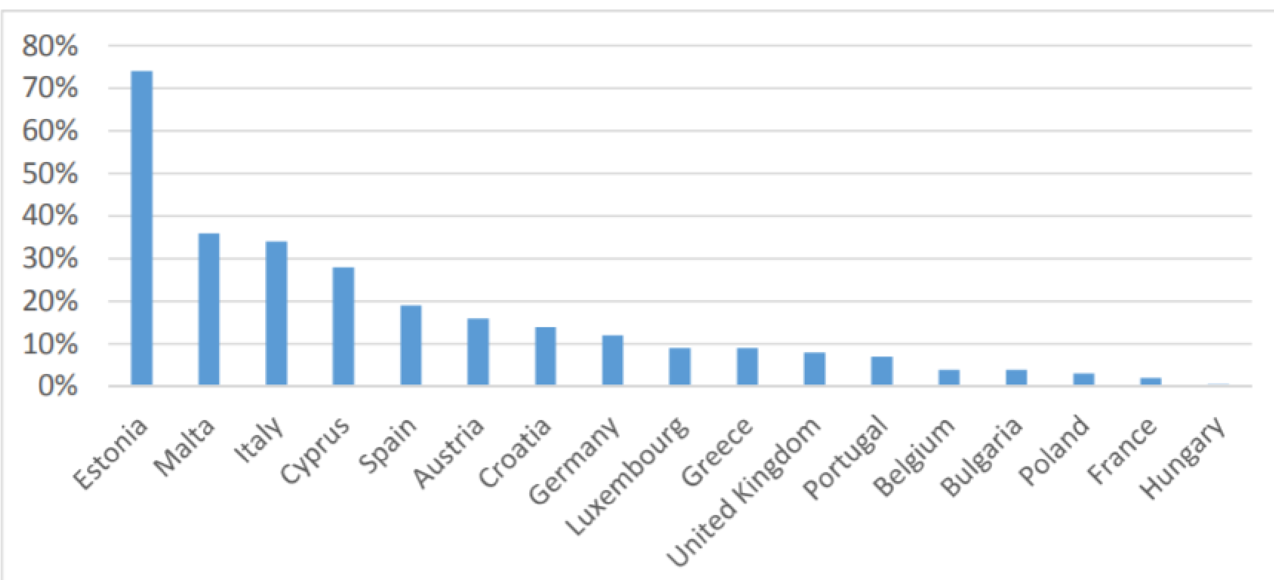

Figure 4 MBT capacity as a percentage of total municipal solid waste in Europe in 2010 (Oakdene Hollins, 2017)

Production of RDF from MSW

Manufacture of RDF is often an objective of MBT plants in Europe and the material may be incinerated in dedicated facilities, or co-incineration plants (Eunomia Research & Consulting, Scuola Agraria del Parco do Monza, HDRA Consultants ZREU, LDK ECO, 2005). Example reference plants and their location, facility type, waste inputs and outputs are outlined in Table 6 in Section 5, as identified by SKM (2012). When comparing the technology provided in the European reference sites to the NSW AWT BAU process, it can be seen that all of the technologies are the same, albeit some are located in different parts of the process line, with the exception of optical sorting capacity. It was noted in the SKM report that optical sorting technology is likely to be required in RDF processing to achieve a low chlorine content to meet market stakeholder specifications. In all of the European reference sites the organic fraction was either processed for RDF or landfilled. Through their research on regulatory frameworks in European countries, the International Solid Waste Association (ISWA) concluded that generally digestate from source separated organics streams have far less restrictions than digestate processed from mixed waste streams (ISWA, 2019).

Addressing physical and chemical contamination in MWOO

There are numerous source materials in MSW that could contribute to the concentrations of contaminants in MWOO. Some of these sources such as larger (>5-6mm) plastics, glass and metals can be targeted and removed, whilst other sources such as household dust, liquids and pigments in paper and fabrics are likely to pass through front-end processing and be incorporated into the organic fraction. The accuracy to which the plastic, glass and metal materials can be removed is dependent on the technology and processes implemented in the AWT facility, this is further described in Section 6 of this report. Further research or trials are required to understand the impact removal of plastic, glass and metal contaminants may have on the chemical concentrations found in MWOO.

Feasibility assessment of alternative pathways

Each alternative pathway was assessed against research questions. The following research questions were addressed for each alternative process option:

- How it generally aligns within the AWT process from a technical perspective (technology & equipment requirements), using the BAU option as a baseline.
- How it treats or removes chemical and physical contaminants from MWOO.
- Its success in removing contaminants (i.e. to what extent and concentration or amount).
- The cost of installing and operating the technology or process change.
- The timeframe required to install (and commission) the change.

Responses were collated from the outputs of the stakeholder engagement and literature review. Table 1 provides an overview of the data collated for each pathway.

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Table 1 Overview of Alternative Pathways for NSW AWT Facilities

Pathway	Process Option	Sub Options	Technologies	Alignment with AWT process	Contamination removal capability	Cost of equipment
One: MSW input	**1. BAU**		• **Material receival**: bobcat, excavator, manual, front-loader. • **Material stream preparation**: bag openers, pre-shredders, screw mills, crushers, rotating drums, ball mills. • **Biological treatment**: in vessel aerobic tunnel composting, mechanical agitator. • **Material separation (including Material refinement)** (pre and post biological treatment): trommel screens, ballistic separators, eddy currents, magnets, manual sorting, hammer milling and size reduction.	Yes, as this is the current process.	**Physical Contamination** • The current AWT processes have varying levels of capabilities to remove physical contaminants. • Physical contamination is removed through more manual sorting technologies; targeting the contaminants' weight, size and/or density, geometry and milling activities to reduce the size of physical contamination fractions. **Chemical Contamination** • It was identified in the TAC report that one-off sampling recorded peaks of chemical contamination significantly higher than accepted concentrations.	Not required for the purposes of this report.
	2. Improved MWOO Where output is intended for land application	**2.1 Low Capital Investment**	As BAU with additional: • Processing lines (repeat BAU equipment) • Process line included to blend in source separated organics at back end of process (rotating drums, additional conveyor systems)	Yes, this process is only marginally different from BAU with reconfiguring of equipment and purchase of some additional equipment required. It was quoted that the implementation of this process would take 6-12 months.	**Physical contamination** • The removal efficiency of the current processing lines will be marginally improved by running the to be processed material through the equipment more than once (several passes). However, without optical sorting equipment, the removal efficiency is limited by the aperture size of equipment used, such as rotating drums. The actual aperture size of the equipment was not disclosed for the purpose of this report. **Chemical contamination** • Blending with source separated organics may achieve a dilution of contaminants, but does not align with best practice for addressing contamination.	Commercial in confidence information has been removed for the purposes of this report.

		2.2 High Capital Investment	As BAU, with additional optical sorting technology at the front and/or back end of the process line: • Near infrared (NIR) and infrared. • X-ray transmission and fluorescence. • Laser.	Yes, with installation of new but well proven equipment. It was quoted that the implementation of this process would take at least 12 months.	**Physical Contamination** • The addition of optical sorting equipment will add to the removal efficiency of the facility. However, the equipment suppliers have confirmed that the optical sorters have not been proven yet to successfully remove contamination below between 2-5mm in an MSW stream. Technology suppliers have noted that the degree to which contamination can be removed is dependent on the input material and its preparation, spread (conveyor belt width) and speed, as well as how many times the material passes through a screen. • Microplastic contamination cannot be wholly addressed through the addition of optical sorting technologies. • An operator has confirmed that it is confident in meeting the physical contamination limits of 0.5% Glass, metal and rigid plastics >2mm **Chemical Contamination** • The impact that additional physical contamination removal has on chemical concentrations of polybrominated diphenyl ethers (PBDEs), phenols, phthalates, cadmium, copper and zinc have not yet been proven. • Operators have claimed significant decreases in chemical concentrations of those contaminants listed in the revoked RRO/E when trialling an improved MWOO process, however these results have not been verified by the project team. The improved MWOO processes are unique to each AWT facility, discussed further in Section 4.1.	Cost estimates for equipment excluding ancillary works (including approximate Australian dollar equivalent as of July 2019): UniSort PR: 1m wide: €126,000 ($204,000) 1.4m wide: €140,000 ($226,000) 2m wide: €167,000 ($270,000) 2.8m wide: €222,000 ($360,000) UniSort Flake: NIR: €145,000 ($235,000) Colour: €134,000 ($217,000) UniSort Black: Add €18,000 ($29,000) to each UniSort PR option UniSort Blackeye: €285,000 ($461,000) An operator stated a total capital cost of $23million is estimated to create an improved MWOO output. Additional commercial in confidence information has been removed for the purposes of this report.
	3. RDF Output Where output can no longer be applied to land	**3.1 High Calorific Value** Where inorganic materials are selected for combustion (e.g. contaminated plastic and fibre). Organic material is utilised for biogas production using anaerobic digestion (AD).	Inorganic processing • As BAU or simplified processing line. Organic processing • Anaerobic digestion: biological processing includes: composting tunnels, hopper, magnetic separators, screen, hard particle separator and maturation bays.	Yes, similar to Option 2.2 Improved MWOO at high capital investment. Where AD is installed as a new biological process, extra time and space will be required, as well as planning approvals. A supplier noted that most of the existing AWT composting bays can be retrofitted to be suitable for dry AD, a process explained in Section 4.2. It was quoted that acquiring the relevant	**Physical Contamination** • The removal of physical contaminants for the purpose of producing RDF does not require the same level of processing as for land application. Bulky materials and recyclables can be successfully sorted as demonstrated from BAU processes. • The presence of inert material such as rocks and sand will increase ash content of the RDF and therefore lower the value of the RDF but do not inhibit the use as RDF. **Chemical Contamination** • Chlorine (Cl) contamination has been identified as a barrier to NSW operators entering the RDF market. Optical sorting technology targeting PVC plastic is proven to reduce Cl contamination in RDF as shown by the use of these technologies in established facilities overseas. • AD digestate is either landfilled directly or processed further by aerobic composting where	Optical sorting equipment likely required to target PVC plastics, to meet Cl concentration requirements under the NSW Energy from Waste Policy. It is proposed costing would be similar to Pathway 2.2. Improved MWOO at high capital investment. As identified in the SKM report, AD as a form of biological composting requires significantly more capital investment, and ongoing operational and maintenance costs than aerobic composting. The recovery of the energy potential of the organic fraction needs to be incentivised to enhance the business case. Suppliers were unable to provide estimated costings to verify operator claims.

				planning approvals would take at least 12 months before extensions, retrofitting and install of new equipment could begin.	the output can be used as a low CV RDF or in some cases applied to land, for example in Italy (ISWA, 2019). Trials would be required to quantify the contamination levels in stabilised digestate to assess whether the material is appropriate for restricted land application.	
		3.2 Low Calorific Value Where both the inorganic and organic fraction can be pre-treated to produce a fuel	• Simplified BAU processing for front end mechanical sorting. • Biological processing to reduce moisture content. Technologies include Biodrying, biostabilization, thermal drying or solar drying. • Back end processing for transport: dried output is processed to create homogenous and compact product via shredding and/or pelletising.	Yes, this option may require little change or even some savings in sorting equipment or process as less sorting may be required depending on quality requirements for RDF output. The timeframe of implementing this option is dependent on the time it takes to establish a local market.	**Physical Contamination** • As above. **Chemical Contamination** • Facilities that accept lower CV RDF are designed to accept materials with higher contamination concentrations.	It is anticipated that this option requires low capital investment for technology acquisition. The key barrier to the economic feasibility of this option is the lack of available local markets.
Two: FOGO input	**1. Compost output meeting the *Compost Order 2016***		• As BAU or simplified processing line (dependent on contamination).	Yes, very similar to BAU.	**Physical Contamination** • The BAU processing line is set up to address higher contamination than what is anticipated in a source separated stream. **Chemical Contamination** • Facilities will be required to meet *Compost Order 2016* chemical contamination specifications.	This option requires low capital investment from a technical perspective. One of the key barriers to the feasibility of this option is the contractual obligations operators have with Councils either directly or indirectly. There may be a lack of sufficient, immediate supply of source separated organics to meet the full operational capacity of the AWT facilities as a limited number of LGAs within the Greater Sydney region offer a FOGO service.
Three: Organics depleted MSW	**1. Do Nothing** Continue BAU process (sort out recyclables, create stabilised organic output).		• As BAU.	Yes, same as BAU	**Physical Contamination** • Potential for higher contamination of the output, where the smaller fraction of glass and plastic are being sorted into the organic fraction. **Chemical Contamination** • Potential for increased contamination if organic fraction of MSW absorbs chemical contamination.	No additional technology required, however lower overall volume of organic input is likely to increase the operating cost per tonne. This option also implies that the process line is operating at less than 100% capacity (dependent on remaining organic content in MSW stream).
	2. RDF output Change technical processing to produce alternative output of refuse derived fuel.		• As, Option 3.2 - Additional of optical sorting for optimising RDF output for particular markets e.g. reducing Chlorine for cement kilns .	Yes, there is a reduced capacity of biological processing which may allow operators to increase annual throughput (as process times are reduced). Timeframes are market dependent.	As for Pathway 3.1 and 3.2	Faster processing time for biological drying means that operators may be able to increase throughput. Available biological processing capacity could be utilised to accept a separate FOGO stream. This would require reconfiguring and may require minor construction dependent on the existing process lines.

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1. Introduction

Australia is one of the greatest producers of domestic and commercial waste in the world. Reduced community acceptance of landfills, government policy to encourage better recycling and rising landfill levies have driven the development of AWT technologies in NSW (Municipal Waste Advisory Council, 2009). AWT is an umbrella term for sophisticated technologies that aim to recover a portion of municipal solid waste (MSW) through mechanical, thermal or biological treatment. These technologies include Mechanical Biological Treatment (MBT) facilities which process waste to extract recyclables and create a stabilised organic-rich fraction – generally through an enclosed composting process. This organic fraction has the potential to be used for land application or as a fuel. Within New South Wales (NSW), the stabilised organic output from MBT processing is referred to as Mixed Waste Organic Output (MWOO).

In October 2018, the NSW Environment Protection Authority (EPA) made a regulatory decision to stop the use of MWOO on agricultural land, and cease its use on plantation forests and mining rehabilitation land until further controls are considered. This decision was taken because of environmental and human health risks associated with MWOO that were identified during a comprehensive scientific research program commissioned by the EPA over a seven-year period (2010-2017). These findings are summarised in the TAC Report, completed for the NSW EPA in 2018. For this reason, the NSW EPA revoked all resource recovery orders and resource recovery exemptions related to the land application of MWOO as a fertilizer or soil amendment (revoked RRO/E) on 26th October 2018. On Friday 2nd November 2018 the then Acting Chair and Chief Executive Officer of the NSW EPA approved the exemption of the waste levy for MWOO produced in NSW for a period of 12 months (NSW Government , 2018). All MWOO produced in NSW is currently being sent to landfill.

In November 2018, Jacobs in partnership with Jackson Environment and Planning (J&JEP) were commissioned by the NSW EPA to perform an alternative market options analysis for MWOO application. The key finding of this report was that all market options assessed have barriers that need to be overcome. The following two market options were concluded to have fewer constraints and could be considered further:

- Option 1.2: Revised RRO/E or alternative legal instrument for mine site rehabilitation including revised limits for chemical and physical properties. This option will require investment in new sorting/processing equipment to meet lower physical contamination thresholds.
- Option 2.1: Use as daily landfill cover in NSW in compliance with landfill guidelines.

The report also noted that there is an opportunity in NSW to potentially adapt AWT infrastructure to accept source separated organic materials, as has occurred overseas.

In May 2019, Jacobs in partnership with Full Circle Advisory (Jacobs) were commissioned by the EPA to provide expert advice on the process and technology options to further remove physical and chemical contaminants from MWOO produced at AWT facilities in NSW. Process and technology options should address the physical and chemical contaminants identified within the TAC report, as outlined in the following management recommendations:

3) Better engineering/technology is needed to reduce sources of metals/plastics/glass during processing of waste if MWOO is to be applied to land.

5) … A limit for physical contaminants having a diameter < 2mm should be set.

6) … The major chemical contaminants of concern are PBDEs, phenol, phthalates, cadmium, copper and zinc.

If MWOO were to be applied to land, it would need to be proved that additional technologies and processes would produce a higher quality product. This would need to negate the outcomes of the independent and comprehensive research program (TAC report) that showed that the use of MWOO posed a risk at application rates below where it could provide a benefit.

The EPA also sought to understand options for alternative pathways for the use of AWT facilities in NSW. This includes assessing how existing AWT facilities can be modified to produce a refuse derived fuel (RDF) as a new output and how that would align with the NSW EPA Energy from Waste (EfW) Policy, or treat source separated Food and Garden Organics (FOGO) as a new input.

Jacobs undertook stakeholder engagement with AWT operators and waste technology suppliers, as well as a targeted literature review to understand and assess the potential pathways for use of AWT facilities in NSW.

The project deliverables are as follows:

Project Deliverables

1) **Undertake Stakeholder Consultation**: To understand local market capabilities and technologies currently available through consulting with technology/equipment suppliers and gain access to intelligence AWT operators may have on technologies and processes based on internal research conducted.
2) **Conduct Literature Review**: To further understand the ability of selected technologies and processes to address chemical and physical contamination in MWOO or provide a feasible alternative pathway for the AWT facilities in NSW. To review current European practice for treatment of MSW, specifically focussed on the use and penetration of AWT facilities.
3) **Provide Overview of Alternative Pathways for AWT facilities in NSW**: To develop representative process flow charts for each of the alternative pathways such that their feasibility as a future pathway can be assessed.
4) **Assess the Technical Feasibility of Alternative Pathways:** Answer a series of research questions regarding the feasibility of commercially available technologies and/or processes that could potentially be implemented by NSW AWT operators.
5) **Deliver Technology and Process Review Report**: To provide options for the available technologies and processes to address physical and chemical contamination of MWOO for AWT facilities and assess the technical feasibility of alternative pathways for AWT facilities in NSW.

A detailed methodology is provided in Section 2 of this report.

2. Methodology

2.1 Stakeholder Engagement

An initial round of stakeholder engagement was conducted to understand the feasibility of possible future pathways for the use of AWT facilities in NSW. Stakeholder engagement was broken into the following:

- Individual interviews with **NSW AWT operators** The interviews were conducted in May – June 2019. The questionnaire sent to AWT operators has been provided in Appendix A.
- Individual interviews with selected AWT and waste solutions **technology suppliers** (Waste Treatment Technologies (WTT), Cemac Technologies (Cemac), and Steinert. The interviews were conducted in May-June 2019. The questionnaire sent to suppliers as well as additional materials have been provided in Appendix A.
- Requests for Information via email were sent to additional technology suppliers during the month of May, but responses were not received in time for inclusion into the report.

A questionnaire was provided to each of the AWT operators and technology suppliers respectively prior to conducting the interviews. Technology suppliers were selected based on the expert knowledge of the project team regarding the key suppliers in Australia and globally. As a part of the questionnaire, NSW operators were asked for suggestions of additional supplier contacts and to confirm they approved the selection of suppliers being interviewed.

Jacobs used international connections through its UK team to gain access to case studies of European sites processing MSW. These studies were used to inform the development of process flow charts for typical AWT sites.

Additional stakeholder engagement was performed following the first round of engagement, to verify questions and seek additional input. Due to the limited timeframe for performing this assessment, a stakeholder engagement method was selected to provide a timely, NSW-specific response to key research questions that could be supported by targeted desktop analysis where literature was available.

2.2 Literature Review

During the first round of stakeholder engagement, wider literature was assessed via desktop analysis to provide a list of alternative pathways and process options for AWT facilities. This review focussed on providing an overview of the different processes used by AWT facilities globally for treating MSW through assessing scientific journal articles, technology supplier information, legislative documents and government reports. European literature was assessed to provide context on the development of AWT processing and its interaction with overarching policy, changes in output applications and its relationship to the rise of source separated food and garden organics collection (Section 5).

A second round of desktop analysis was undertaken concurrently with the additional round of stakeholder engagement. This analysis focused on assessing literature to support technology supplier and operator claims, locate reference sites and identify the limitations and applications of the technologies identified for each process option.

2.3 Overview of Alternative Pathways for AWT facilities in NSW

The alternative pathways for AWT facilities have been identified as:

- **Pathway One**: Continue to process Municipal Solid Waste (MSW) as an input under the following three process options:
  1) *BAU*: Maintain current technical processing to recover recyclable material and send treated waste as a stabilised organic material to landfill.

As of October 2018, each NSW AWT facility has continued to process MSW under the same processing operations prior to the revocation of the RRO/E. From November 2018 the application of MWOO to landfill has been given a 12-month waste levy exemption as published in the NSW Government Gazette (NSW Government , 2018).

  2) *Improved MWOO*: Increase technical processing to reduce physical and chemical contamination of MWOO.

As per the recommendations in the TAC report, if MWOO is to be applied to land additional technology or processes would be required to reduce the physical and chemical contamination of the output. Varying degrees of contamination removal can be achieved, dependent on the level of capital investment made. Two sub options of low and high capital investment were determined through stakeholder engagement.

  3) *RDF Output*: Change technical processing to produce alternative output of refuse derived fuel (RDF).

If MWOO is to be restricted from land application, MSW could be processed into RDF to be utilised as alternative fuel source for energy and heat generation, as is common in parts of Europe and the US. Both stakeholder engagement and the literature review have identified two main sub options for RDF production. The first, is to produce an RDF with a high calorific value from the inorganic fraction of the MSW and utilise the organic fraction for biogas production via anaerobic digestion. The second option is to produce RDF with a low calorific value from processing both the inorganic and organic fractions MSW. These processes are explained in detail in Sections 4.2 and 5 of this report.

- **Pathway Two**: Accept source separated food and garden organic (FOGO) only as an input (instead of the broader contents of MSW) to produce compost quality to meet the Compost Order.
- **Pathway Three**: Accept an organics depleted MSW as an input under the following two process options:
  1) *Do Nothing:* Continue to process MSW to sort out recyclables and create a stabilised organic output, with a reduced organics content

If a source separated kerbside organics collection stream is in place, it is anticipated that the percent of organics in the MSW stream will reduce by approximately 13%[2] on average, but could be as high as 78%. AWT operators may choose to continue to process MSW to create a stabilised organic output, noting that this output cannot be applied to land under this option.

  2) *RDF Output*: Change technical processing to produce alternative output of RDF

A reduced organic content in the MSW stream may lead AWT operators to change technical processing to produce an RDF output. This may increase the operational capacity of biological processing, allowing this section of the facility to accept an additional organics stream.

To assess the technical feasibility of AWT facilities in NSW implementing these pathways and associated process options, Jacobs identified the technologies and equipment required to facilitate each option. The

[2] As calculated by the Rawtec 2018 report on the Analysis of NSW Food and Garden Bin Audit Data. This is an average that is highly dependent on the kerbside service offered, service area and level of education conducted

identification of these technologies was realised through stakeholder engagement and the literature reviews. The following technologies associated with each pathway is provided in Table 2.

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Table 2 Technologies associated with potential future pathways for NSW AWT facilities

Pathway	Process Option	Sub Options	Technologies
One: MSW input	1. BAU		• **Material receival**: bobcat, excavator, manual, front-loader. • **Material stream preparation**: bag openers, pre-shredders, screw mills, crushers, rotating drums, ball mills. • **Biological treatment**: in vessel aerobic tunnel composting, mechanical agitator. • **Material separation** and Material Refining (pre and post biological treatment): trommel screens, ballistic separators, eddy currents, magnets, manual sorting.
	2. Improved MWOO Where output is intended for land application	2.1 Low Capital Investment Where quality of output is marginally improved from BAU	As BAU with additional: • Processing lines (repeat BAU equipment). • Blending of source separated organics (rotating drums, additional conveyor systems).
		2.2 High Capital Investment Where quality of output is significantly improved from BAU	As BAU with additional optical sorting technology (at front end and back end of process line): • Near infrared (NIR) and infrared. • X-ray transmission and fluorescence. • Laser.
	3. RDF Output Where output can no longer be applied to land	3.1 High Calorific Value Where processing selects for inorganic materials e.g. contaminated plastic, textiles and fibre	Inorganic processing (mechanical) • As BAU or simplified processing line. Organic processing • Anaerobic digestion: Biological processing includes: composting tunnels, hopper, magnetic separators, screen, hard particle separator and maturation bays.

		Organic material is utilised for biogas production using anaerobic digestion (AD).	
		3.2 Low Calorific Value Where both the inorganic and organic fraction can be pre-treated to produce a fuel	• Simplified BAU processing for front end mechanical sorting. • Biological processing to reduce moisture content. Technologies include Biodrying, biostabilization, thermal drying or solar drying. • Back end processing for transport: dried output is processed to create homogenous and compact product via shredding and/or pelletising.
Two: FOGO input	1. Compost output meeting the *Compost Order 2016*		• As BAU or simplified processing line (dependant on level of contamination in FOGO stream).
Three: Organics depleted MSW stream	1. Do Nothing Continue BAU process (sort out recyclables, create stabilised organic output)		• As BAU
	2. RDF Output Change technical processing to produce alternative output of refuse derived fuel		• As, Option 3.2 - Additional of optical sorting for optimising RDF output for particular markets e.g. reducing Chlorine • Additional technology may be required if AWT operators look to utilise the biological processing capacity made available through this option to accept an additional organic stream.

Process flow charts of reference sites and case studies have been used as references for each process option. Case studies are provided in Section 3 and 5.

2.4 Feasibility Assessment

Each alternative pathway was assessed against research questions as defined by the NSW EPA in their project brief. The following research questions were addressed for each alternative process option:

- How it generally aligns within the AWT process from a technical perspective (technology & equipment requirements), using the BAU option as a baseline.
- How it treats or removes chemical and physical contaminants from MWOO.
- Its success in removing contaminants (i.e. to what extent and concentration or amount).
- The cost of installing and operating the technology or process change.
- The timeframe required to install (and commission) the change.
- Any further technical, social, or environmental considerations.

Responses were collated from the outputs of the stakeholder engagement and literature review.

Limitations of the Analysis

It is recognised that there are limitations in this feasibility assessment. These have been identified as:

- The time frame in which literature review was conducted has limited the breadth of the review under some pathways.
- The project team relied on information provided in the TAC report, as the HHERA commissioned by the NSW EPA was not yet completed. The results of the trials conducted under the seven-year research program were not provided to inform this report.
- The sampling data behind all of the claims made throughout this report regarding the sorting capabilities of suggested technology have not been sighted by the project team.
- Each site in NSW has unique circumstances that could not be directly addressed in this report. Whilst some of the AWT operators have made available very generalised flow charts about how they think an improved MWOO could be achieved, a much more detailed technical and engineering discussion would be required to determine the technical feasibility and the costing of an improved MWOO for each site.
- The costs provided for technologies are not always in Australian dollars, as these have been informed by overseas sources (however conversions have been provided correct as of July 2019). Some costings are dated and will be subject to increases in annual Consumer Price Index (CPI).
- This report has been developed as follow on work from the alterative market options feasibility study performed by J&JEP (2019). It is assumed that this report is read in conjunction with the previous report.

3. Overview of an AWT process in NSW

AWT technologies include Mechanical Biological Treatment (MBT) facilities which process waste to extract recyclables and create a stabilised organic-rich fraction (MWOO) – generally through a composting process. Within NSW, there are commonalities between most or all of the AWT facilities in NSW in terms of the technology or equipment currently being utilised. All of the NSW AWT facilities include the following generic process steps:

- Material receival.
- Material stream preparation.
- Material stream separation.
- Biological treatment.
- Material refinement.

Detail regarding the technologies and equipment utilised as part of each process step is provided in Table 3.

Material receival

The waste material is received, typically by the delivering truck unloading the material on a tipping floor, where the material undergoes visual inspection of various degrees of intensity. At this stage larger pieces of contaminants or larger items of waste can be removed by a material handler, an excavator with a finger or pincer grab or a bobcat. Manual intervention by handpicking is also possible.

Material stream preparation

At this stage garbage bags are being opened by a bag opener, which can be a separate piece of equipment or part of a rotating drum or coarse pre-shredder. Pre-shredding also leads to an initial particle size reduction, a necessary step for the material to pass through further processing equipment (but also a step which makes any subsequent removal of physical contamination more difficult due to particle size reduction**)**. One NSW AWT operator uses an autoclave at this stage, and has described that the main purpose of the autoclave is to begin the process of breaking down the organic component of the MSW material through application of steam into the rotating drums before the material is then composted.

Material stream separation

At this stage the materials are being separated from each other by their physical characteristics such as weight, particle size, material type (ferrous vs non-ferrous) or physical form such as flat vs round. The purpose of this step is to separate or decontaminate the organic fraction from the inorganic and associated contaminants.

Biological treatment

The organic output following material stream separation is stabilised through aerobic composting. Composting of the processed organic output is usually located in enclosed tunnels, which are supplied with water and agitation by either aeration pipes under the stockpiles or with mechanical agitators.

Refinement

This step occurs after the biological treatment and includes a final metal separation exercise, as well as particle size reduction such as hammer-milling that may reduce particle size of contaminants. At this stage further sorting equipment, such as optical sorters could be used for further refinement or removal of contaminants. No NSW AWT facilities currently have optical sorting technologies.

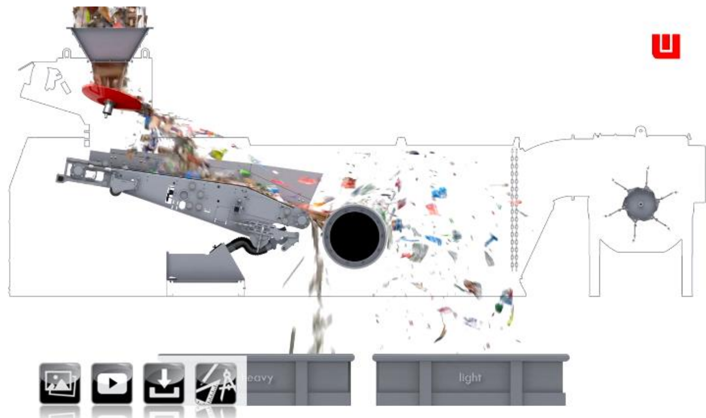
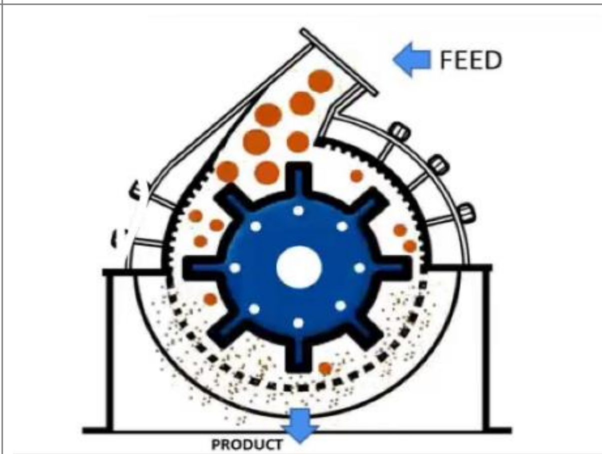
A generic process flow chart is shown in Figure 5.

Table 3 Description of technologies and equipment found in a generic AWT

Equipment	Description	Graphic Example	Sources
Bag openers	Put simply, bag openers are typically rotating drums with knifes attached to the inside of the drum. The knifes slash open plastic bags and the rotating motion of the drum causes the inside of the bag to spill into the open to be presented for further sorting. At this point containers or bags containing chemicals can be opened as well and the content can spill and seep into organic matter.		https://www.environmental-expert.com/products/matthiessen-bag-opener-41687 http://www.cpmfg.com/recycling-equipment/recycling-sorting-equipment/bag-opener/

Equipment	Description	Graphic Example	Sources
Pre-shredders	Pre-shredders are designed to break, tear and rip large volumes of non-homogenous material streams like MSW, whole cars, commercial and industrial (C&I) and construction and demolition (C&D) waste into smaller particle sizes so that the output can then be sorted by other sorting equipment. Pre-shredders are low speed, high torque pieces of equipment designed to process “unusual” or unexpected materials (such as metals, hard or long pieces of wood, particle board etc.)		https://www.metso.com/products/shredders/pre/mj-4000/ https://www.bhs-sonthofen.de/en/products/recycling-technology/pre-shredder.html
Screens and drums	There is a wide variety of drums and screens available on the market, each of which have been developed to suit a particular application or waste material over time, these include trommel screen or rotating drums, disc screens, star screens, and scalping screens. All of these have the function to separate materials by particle size. The wide variety of screens is due to the wide variety of materials to be sorted, from MSW, C&I and C&D waste.		https://www.cemactech.com/technologies http://cssequipment.com.au/product-category/ecostar/ http://www.cpmfg.com/material-recovery-facility/municipal-solid-waste-recycling/solid-waste-management-equipment/

Equipment	Description	Graphic Example	Sources
Metal separators	To remove ferrous metals usually overband magnets are being used and for all non-ferrous metals eddy current separators are being used. The efficiency of these separators depends largely on how the materials are being presented to the separators. The better distributed they are, the more efficient the removal will be.		https://steinertglobal.com/au/magnets-sensor-sorting-units/magnetic-separation/
Ballistic separators	Ballistic separators separate materials based on their different geometry. A ballistic separator has moving floor pedals with different aperture size openings (a perforated floor). The floor is set at an angle. The pedals move up, down and forward. Due to the angle, any rolling or round materials (most glass and plastic bottles, aluminium or steel cans, etc.) as well as larger heavy materials fall backwards. Due to the perforated floor and depending on the aperture size, heavy materials (mostly organics) fall through the floor. Due to the forward motion of the pedal any flat materials (paper, cardboard, plastics, fabric) are moved forward over the top of the ballistic separator.		https://www.w-stadler.de/us/komponenten/ballistik-separatoren/ https://www.amutgroup.com/amutecotech/en/ballistic-separators

Equipment	Description	Graphic Example	Sources
Wind shifting or air separation	Windsifters (sometimes called windshifters) or air separators are used to separate heavy from light materials to then further sort the two separated fractions. Targeted fan forced air streams either propel the to be sorted materials in a particular direction utilising their different density and ballistic behaviour, or, lift the lighter fraction of materials from a heavier fraction, so that the lighter fraction can be separated (i.e. by suction) from the heavier fraction.		http://www.westeria.de/windsichter/windsichter_ws2.php?lang=en https://doppstadt.de/en/products/smart-sifting/windsifter-line/ https://www.nihot.co.uk
Hammer Mill	Hammer milling is sometimes used in the back end of a processing facility to refine and reduce particle size and create a more homogenous output. This can lead to uniform maturation of organic material, improving nutrient availability of the product.	 *Feeding section of a hammer mill*	https://www.spiegelbeeldinkunst.nl/stone/1495-municipal-mixed-waste-hammer-mill/ https://www.saintytec.com/working-principle-hammer-mills/

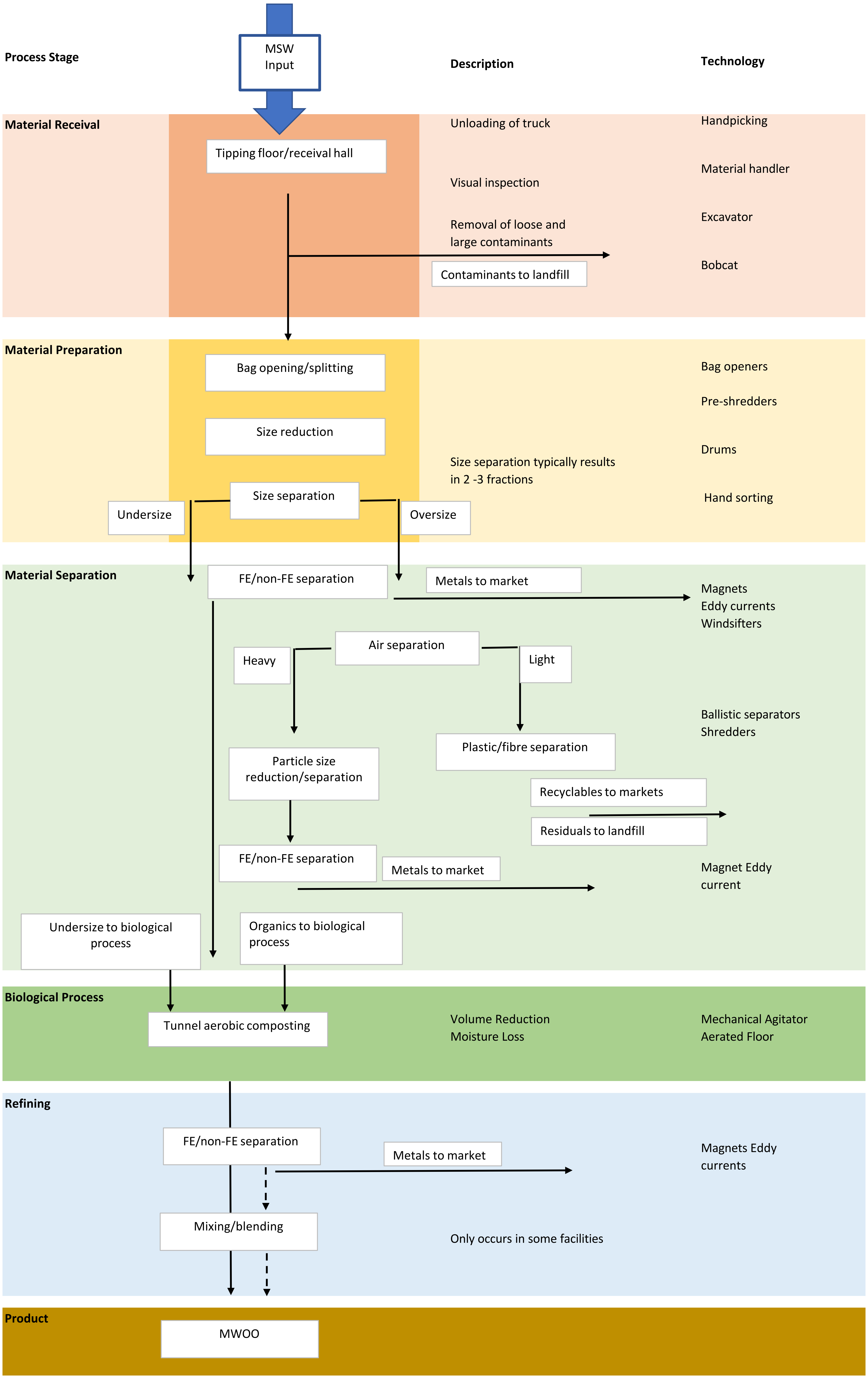


Figure 5 Generic AWT processing flow chart

4. Outcomes of Stakeholder Engagement

4.1 AWT Operator Engagement

The first round of stakeholder engagement included interviewing each AWT operator in NSW. A questionnaire was sent to the four operators prior to a stakeholder meeting. The questions focused on gaining an understanding of the level of investigation AWT operators have undertaken to assess the feasibility of the following alternative pathways and associated process options:

Pathway One: Continue to process Municipal Solid Waste (MSW) as an input under the following three process options:

1) *BAU*: Maintain current technical processing to recover recyclable material and sending pre-treated organic waste to market[3].
2) *Improved MWOO*: Increase technical processing to reduce physical and chemical contamination of MWOO.
3) *RDF Output*: Change technical processing to produce alternative output of refuse derived fuel (RDF).

Pathway Two: Accept source separated food and garden organic (FOGO) as an input to produce compost quality to meet the *Compost Order 2016*.

Outcomes from the discussion of these potential pathways were used to inform the assessment of Pathway Three.

Pathway One: *BAU*

The majority of operators expressed that the landfilling of MWOO is not suitable for long term operations due to contractual breaches. Some operators have contractual obligations to divert material from landfill over a certain percentage, that would not be met if output was to continue to be landfilled indefinitely. Each operator provided Jacobs with a process flow chart outlining the mechanical and biological processing currently conducted at their sites. Each site varied in the technology and process line configuration utilised for processing MSW. These variances can be attributed to differences of input quality and capacity, intended output market, associated on-site processing systems, contractual conditions and level of investment. It should be noted that for the purposes of this report, a generic base case AWT process flow chart has been developed to demonstrate the potential feasibility of implementing alternative pathways, see Section 3. Each NSW operator has unique challenges associated with their individual operations that cannot be wholly addressed within the scope of this report. These challenges have been highlighted throughout this section of the report.

Pathway One: *Improved MWOO*

All operators have identified that there are a number of technologies and processes that could significantly reduce physical contamination of the materials highlighted as a concern in the TAC report including metals, plastics and glass.

Addressing Physical Contamination

All operators noted that improved source separation at the kerbside through the provision of additional collection services or targeted education campaigns may significantly reduce the presence of physical and chemical

[3] The pre-treated organic waste is currently being sent to landfill, following the revocation of the Resource Recovery Orders and Exemptions for land application of MWOO. From November 2018 the application of MWOO to landfill has been given a 12-month waste levy exemption as published in the NSW Government Gazette (NSW Government , 2018).

contaminants before the MSW reaches the AWT facility. Once the MSW has reached the facility, operators have suggested the following technologies and processes could be implemented to significantly reduce the presence of physical contaminants in MWOO:

- Keeping containers or materials intact allows for easier identification and sorting of the material stream, this can be achieved through changing the handling of front end processing.
- Adjust current screen apertures for screening processes on site (trommels, shredder, flip flop screen) to sort for tighter specifications such as finer particle sizes.
- Introduce optical sorting technology in front end and back end processing to sort for plastic and glass. Optical sorting technologies include near infra-red, x-ray and colour sensors. Additional metal detection technologies can also be installed.
- Introduce optical sorting technology in front end processing to positively sort for organic material.

Operators made note that there would be a reduction in the diversion rate of organic material if a higher quantity of non-putrescible material is sorted out of the process earlier. Non-putrescible materials such as hard plastics, and glass may contain putrescible waste such as food waste that will no longer contribute to the organic output if they are removed in front end processing.

Some operators noted that they have run trials on the implementation of the aforementioned technologies and processes, showing significant decreases in physical contamination. Results were not provided to inform this report. One operator confirmed that it is confident in meeting the physical contamination limits of 0.5% Glass, metal and rigid plastics >2mm (similar to the Australian Standard; AS 4454-2012 and Compost Order 2016) following the installation of optical sorting technology to complement the existing capability. It is noted that compost produced and applied to land in NSW must meet the Compost Order 2016, and only contain the inputs specified in that order.

When approaching the topic of microplastics, some operators suggested that reduction in microplastic volume could be addressed by removing a higher percentage of plastic contaminants (>5mm by optical sorting) at the front end of the processing (prior to biological processing). Other operators noted that if the microplastics are already present in the raw MSW, there are no known technologies that can sort out plastic of that particle size (less than 2mm). Operators have not as yet run trials on how the increased removal of the >5mm plastic fraction may impact the presence of microplastics in MWOO.

The application and limitations of these technologies and processes are detailed in Section 6 of this report, including outcomes of operator trials and case studies.

Addressing Chemical Contamination

Operators noted that there are some factors that cannot be influenced by any of the existing (or new) processes. The first time the material arrives at the processing facility, it has already had several potential exposures to chemical contamination.

- The first potential exposure is when waste is placed into the red lidded bin for residual MSW. Any spillage of household chemical, paints, thinners, leaching batteries etc. can occur at this stage.
- The second potential exposure of chemical contamination is when the waste is transferred from the bin into the collection vehicle/truck. Collection vehicles commonly have a compaction unit, where the waste is compacted and chemicals can be squeezed out of containers and batteries broken and mixed with the waste on board the truck.
- There is also potential for cross contamination when the collection truck tips onto the AWT facility floor.

Chemical contaminants of concern as outlined in the TAC Report are polybrominated diphenyl ethers (PBDEs), phenols, phthalates, cadmium, copper and zinc. It should be noted that this list of contaminants are not the only contaminants identified as requiring management in MSW processing for a product destined for land application. Operators have highlighted that through their research of publicly available literature including the TAC report, the occurrence of these chemicals can be associated with the presence of physical contaminants such as plastic, batteries, electrical goods and other inert household items. Some operators have therefore suggested that if those physical contaminants are removed as early into the sorting process as possible, the presence of associated chemical contaminants will be reduced.

Other operators have identified that blending with a cleaner recycled organic stream, such as green waste to improve the nutrient value and beneficial impact of MWOO, may also dilute chemical contamination, reducing overall contamination of MWOO applied to land to potentially acceptable levels. It is noted that the practice of dilution is not endorsed by the EPA as a waste management approach.

Table 4 shows the suggestions made by operators on the source and proposed processing options for addressing chemical contaminants identified in the TAC report. Assessment of operator and supplier claims against scientific literature is provided in Section 5 of this report.

Table 4 AWT operator claims on process and technology options to address chemical contamination

Chemical Contaminant	Source of contaminant – as stated by operator	Process and technology options
Polybrominated diphenyl ethers (PBDEs)	Hard and soft plastics	Optical sorting: near infrared or x-ray technology
Phenol(s)	Naturally occurring In hard plastics (Bisphenol A (BPA))	Addressed by extending withholding periods Optical sorting: near infrared or x-ray technology
Phthalates	Hard and soft plastics	Optical sorting: near infrared or x-ray technology
Cadmium	Wires, coins, foil, batteries	Sorted out with metal detectors: Eddy current separator (ferrous and non-ferrous) and magnets
Copper		
Zinc		

An operator stated that its current operating capacity can consistently meet the chemical contamination limits for Contaminant Grade C set in the NSW EPA *Environmental Guidelines: Use and Disposal of Biosolids* 2000 (Biosolids Guidelines). It is noted that the Biosolids Guidelines do not regulate some of the contaminants listed in Table 4.

Pathway One: *RDF Output*

The majority of the operators stated that they have already investigated opportunities to produce refuse derived fuel (RDF) as an alternative product to MWOO, with some operators already approved for the production of RDF as part of their relevant approvals. Almost all of the technology utilised within the AWT process can be utilised for RDF production, and in some cases RDF production requires less processing and hence fewer pieces of equipment.

A majority of the operators noted that the barrier to producing RDF is accessing local markets as opposed to accommodating the appropriate technology. It was raised that there are generally two markets for RDF dependent on the calorific value (CV) of the output:

- High CV: Cement kiln, ceramic and brick processing.
- Low CV: Coal fired plant, Energy from Waste (EfW) facility.

There are a limited number of cement kilns and brick processing facilities, and no Energy from Waste facilities operating in NSW. It was noted that transport of RDF to wider interstate or overseas markets is currently cost prohibitive. Where the organic fraction is processed into a low CV RDF, an operator identified that the high ash content following incineration can further restrict access to local markets. Some operators have stated that their business case for RDF processing is only commercially viable where the high calorific fraction, generally made up of plastic and contaminated pulp/fibre is processed into an RDF and the remaining organic fraction is still processed into MWOO. It should be noted that business cases were made before the revocation of the RRO/E and assumes there is a land application market for MWOO.

Another operator has stated that despite the limited market from potential large-scale facilities, there are smaller, local consumers who are investigating the feasibility of cogeneration and local energy production that may offer a more immediate market.

In response to the limited markets, an operator has investigated the feasibility of constructing and operating its own small-scale energy from waste facility on site (11,000 tpa). This option was not considered feasible due to high capital costs, long planning approval timeframes and a comparatively low return on investment. It was suggested that a larger facility with a higher capacity would be more feasible. The indication (subject to a business case) is that a small EfW facility would require a minimum of 50,000 tpa throughput capacity.

Pathway Two: *FOGO as an input*

All operators reported that from a technical perspective there are no limitations in their current processing to accept FOGO as an input. In most cases, only the 'biological' processing section of the AWT would be utilised, where there was a clean FOGO stream as an input. Operators stated that the contractual obligations they currently adhere to restrict the ability to accept a different waste stream as contractual clauses specifically reference the processing of MSW exclusively.

Pathway Three: Do Nothing

Some operators have noted that the increased uptake of a FOGO service may only have a relatively small impact on reducing the organic content in the MSW stream, particularly during the first couple of years of this service being implemented. In this case, processing the MSW input to produce a stabilised organic output may still be feasible if there is a viable market for the output (refer to findings under Pathway One). If there is a significant decrease in organic content of the MSW stream, this will have implications for the diversion performance of the AWT as less material will be diverted per tonne of MSW. An organic depleted input stream may impact the operational biological processing capacity of the AWT as less organic material is passing through the biological processing stage.

Pathway Three: RDF Output

Comments as described under *Pathway One: RDF Output* also can be applied to this pathway. Ultimately, there are few technical barriers to this option, rather market accessibility and sufficient demand are noted as the greatest barriers. An AWT operator noted that the ash content of RDF limits the accessibility to the brick industry; a reduction in organics content could decrease ash content dependent on the level of organics reduction achieved. Two of the four AWT operators already accept two waste streams for processing within their facilities and will likely have reduced technical challenges to accepting an increased input of FOGO when compared to the operators only processing a single input stream.

4.2 Waste Technology & Equipment Suppliers

The first round of stakeholder engagement included interviewing waste treatment technology and equipment suppliers. A questionnaire was sent to each supplier prior to a follow up phone interview. The questions focused on gaining an understanding of the technical feasibility of the following alternative pathways and associated process options:

Pathway One: Continue to process MSW as an input under the following three process options:

1) *BAU*: Maintain current technical processing to recover recyclable material and sending pre-treated organic waste to market[4].
2) *Improved MWOO*: Increase technical processing to reduce physical and chemical contamination of MWOO.
3) *RDF Output*: Change technical processing to produce alternative output of refuse derived fuel (RDF).

Pathway Two: Accept source separated food and garden organic (FOGO) as an input to produce compost quality to meet the Compost Order.

Pathway Three: Accept an organics depleted MSW as an input under the following two process options:

1) *Do Nothing*: Continue to process MSW to sort out recyclables and create a stabilised organic output, with a reduced organics content.
2) *RDF Output*: Change technical processing to produce alternative output of refuse derived fuel.

Pathway One: BAU

Technology suppliers did not comment on the technical feasibility of this process option as there are no technical barriers for an existing operation. Suppliers agreed that there are established and well proven AWT technologies that can produce:

- RDF.
- Stabilised organics (with varying levels of quality dependent on market).
- Digestate (under anaerobic digestion).
- All the other typical recycling outputs (plastics, metals, glass).

Under the BAU pathway, AWT facilities are sorting out recyclables such as metals, plastics and glass as well as creating a stabilised organic output for landfill. Suppliers noted that in many of their reference facilities globally, the stabilised organic fraction is destined for landfill as a long term, feasible process option. The argument for stabilising organics prior to landfill is the reduction in Greenhouse Gas emissions and leachate generation.

[4] The pre-treated organic waste is currently being sent to landfill, following the revocation of the Resource Recovery Orders and Exemptions for land application of MWOO. From November 2018 the application of MWOO to landfill has been given a 12-month waste levy exemption as published in the NSW Government Gazette (NSW Government , 2018).

Pathway One: *Improved MWOO*

All technology suppliers acknowledged that the sorting investment is dependent on the level of contamination of the input and the accepted purity level of the product. Generally speaking, suppliers noted that Australia has typically followed a lower capital investment pathway due to the low value of the output and restricted local markets. There are more capital-intensive technologies commercially available that have the capacity to significantly clean up the product that are currently being used globally.

Addressing Physical Contamination

All the suppliers noted that optical sorting technology can be implemented in both the front end and back end of the processing line to specifically target plastic and glass and successfully reduce the physical contamination of the product. Suppliers noted that the degree to which contamination can be removed is dependent on the input material and its preparation, spread (conveyor belt width) and speed, as well as how many times the material passes through a screen.

There are various types of optical sorting equipment used in waste management. They differ in regard to which type of sensor they use to detect materials that are either wanted or unwanted and removed via ejection. The type of sensors on the market as provided by the suppliers for the detection of materials in the waste industry are:

- Near Infrared (NIR).
- Colour.
- Visual.
- Infrared.
- Laser.
- Induction.
- X-ray transmission.
- X-ray fluorescence.
- Light-emitting diode (LED).

Detailed optical sorting equipment descriptions can be found on the supplier websites:

- https://www.cemactech.com/technologies
- https://www.tomra.com/en/sorting/recycling
- https://steinertglobal.com/au/waste-recycling/household-waste/

Not all of these sensors are recommended or useful for removing contamination from organics. Suppliers confirmed that the sensors most used in the context of sorting contaminants from organics or compost are NIR, laser or x-ray sensors. An example of this technology installed within Australia is provided in the case study below.

CASE STUDY: JEFFRIES FACILITY, ADELAIDE

Video Link: https://video.tomra.com/compost-cleaning-jeffries-adelaide-australia.

The Jeffries Facility in Adelaide has installed NIR and x-ray sensors to clean up contamination from a source separated organics stream.

This application is reflective of the same process of sorting out contaminants from MWOO at the back end of the process line (following the biological process) in any of the AWT facilities in NSW. It is similar because the sensors can detect contaminants such as plastic amongst organic materials.

Suppliers have stated that the determining factors for the successful detection and ejection of contaminants using NIR are belt width, material distribution (so that material is spread in a single layer on the conveyor belt and can be "seen" or detected) and the speed of the belt. The supplier for the equipment indicated that the removal efficiency for plastics >5mm is between 80 and 85% in one pass. Noting that a source separated organic stream is likely to have less plastic contamination than MSW, suppliers have identified that relative levels of contamination reduction can be accomplished by passing the material through a sensor more than once.

For x-ray sensors the material spread is not as important because x-ray sensors can "see through" materials and detect the contaminants even if it is covered by MWOO or compost. It was noted that using an x-ray sensor could also lead to a larger removal of organic matter that is over or under a piece of contamination and therefore lower the amount of materials recovered for the overall process.

A key limiting factor of these sensors is particle size. Suppliers have indicated that in the context of removing contaminants from organics, the smallest particle size that can be removed with confidence is between 6 to 5mm. Whilst optical sorters have removed particle sizes down to 2mm, this has not been proven yet for the application of contaminants from MWOO. An overview of the optical sorting equipment provided by the technology suppliers is shown in Table 5, additional material provided by suppliers is provided in Appendix A.

Table 5 Overview of optical sorting equipment types, capabilities and limitations

Equipment name	Capability description	Typical application	Technical limitations	List price
UniSort flake, Steinert	High resolution NIR sorter for bulk materials in the fraction range of 3 – 25mm	Sorting contaminants (foreign matter) from PET flakes	Fraction size 5 – 20mm	NIR: €145,000 ($235,000) Colour: €134,000 ($217,000)

<table>
<tr><td>UniSort PR, Steinert</td><td>Can detect differences in chemical composition to i.e. separate a PET bottle from a PET tray</td><td>Sorting plastics from plastic mixtures, sorting of substitute fuels or in the green waste / waste wood sector.</td><td>40 – 300mm</td><td>1m wide: €126,000 ($204,000)
1.4m wide: €140,000 ($226,000)
2m wide: €167,000 ($270,000)
2.8m wide: €222,000 ($360,000)</td></tr>
<tr><td>UniSort Black, Steinert</td><td>Can detect dark and black objects</td><td>Sorting out dark objects in automotive shredder residue and substitute fuel sector or green waste (black plastics, dark glass, etc.)</td><td>15 – 200mm</td><td>Add €18,000 ($29,000) to each UniSort PR option</td></tr>
<tr><td>Tomra Autosort</td><td>Various input materials incl. MSW, organic waste etc. (see brochure); for example see right:</td><td colspan="2"><table>
<tr><th>Materials</th><th>Input (Organics >20mm)</th><th>Output</th></tr>
<tr><td>Organic material</td><td>69.3%</td><td>95.5%</td></tr>
<tr><td>Plastic</td><td>7.6%</td><td>2.5%</td></tr>
<tr><td>Metals</td><td>5%</td><td>1%</td></tr>
<tr><td>Other inerts</td><td>18.1%</td><td>1%</td></tr>
</table></td><td>The Tomra supplier gave a range of $150,000 for a 1m wide sorter to $600,000 for a 3m wide sorter;</td></tr>
<tr><td>Tomra Autosort fines</td><td></td><td>WEEE electronic scrap</td><td>Not disclosed</td><td>Not disclosed</td></tr>
<tr><td>Tomra Autosort Flake</td><td>Simultaneously detecting colour, metals and enhanced material information independent on grain size</td><td>Sorting plastic flakes. I.e. PET into 99.9% purity</td><td>Not disclosed</td><td>Not disclosed</td></tr>
<tr><td>Autosort RDF</td><td>Online analysis of production of substitute fuels</td><td>Permanently measuring heating value, chlorine and water content of RDF being produced</td><td>Not disclosed</td><td>Not disclosed</td></tr>
<tr><td>Autosort Laser</td><td>Glass, MSW, WEEE electronic scrap</td><td>C&I and MSW, separating thin, thick or opaque glass from thin film</td><td>Not disclosed</td><td>Not disclosed</td></tr>
</table>

Autosort colour	I.e. Glass sorting	Sorting glass even when wet, dusty or dirty	Not disclosed	Not disclosed

Whilst the attachments in Appendix A do not disclose specific information about the technical limitations of certain equipment/sensors, a supplier has stated that the optical sorting equipment below 5-6mm is not considered proven. A supplier has also stated that in particular the flake sorter can detect and remove smaller particles, though it is not proven to work on organics. Flake sorters are typically used to sort plastic flakes to achieve a very high purity level (99.9%).

Addressing Chemical Contamination

All technology suppliers acknowledged that commercially available sorting technologies do not have chemical sorting capabilities, rather these sorting technologies target specific materials based on their physical characteristics. Reducing physical contamination, may however reduce the presence of certain chemical contaminants.

Pathway One: *RDF Output*

Suppliers agreed that the are no technical limitations to RDF production which is widely carried out in Europe and the US, but the market settings for RDF do not (yet) exist in Australia. Typically, the processing of MSW for RDF results in the production of a low CV RDF and a high CV RDF. The reason provided by suppliers is that both low and high CV RDF have very different markets or marketing pathways.

High calorific RDF is sought after by the cement industry internationally as a replacement for fossil fuels. Cement kilns need to achieve a high temperature in their clinker process (typically above 1400 degrees Celsius). In many parts of Europe, the US and parts of Australia, instead of paying for the fossil fuel such as coal or diesel, cement kilns have been using a well-defined high CV RDF. RDF is typically much cheaper or can even achieve a negative price (the cement kiln gets paid to take the RDF). Anecdotally, suppliers have noted that the cement industry appears to have moved from receiving payment for accepting RDF to paying for a (well defined high CV) RDF in recent years.

Low calorific RDF is typically used in EfW facilities as a fuel. The core part of an EfW facility is the boiler, which is designed to a specific thermal capacity. When the thermal capacity of the boiler is reached, no more fuel can be processed (per hour). The more fuel the EfW facility can accept, the more revenue the facility can generate. The lower the CV of the material received (to a certain limit – it still must be combustible and not use more energy than it releases in the process), the more tonnes (at a set thermal capacity) the facility can accept. Therefore, EfW facilities do prefer lower CV materials over higher CV materials. Higher CV materials are likely to exhaust the thermal capacity of the facility faster.

The main difference between the 2 processing options (low versus high CV RDF) is that in the low CV version of RDF, the organics can remain (typically after being dried out in the biological process step), whereas in the high CV version, any high moisture or low CV materials are being removed.

Producing a low CV RDF

The process of making a low CV RDF from MSW input follows very similar processing steps as the BAU MWOO process. The main difference is that the organics and many of the combustible contaminants can remain together. The process sorts out materials of higher value (such as metals and PET, HDPE) as well as inert materials that are not combustible (sand, rocks and grit). Some suppliers noted that low CV RDF production may require the same or less sorting activity than MWOO production. Despite this, if NSW AWT facilities were to move towards RDF production; additional costs would be incurred as any facility would need re-engineering and installation of new/different equipment.

Producing a high CV RDF

Producing a higher CV RDF means removing materials with a low CV such as organics, as well as materials containing chlorine (Cl) such as PVC, as cement kilns do have low acceptance criteria for Cl containing feedstock. As the organic fraction is not desirable in a high CV RDF, there are various options for how to treat the organic fraction.

Suppliers noted that there are multiple pathways for processing the remaining organic material not destined for high CV RDF. WTT provided process flows for two of the following pathways:

- Aerobic biological processing to stabilise organic output (Figure 6).
- Wet anaerobic digestion to extract the biological methane potential (BMP) of the organics.
- Dry anaerobic digestion to extract the biological methane potential (BMP) of the organics (Figure 7).

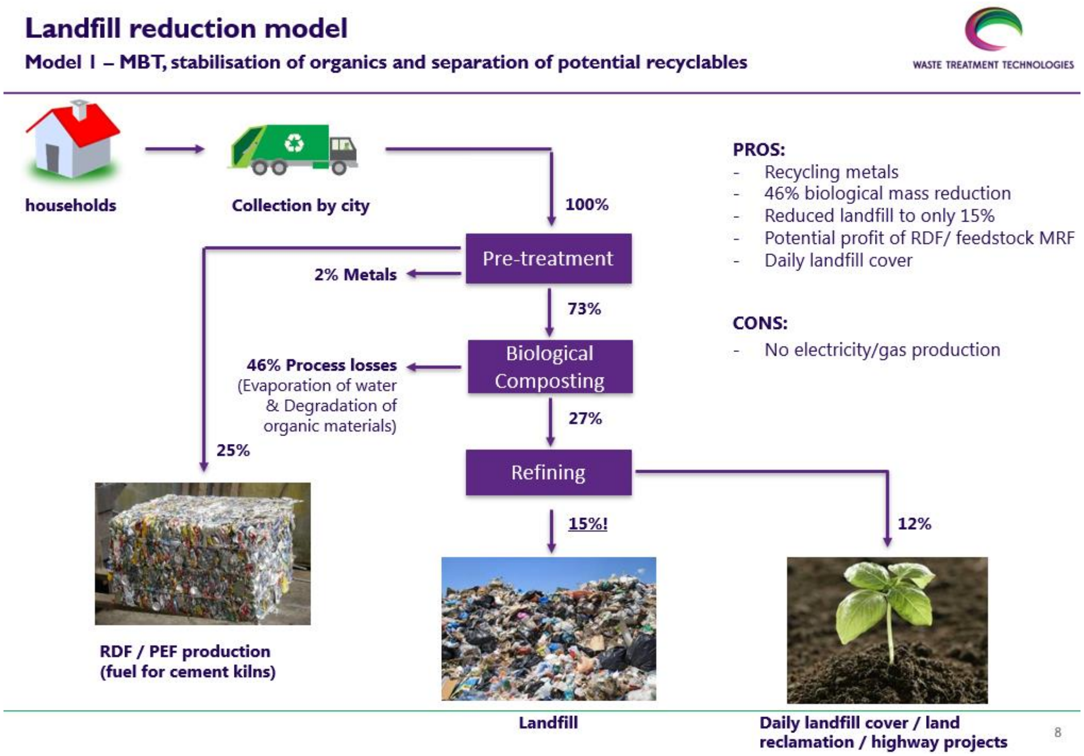


Figure 6 Generic process flow chart of AWT process with aerobic composting provided by WTT

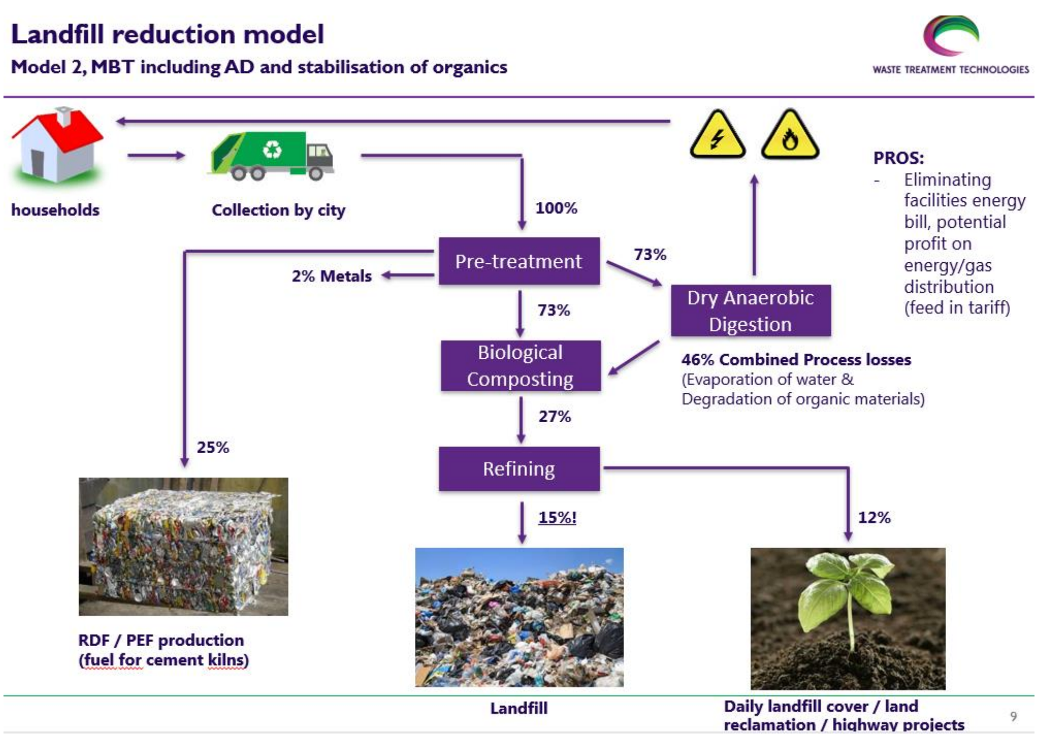


Figure 7 Generic process flow chart of AWT process with AD provided by WTT

THE DIFFERENCE BETWEEN DRY & WET ANAEROBIC DIGESTION

Description provided by WTT Solutions

A main distinction between anaerobic digestion (AD) technologies for treatment of municipal and industrial biodegradable wastes is the operating process solids content.

Wet AD systems operate at low total solids (TS) (<10% TS), semi-dry digestion has a total solid (TS) range of 10-25% and dry systems have high operating solids (20–>40% TS). The performance of wet and dry AD systems is quantified in relation to:

- Technical operation (footprint, capacity, feedstock characteristics, pre-treatment and post-treatment, retention time, water usage)
- Energy balance (biogas productivity, parasitic energy, methane [CH_4] content, utilization of biogas and produced energy)
- Digestate management
- Economic performance (capital and operational costs, revenues, specific capital costs [per tonne of waste and per m^3 biogas]).

Wet AD plants have improved energy balance and economic performance compared to dry AD plants. However, dry AD plants offer several benefits, including greater flexibility in the type of feedstock accepted, shorter retention times, reduced water usage and more flexible management of, and opportunities for marketing the end-product.

WTT noted that several of their reference sites overseas have been successfully processing the organic rich fraction of MSW using anaerobic digestion to recover energy prior to landfilling. Additional case study information is provided in Appendix A. Sites include:

- *Braval, Portugal*: Accepts 15,000 t/a 0-80mm MSW to produce first phase compost and 250 kW electric energy using dry AD tunnels. Operational since 2014.
- *Wiefels, Germany*: Accepts 20,000 t/a, mix of 20-40mm coming from pre-treatment wet digestion and screen fraction of 40-120mm MSW to produce first phase compost and 536 kW electric energy using Dry AD, hybrid and conditioning tunnels. Operational since 2011.
- *Alytus, Lithuania:* Accepts 21,000 t/a, 0-80 MSW to produce first phase compost and 450 kW electric energy using Dry AD, hybrid and conditioning tunnels. Operational since 2015.

In terms of application in NSW, WTT identified that financial incentive to create energy from AD would tip the scales favourably towards a business case for inclusion of this process. Financial incentive could follow the Australian Federal Government Renewable Energy Target certificate scheme, or similar.

Pathway Two: *FOGO as an input*

Technology suppliers agreed with AWT operators that there are no technical barriers to accepting a cleaner[5] organic input for processing.

The FOGO process generally requires a reduced mechanical processing step. Following materials receival, there is light processing via hand picking, then FOGO may be shredded to achieve homogenisation of particle size to increase consistent composting across the batch.

Pathway Three: *Do Nothing*

There are no technical barriers to implementing this option, although there are likely to be contract and cost implications. A reduced operating capacity will increase the operating cost per tonne for generating a stabilised organic output. If this cost cannot be recovered by selling on the product to a viable market, the long-term economic feasibility of this process may be challenged.

If it is the case that chemical contamination is absorbed by the organic material within the MSW stream and assuming that the sources of chemical contamination remain the same, there is a potential for chemical contamination to increase in the organic output. This may also be reflected in increased physical contamination of the smaller plastic and glass particle sizes (under 5mm) as more MSW will need to be processed to achieve a tonne of MWOO increasing the potential for more physical contaminants to pass through into the biological processing stage. Additional sorting at the back end of the process line may address this concern.

Pathway Three: *RDF Output*

If AWT operators were to transition towards generating an RDF output, the processed MSW stream would require a shorter period of time in biological processing, referred to as 'biological drying'. The objective of this step is to reduce moisture content rather than stabilise the output, requiring approximately 2-4 weeks less than the production of MWOO. The reduced operational time required for biological processing may allow for operators to increase their throughput, increasing MSW processing capacity. The market for RDF will be dependent on the organic content of the MSW and will follow the same assessment as Pathway One: RDF Output.

Most of the AWT facilities in NSW either use enclosed bay or tunnel composting in their biological processing stage. Enclosed composting operates as a batch process. As RDF production is likely to decrease the operational capacity of this stage, operators may look to utilise a portion of this underutilised capacity to process an additional organics stream. The level of re-engineering is mainly dependent on front end receival space, and how the AWT facility can utilise separate batches in their enclosed composting process. The division of two streams in enclosed composting requires increased controls and minor works such as additional of physical dividers to reduce cross contamination of the two streams. This option has not been assessed in detail but is likely to require at least 12-18 months of planning approval and construction to be implemented, and is site specific.

[5] Assumes a low contamination rate for food and garden organics stream

5. Literature Review

The purpose of this literature review is to:

- Provide an overview of which processes and technology options are in use in Northern/Southern Europe for processing MSW, including best practice options for AWT outputs.
- List example AWT facilities and their associated processes, including the quality and destination of the outputs and processing technologies used.
- Outline where there are differences in the reference facilities to the NSW AWT BAU process.
- Summarise the literature responses regarding addressing physical and chemical contamination in MSW.

Trends in Processing of Municipal Solid Waste in Europe

In 2018, the European Parliament stated that landfilling is almost non-existent in countries such as Belgium, the Netherlands, Denmark, Sweden, Germany, Austria and Finland. This is achieved through high rates of recycling and utilisation of Energy from Waste facilities; where non-recyclable waste is processed into RDF and incinerated for heat and energy generation. Landfilling remains popular in parts of eastern and southern Europe such as Malta, Cyprus, Greece, Croatia, Spain, Hungary and Portugal, where more than half of municipal waste is still being landfilled (European Parliament, 2018). It has been identified that policy mechanisms such as the landfill tax or landfill bans correlate to a reduction in waste to landfill. For example Spain has one of the highest rates of MSW landfilling (over 60 per cent) and has no national landfill tax (Oakdene Hollins, 2017). Further to this, the International Solid Waste Association (ISWA) notes that the following policy levers are most common for achieving increased waste diversion:

- Landfill and/or incineration taxes.
- Landfill ban on organic or non-treated MSW.
- Mandatory separation and collection of recyclables.
- Consumer-oriented economic incentives for recycling MSW for example Pay-As-You-Throw schemes (D. McKinnon, 2017).

All countries which are a part of the European Union must meet landfill diversion requirements under the Landfill Directive (Directive 2008/98/EC). This Directive was amended in 2018 by Directive (EU) 2018/851, and more ambitious recycling targets were introduced for the period up to 2035. EU countries have flexibility in how they regulate their countries to meet these targets. The following are examples of European countries that have specific policy mechanisms to direct putrescible waste away from landfills and increase source separated organics recycling:

- The Netherlands: The Dutch implemented a differentiated tariff system (DIFTAR) to provide incentive to improve waste segregation at source.
- Belgium: Has one of the highest landfill taxes, and a landfill ban. The ban introduced in 1998 and 2000 prevents the landfilling of unsorted waste, separated waste suitable for recovery and combustible waste.
- Estonia: Banned landfilling of untreated waste in 2009 and has a landfill tax.
- Scotland and Wales: Mandatory segregation of bio-waste introduced in 2011.
- Barcelona, Spain: Moved from AWT to the separate collection of bio-waste (FOGO) in 2010 to achieve a higher quality compost to be used as soil improver.

Weghmann (2017) provided a snapshot of the waste treatment methods used for MSW in the European Union in 2014, see Figure 8. A large percentage of waste is still being sent to landfill (41%), followed by recycling which may include the use of recycled organics.

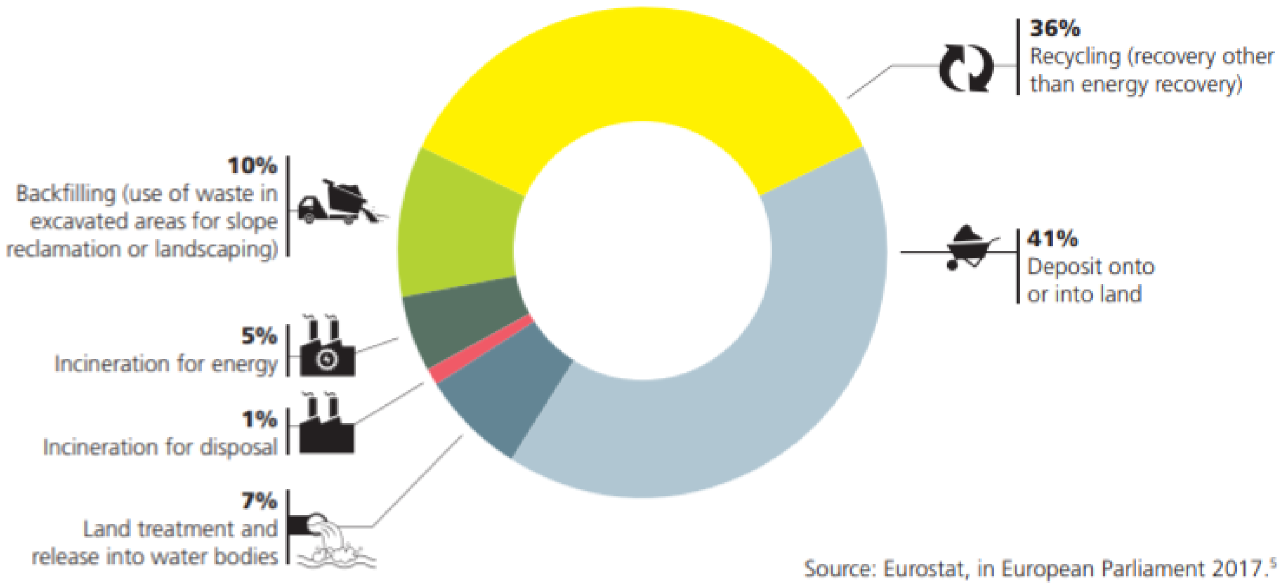


Figure 8 waste treatment methods used for waste generated in the EU-28 in 2014 (Weghmann, 2017)

It is reported that Estonia has the highest MBT capacity as a percentage of overall municipal waste due to the implementation of national policies to divert biodegradable municipal waste from landfill (ETC/SCP, 2013d)(Figure 9). Many of the MBT facilities are operating below their capacity, with some facilities recorded to be operating at just one fifth of their capacity. The majority of the MBT output is sent to an incineration plant in Talinn (Global Recycling, 2019). Notably, some of the countries with the highest percent of waste to landfill also have some of the higher MBT capacities, see Figure 9.

It is likely that the data for Hungary in Figure 9 is not representative. Herczeg (2013) states that Hungary started to build several MBT plants after 2000, although many MBT plants were facing a shortage in demand for RDF produced and may not be operational. Additionally, the market for the stabilised organic fraction from MBT is reported as poor due to strict technical standards on composts and the general public aversion to waste-derived composts. This has led to MBTs operating at 50% capacity. Hungary's landfill tax was implemented in 2013 and may have influenced the greater trend towards diversion from landfill in recent years.

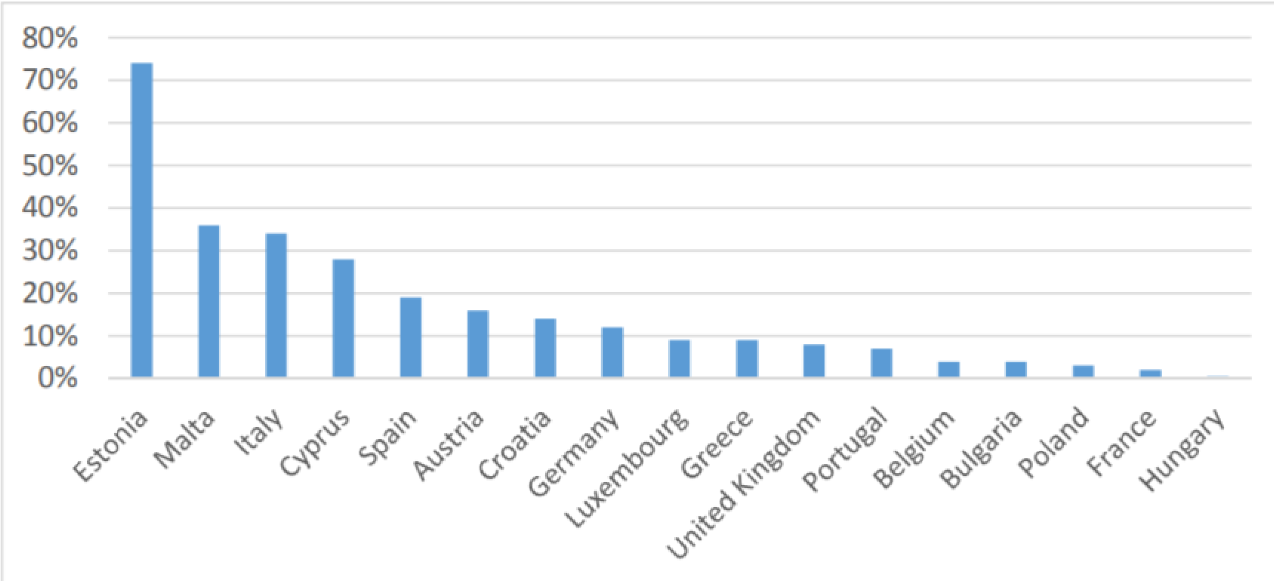


Figure 9 MBT capacity as a percentage of total municipal solid waste in Europe in 2010 (Oakdene Hollins, 2017)

The EU has stated that the two potential markets for residual MSW[6] are landfilling or incineration. As of 2016, the EU has noted that biowaste (food waste, agricultural, forestry, marine and animal derived residues) is being re-categorised away from waste specific classifications to either feedstock, raw materials or energy under the new Circular Economy framework. To support the utilisation of recycled organics from source separated biowaste, the EU is providing R&D funding for the 'bio-economy' through the Bio-Based Industries (BBI) public private partnership.

On 27 February 2018, the environment committee (ENVI) of the European Parliament approved the Circular Economy Package, which included an additional target in the Revised Waste Framework Directive for all Member States to collect bio-waste separately by 31 December 2023. By 1 January 2027, stabilised organic outputs from MBT facilities will no longer count towards recycling targets (European Compost Network, 2019). The actions of the European Union have been taken to assist in transitioning to a circular economy, whilst aiming to maximise the protection of the environment and human health.

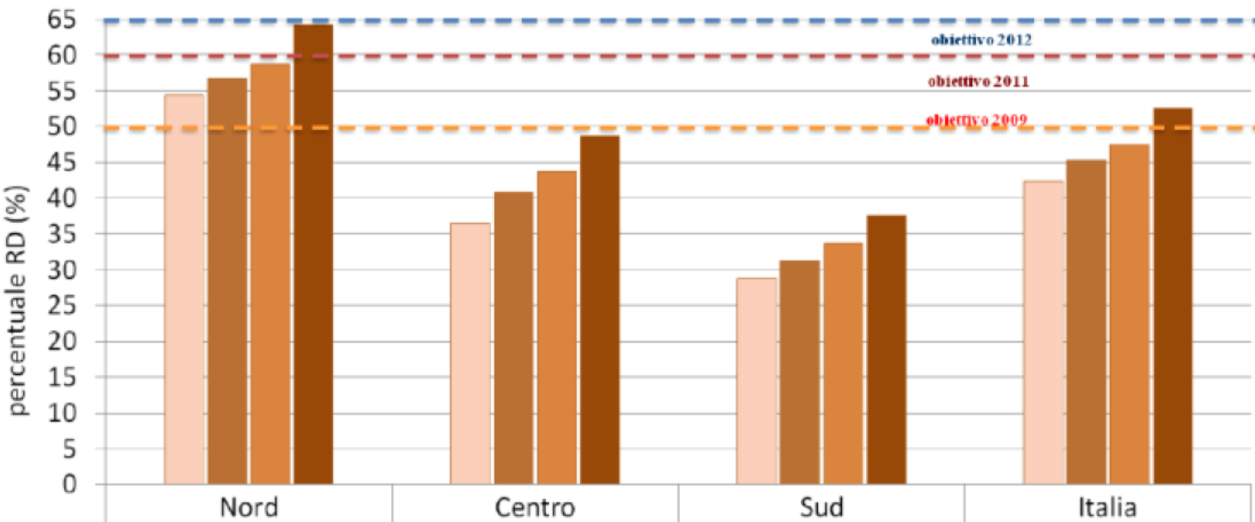
Many European countries recover energy from both source-separated biowaste, and the stabilised organic output from MBT using anaerobic digestion. Interestingly, Germany, the Netherlands, Belgium and Spain which are the largest producers of digestate from AD send over 60% of their digestate to landfill. This may be due to the source of organic input being more contaminated e.g. from an MSW stream (Oakdene Hollins, 2017).

Italy, the fifth largest producer of AD digestate, recovers over 60% of its digestate through applications of one-off landscaping such as for golf courses. It is proposed that AD digestate in Italy has a higher value application as it is aerobically composted following the AD process. This is because digestate from a mixed waste source must be composted to then be considered a product and used as an organic fertiliser to comply with Italian Fertilizer Law (ISWA, 2019). Italy has more than 120 MBT plants across the country that treat approximately 23% of the total MSW produced in Italy, some of which use anaerobic digestion to treat the organic fraction of MSW. It has been reported that 67% of the MSW processed through MBT can be recovered; (34% inert recyclables, 23% organic output and 10% energy recovered) (Oakdene Hollins, 2017).

In Italy, ambitious MSW separate collection targets, including the separate collection of biowaste (FOGO) were introduced with the national Waste Framework Act (D_LGS 152, 2006), which required Municipalities/District

[6] Assumes organics are source separated as 'biowaste'

Areas to reach at least 65% separate collection by the end of 2012. In 2013, Italy adopted the national waste prevention program which included an incentive to promote greater use of green public procurement and recycling (European Commission, 2019). Despite not meeting the ambitious collection targets, rates of separate biowaste collection and recycling of municipal waste have been growing across Italy during the period 2013-2016, as shown in Figure 10. As of 2016-17, 55% of organic material is being recovered by separate biowaste collection, and approximately 23% of MSW is being processed using MBT.



	Nord	Centro	Sud	Italia
2013	54,4	36,4	28,8	42,3
2014	56,7	40,8	31,3	45,2
2015	58,6	43,8	33,6	47,5
2016	64,2	48,6	37,6	52,5

Figure 10 Regional separate biowaste collection rates for north Italy (Nord), central Italy (Centro), south Italy (SUD), and the whole of Italy (Italia) over a period from 2013 to 2016, (European Commission, 2019)

Greece, which as of 2017 is only diverting 19% of its municipal waste has been identified by the European Commission as unlikely to meet the 2020 target of 50% municipal waste recycled. Greece adopted a landfill tax law in 2012, but its application has been postponed until 2019 at the earliest. Greece has 49 MBTs in the planning stages, and the European Commission warn that the heavy investment into residual waste treatment at the lower levels of the waste hierarchy will not be adequate to reach the 2020 target (European Commission , 2019). The Early Warning Report commissioned by the Commission recommends Greece redirect EU funding to support separate collection, recycling and composting.

Production of RDF from MSW

Manufacture of RDF is often an objective of MBT plants and the material may be incinerated in dedicated facilities, or co-incineration plants (Eunomia Research & Consulting, Scuola Agraria del Parco do Monza, HDRA Consultants ZREU, LDK ECO, 2005). Sinclair Knight Merz (SKM) performed a waste management study tour in 2012 visiting seven waste processing sites across Europe to inform a major waste management company on the potential process options for treating MSW (Sinclair Knight Merz , 2012). Of the seven sites visited, five sites were MBT facilities. The location of each MBT facility, its respective facility type and waste inputs and outputs are outlined in Table 6.

The report surmised that operational costs can be far more significant for biological treatment when compared to mechanical processing. In the life time of a biological treatment facility, the operational costs are likely to significantly outweigh the original capital expenditure. It was suggested that treating the organic rich component of the waste by dry or wet anaerobic digestion to provide renewable energy, may offset the energy consumption of the facility either directly or indirectly. The SKM report notes that none of the visited facilities were producing an organic product for direct land application.

When comparing the technology provided in the European reference sites to the NSW AWT BAU process, it can be seen that all of the technologies are the same, albeit some are located in different parts of the process line, with the exception of optical sorting capacity in the Barcelona facility. It was noted in the SKM report that optical sorting technology is likely to be required in RDF processing to achieve a low chlorine content of 0.2% on a dry basis by sorting out Polyvinyl Chloride (PVC) plastic. In all of the European reference sites the organic fraction was either processed for RDF or landfilled.

Table 6 Overview of five waste processing sites across Europe, SKM 2012

Location	Waste Input (tonnes per annum)	Facility Type	Technologies	Capital Costs	Outputs
Facility One, Spain	90,000 Commercial and Industrial waste	Mechanical treatment	Primary shredder, ballistic separator, overband magnet, optical sensors	Capital including Civil €5.5 million.	67,500 tonnes - Refuse Derived Fuel (15% moisture content) 13,500 tonnes - Landfill
Facility Two, UK	130,000 MSW	Mechanical biological treatment with Anaerobic Digestion	Grab crane, primary shredder, drum screen, magnetic separator, air density sensor, NIR separator, non-ferrous metals separator	£40 million	23,187 tonnes – Recyclables (Ferrous and non-ferrous metals, sand, stone and glass) 68,633 tonnes – High CV RDF 15,074 tonnes – Low CV RDF 6,322 tonnes – Biogas 16,669 tonnes – Landfill

Facility Three, Slovenia[7]	70,000 MSW	Mechanical biological treatment	Fast rotating trommel, screen, biological treatment, shredder, magnetic separator, non-ferrous metal separator	€15 million	14,000 tonnes – Recyclables (Ferrous and non-ferrous metals) 29,400 tonnes – RDF to district heating plant 18,200 tonnes – Landfill (fines and heavy fraction)
Facility Four, Germany	100,000 MSW	Mechanical biological treatment	Screen, shredder, biological drying (aerobic), trommel/drum, magnetic separator, non-ferrous metal separator	€25 million	<5% of input tonnes– Recyclables (Ferrous and non-ferrous metals) >70% of input tonnes – RDF for use in cement kilns (2% of RDF made from light materials/dust and pelletised) Remainder landfilled.
Facility Five, Germany	198,000 MSW (accepted bulky waste) Includes 43,000 tonnes of pre-treated waste from a neighbouring MBT	Mechanical biological treatment	Shredder, sieving drum, magnetic separator, non-ferrous metal separator, zigzag screen (density sorter), biological drying (aerobic)	€40 million + €8 million on improvements	Mass Balance not provided Recyclables (Ferrous and non-ferrous metals) RDF for use in combined heat and power plant

[7] It should be noted that Slovenia has implemented door-to-door collection for source separated materials. Residents are required to sort eight types of waste; paper, plastic, glass, household hazardous waste, metal, electrical and electronic, kitchen waste and garden waste (Slovenian Waste Management Plan, 2012).

Energy recovery from the organic fraction of municipal waste

Anaerobic Digestion (AD) of MSW has been commercially available for approximately 25 years. As of 2005, AD of biowaste (source separated food and garden organics) was only part of a few countries waste management strategies; being Germany, Austria, Belgium and Denmark. Digestion of mixed or residual waste under an MBT process has been adopted in countries such as, France, Italy and Spain (Oakdene Hollins, 2017). Rapid growth of AD processing in Spain during 2005 can be attributed to EU funding programs supporting the implementation of this technology. The uptake of AD across Europe varies, and may be due to the concerns regarding long term performance of AD infrastructure (Eunomia Research & Consulting, Scuola Agraria del Parco do Monza, HDRA Consultants ZREU, LDK ECO, 2005).

The International Solid Waste Association (ISWA) released a factsheet noting the legislative framework regulating the application of digestate on land for several European Countries (Figure 11). In this Figure, 'digestate' can be from either a mixed waste stream or source separated stream source. Generally speaking; digestate from source separated organics streams have far less restrictions than digestate processed from mixed waste streams. For example, in the UK the AD Quality Protocol is only met if the organic material is supplied from source-segregated organic waste (UK Government , 2014).

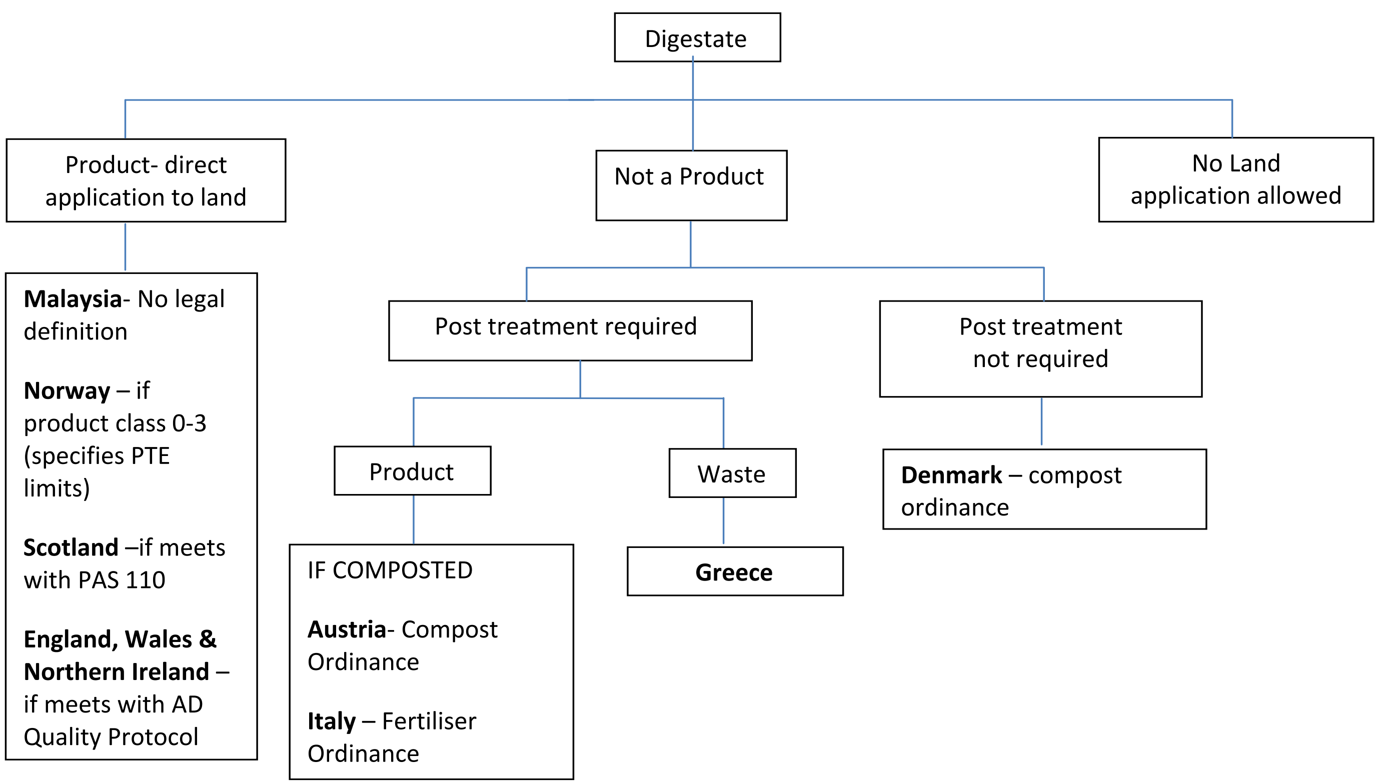


Figure 11 Schematic overview of legislative framework regulating the application of digestate on land, ISWA Factsheet 2019

Eunomia et al (2005) notes that the use of subsidies or above-market prices for the energy generated by combusting or composting MSW can incentivise the production of RDF and the use of AD, as seen in countries such as Italy (Green Certificates) and the UK (Non-Fossil Fuel Obligation). The UK Parliament has a series of financial incentives in place to encourage anaerobic digestion and use of biogas, these are:

- The Renewable Obligation: introduced in 2002, requires suppliers to purchase tradable Renewable Obligation Certificates.
- Feed-in Tariffs: introduced in 2010, provides payment for renewable electricity producers (<5 MW_e).
- The Renewable Heat Incentive: introduced in 2011, provides guaranteed payment for heat used from biogas combustion (<200 kW_{th}) and all biomethane injected into the grid.
- Renewable Transport Fuels Obligation: introduced in 2008, obliges suppliers to source 5% of transport fuels from renewable resources by 2014 (UK Houses of Parliament, 2011).

Alternatives to RDF – Pyrolysis and Gasification

The Coolsweep (2015) report 'Global Analysis of the WtE Field' states that pyrolysis, plasma gasification and gasification could all gain relative market share but there are still concerns about these technologies being applied to processing MSW. For gasification, the need for a certain degree of pre-treatment makes it costly when compared with EfW and the benefits have yet to be defined at a commercial scale. Despite pyrolysis and gasification being widely used in industrial processes for energy recovery from a hydrocarbon feedstock, their utilisation to process heterogeneous MSW is at an early stage of development (Eunomia Research & Consulting, Scuola Agraria del Parco do Monza, HDRA Consultants ZREU, LDK ECO, 2005). These technologies have not been further analysed for their feasibility in NSW, as this report is assessing the feasibility of established and widely used technology.

Addressing physical and chemical contamination in MWOO

D McKinnon *et al* (2017) notes that there are two different conceptual approaches to sorting waste: positive sorting and negative sorting. Positive sorting focuses on the selection and separation of a desirable fraction, for example to extract non-ferrous materials, eddy current sorters are used. Negative sorting focuses instead on identifying and removing a non-desired fraction, for example soft plastic from an organics stream is sorted out using a ballistic separator. The report concludes that generally positive sorting results in a high-quality material product, but at the cost of efficiency, whilst negative sorting tends to be more efficient, although to the detriment of quality of the obtained materials. NSW AWTs utilise a combination of positive and negative sorting methods.

D McKinnon *et al* (2017) also identifies that several factors influence the decision making behind what technologies are implemented in a sorting facility (Figure 12). Performance relates to whether the technology can meet the desired specification outputs, whereas reliability relates to the ability of the technology to perform a required function under stated conditions for a specific period of time.

The factors of performance and reliability of the current NSW AWT technologies have been questioned as part of the TAC report with regards to adequacy for the application of the product to land. Following its review, the TAC found that the presence of physical contaminants in MWOO raises significant concerns in terms of human and animal health (glass contamination of crops and forage), as well as concerns for aesthetic quality of soils and soil physical quality degradation (plastics). The TAC report recommended that further consideration be given to additional technologies for removing physical contaminants in MWOO processing [in NSW] if it is to be applied to land (Technical Advisory Committee, 2018).

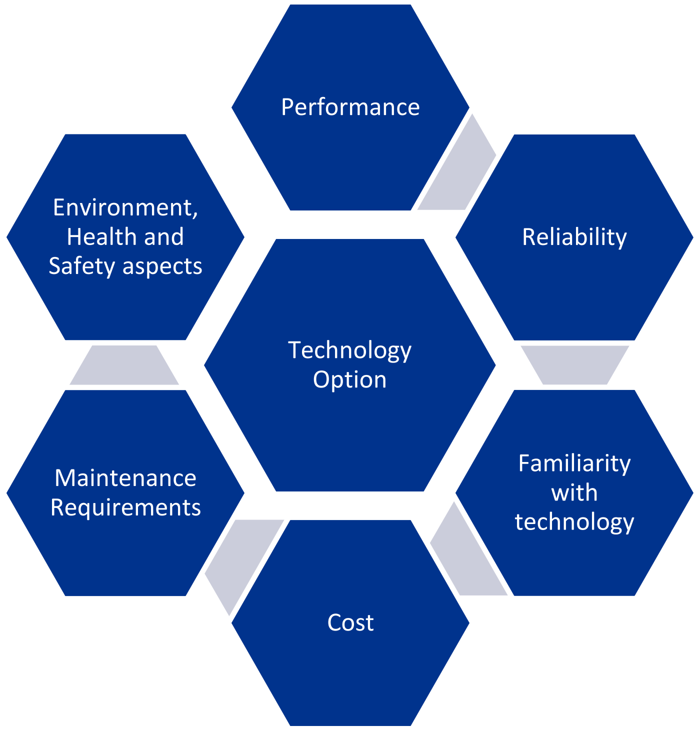


Figure 12 Deciding factors when determining appropriate sorting equipment, D. McKinnon et al, 2017

Oakdene Hollins (2017) outlines the sorting capabilities of optical sorters specifically targeting plastic contamination in a table provided in Appendix B. The performance statistics of the technology assessed in the report align with the claims made by NSW AWT operators and technology suppliers, such as the Tomra Autosort being effective in sorting >2mm particle size (dependent on input stream). The table notes that ongoing research is being undertaken for a number of applications, highlighting the areas of uncertainty in some technology performances.

Chemical contaminants of concern as outlined in the TAC report are polybrominated diphenyl ethers (PBDEs), phenols, phthalates, cadmium, copper and zinc (Technical Advisory Committee, 2018). It should be noted that this list of contaminants are not the only contaminants the NSW EPA has identified as requiring management in MSW processing for a product destined for land application. NSW AWT operators stated that plastics, wires, coins, foil and batteries were the key physical contaminants associated with the leaching and subsequent contamination of chemical compounds and elements.

Slack (2005), notes that kerbside MSW includes waste from a number of household products such as paint, garden pesticides, pharmaceuticals, photographic chemicals, certain detergents, personal care products, fluorescent tubes, waste oil, heavy metal-containing batteries, wood treated with dangerous substances, waste electronic and electrical equipment and discarded CFC-containing equipment. Table 7 provides an overview of the likely sources of contamination for each chemical of concern, and the reported levels of contamination in NSW MWOO as detailed by the TAC report (Technical Advisory Committee, 2018). The table highlights that there are numerous sources in MSW that could contribute to the concentrations of contaminants in MWOO. Some of these sources such as plastics, glass and metals can be targeted and removed, whilst other sources such as household dust, liquids and pigments in paper and fabrics are likely to pass through front-end processing and be incorporated into the organic fraction. It is not clear the level to which each potential source contributes to overall contamination. Further research or trials could be instigated to understand the impact removal of plastic, glass and metal contaminants may have on the chemical concentrations found in MWOO.

Table 7 Sources of contaminants in MSW as referenced in literature

Chemical Contaminant	Source of contaminant – as referenced in literature	Concentrations in MWOO (TAC Report 2018)
Polybrominated diphenyl ethers (PBDEs)	• PBDEs are used as flame retardants in a wide variety of products, including plastics, furniture, upholstery, electrical equipment, electronic devices, textiles and other household products (ATSDR 2015; EPA 2009).	• PBDEs were identified in MWOO at concentrations up to 720 mg/kg. • TAC reported that high concentrations of PBDEs occurring in MWOO could be of concern for human health, further research required.
Phenol(s)	• Naturally occurring. • Phenolic resins (human made polymers consisting of phenol) used in plywood adhesive, construction, automotive, and appliance industries. Bisphenol A is used primarily in the manufacture polycarbonate plastics, epoxy resins and non-polymer additives to other synthetic polymers.	• High concentrations of phenol were detected in MWOO (98 mg/kg), and 3&4-methylphenol (71 mg/kg). • Bisphenol A was detected in all MWOO sampled by NSW OEH (Project 3) with concentrations ranging from 4 to 100 mg/kg. • According to the European Chemical Agency, the ecological threshold for 'predicted no effect concentration' is 0.13mg/kg.
Phthalates	• The most commonly recognised sources of these pollutants within MSW are attributed to plastics, electrical equipment and remnant pesticides and herbicides on food and garden waste (Technical Advisory Committee, 2018).	• Phthalates are considered to have harmful effects on the reproductive and endocrine systems (Technical Advisory Committee, 2018). • Dibutyl phthalate (DBP), bis-2-ethylhexyl adipate (DEHA) and bis-2-ethylhexyl phthalate (DEHP) are the main plasticisers found in MWOO, with concentrations of up to 2,600 mg/kg measured for DEHP.
Cadmium (Cd)	• The major sources of cadmium in MSW are household batteries, plastics and consumer electronics. Other sources include glass, ceramics and pigments (E. A. Korzun, 1990).	• Concentrations of Cd in MWOO are similar to biosolids, and high enough to cause concerns for food chain contamination. • The TAC report proposes that Cd contamination in MWOO be managed using an approach consistent with current biosolid guidelines.
Copper (Cu)	• In waste electrical and electronic equipment, plumbing and scrap metal • Significant concentrations of heavy metals (Ni, Cu, Zn, and Pb) can be found in household dust, dependant on residential location (traffic and industrial regions) (D. Wan, 2016) (F. Nakajima, 2018) (N. Jabeen, 2001). • Zinc Oxides can be used in pharmaceutical cream and sanitary items.	• Cu was identified as high-risk metal due to possible adverse effects on plants and soil organisms.
Zinc (Zn)		• Zn was identified as high-risk metal due to possible adverse effects on plants and soil organisms.

The TAC report recommends a limit for microplastic contaminants <2mm should be included and that a volumetric based limit for plastics should be used instead of gravimetric based limit. The TAC report suggests that MWOO could be a source of secondary microplastics. The report hypothesises existence of microplastics could encourage absorption of heavy metals and organic contaminants over long time frames (Technical Advisory Committee, 2018).

F Watteau *et al* (2018) also found that plastics and microplastics were present in soil that was amended with stabilised organic material from an MBT facility. The report notes that microplastics derive from a wide range of sources in household composts such as from synthetic fibres from clothing, polymer manufacturing, processing industries and personal care products. W Brinton (2005) further supports this, finding that nondegradable textiles and plastic comprised of strands of synthetic material may be a principle inert component of fine fractions (microplastics) of compost. Despite AWT operators targeting the removal of large textiles in the front end processing through the ‘material stream preparation’ stage (see Section 3), it is recognised that a small portion of textiles will pass through to the biological processing stage. Smaller material containing synthetic fibres such as cigarettes and sanitary items may also pass through front end processing and contribute to the proportion of microplastics found in the stabilised organic output. As identified by Oakdene Hollins (2017), and stated by the AWT operators and technology suppliers, commercially available optical sorting technologies have not been proven to adequately remove plastics below 2mm from a mixed organics stream.

Further research would be required to quantify the risks microplastics have in a terrestrial environment to determine what level of contamination would be acceptable. The level of microplastic contamination in MWOO would also need to be tested and quantified to characterise the sources of contamination before an appropriate technology or process could be suggested to address this type of contamination if it is considered to be harmful to human health and the environment. Recent literature from F. Corradini (2019) and F Watteau *et al* (2018) suggests an array of methodology is being used to quantify microplastic in soils; such as transmission electronic microscopy, vis-NIR spectroscopy and using chemical elements such as Titanium (Ti) and Barium (Ba) as proxies for the presence of plastics. The variability in methods of microplastic detection highlights that there is no standardised method to test for microplastics. As this is a relatively new area of research, it may take some time before reliable methodologies are established.

6. Feasibility Assessment of Alternative Pathways

The following research questions were addressed for each alternative process option:

- How it generally aligns within the AWT process.
- How it treats or removes chemical and physical contaminants from MWOO.
- Its success in removing contaminants (i.e. to what extent and concentration or amount).
- The cost of installing and operating the technology or process change.
- The timeframe required to install (and commission) the change.

Responses were collated from the outputs of the stakeholder engagement and literature review. Table 8 provides a detailed overview of the data collated for each pathway. Summaries of the findings under each research question are provided in Section 6.1.

Table 8 Overview of Alternative Pathways for NSW AWT Facilities

Pathway	Process Option	Sub Options	Technologies	Alignment with AWT process	Contamination removal capability	Cost of equipment
One: MSW input	**1. BAU**		• **Material receival**: bobcat, excavator, manual, front-loader. • **Material stream preparation**: bag openers, pre-shredders, screw mills, crushers, rotating drums, ball mills. • **Biological treatment**: in vessel aerobic tunnel composting, mechanical agitator. • **Material separation (including Material refinement)** (pre and post biological treatment): trommel screens, ballistic separators, eddy currents, magnets, manual sorting, hammer milling and size reduction.	Yes, as this is the current process.	**Physical Contamination** • The current AWT processes have varying levels of capabilities to remove physical contaminants. • Physical contamination is removed through more manual sorting technologies; targeting the contaminants' weight, size and/or density, geometry and milling activities to reduce the size of physical contamination fractions. **Chemical Contamination** • It was identified in the TAC report that one-off sampling recorded peaks of chemical contamination significantly higher than accepted concentrations.	Not required for the purposes of this report.
	2. Improved MWOO Where output is intended for land application	**2.1 Low Capital Investment**	As BAU with additional: • Processing lines (repeat BAU equipment) • Process line included to blend in source separated organics at back end of process (rotating drums, additional conveyor systems)	Yes, this process is only marginally different from BAU with reconfiguring of equipment and purchase of some additional equipment required. It was quoted that the implementation of this process would take 6-12 months.	**Physical contamination** • The removal efficiency of the current processing lines will be marginally improved by running the to be processed material through the equipment more than once (several passes). However, without optical sorting equipment, the removal efficiency is limited by the aperture size of equipment used, such as rotating drums. The actual aperture size of the equipment was not disclosed for the purpose of this report. **Chemical contamination** • Blending with source separated organics may achieve a dilution of contaminants, but does not align with best practice for addressing contamination.	Commercial in confidence information has been removed for the purposes of this report.

		2.2 High Capital Investment	As BAU, with additional optical sorting technology at the front and/or back end of the process line: • Near infrared (NIR) and infrared. • X-ray transmission and fluorescence. • Laser.	Yes, with installation of new but well proven equipment. It was quoted that the implementation of this process would take at least 12 months.	**Physical Contamination** • The addition of optical sorting equipment will add to the removal efficiency of the facility. However, the equipment suppliers have confirmed that the optical sorters have not been proven yet to successfully remove contamination below between 2-5mm in an MSW stream. Technology suppliers have noted that the degree to which contamination can be removed is dependent on the input material and its preparation, spread (conveyor belt width) and speed, as well as how many times the material passes through a screen. • Microplastic contamination cannot be wholly addressed through the addition of optical sorting technologies. • An operator has confirmed that it is confident in meeting the physical contamination limits of 0.5% Glass, metal and rigid plastics >2mm **Chemical Contamination** • The impact that additional physical contamination removal has on chemical concentrations of polybrominated diphenyl ethers (PBDEs), phenols, phthalates, cadmium, copper and zinc have not yet been proven. • Operators have claimed significant decreases in chemical concentrations of those contaminants listed in the revoked RRO/E when trialling an improved MWOO process, however these results have not been verified by the project team. The improved MWOO processes are unique to each AWT facility, discussed further in Section 4.1.	Cost estimates for equipment excluding ancillary works (including approximate Australian dollar equivalent as of July 2019): UniSort PR: 1m wide: €126,000 ($204,000) 1.4m wide: €140,000 ($226,000) 2m wide: €167,000 ($270,000) 2.8m wide: €222,000 ($360,000) UniSort Flake: NIR: €145,000 ($235,000) Colour: €134,000 ($217,000) UniSort Black: Add €18,000 ($29,000) to each UniSort PR option UniSort Blackeye: €285,000 ($461,000) An operator stated a total capital cost of $23million is estimated to create an improved MWOO output. Additional commercial in confidence information has been removed for the purposes of this report.
	3. RDF Output Where output can no longer be applied to land	**3.1 High Calorific Value** Where inorganic materials are selected for combustion (e.g. contaminated plastic and fibre). Organic material is utilised for biogas production using anaerobic digestion (AD).	Inorganic processing • As BAU or simplified processing line. Organic processing • Anaerobic digestion: biological processing includes: composting tunnels, hopper, magnetic separators, screen, hard particle separator and maturation bays.	Yes, similar to Option 2.2 Improved MWOO at high capital investment. Where AD is installed as a new biological process, extra time and space will be required, as well as planning approvals. A supplier noted that most of the existing AWT composting bays can be retrofitted to be suitable for dry AD, a process explained in Section 4.2. It was quoted that acquiring the relevant	**Physical Contamination** • The removal of physical contaminants for the purpose of producing RDF does not require the same level of processing as for land application. Bulky materials and recyclables can be successfully sorted as demonstrated from BAU processes. • The presence of inert material such as rocks and sand will increase ash content of the RDF and therefore lower the value of the RDF but do not inhibit the use as RDF. **Chemical Contamination** • Chlorine (Cl) contamination has been identified as a barrier to NSW operators entering the RDF market. Optical sorting technology targeting PVC plastic is proven to reduce Cl contamination in RDF as shown by the use of these technologies in established facilities overseas. • AD digestate is either landfilled directly or processed further by aerobic composting where	Optical sorting equipment likely required to target PVC plastics, to meet Cl concentration requirements under the NSW Energy from Waste Policy. It is proposed costing would be similar to Pathway 2.2. Improved MWOO at high capital investment. As identified in the SKM report, AD as a form of biological composting requires significantly more capital investment, and ongoing operational and maintenance costs than aerobic composting. The recovery of the energy potential of the organic fraction needs to be incentivised to enhance the business case. Suppliers were unable to provide estimated costings to verify operator claims.

				planning approvals would take at least 12 months before extensions, retrofitting and install of new equipment could begin.	the output can be used as a low CV RDF or in some cases applied to land, for example in Italy (ISWA, 2019). Trials would be required to quantify the contamination levels in stabilised digestate to assess whether the material is appropriate for restricted land application.	
		3.2 Low Calorific Value Where both the inorganic and organic fraction can be pre-treated to produce a fuel	• Simplified BAU processing for front end mechanical sorting. • Biological processing to reduce moisture content. Technologies include Biodrying, biostabilization, thermal drying or solar drying. • Back end processing for transport: dried output is processed to create homogenous and compact product via shredding and/or pelletising.	Yes, this option may require little change or even some savings in sorting equipment or process as less sorting may be required depending on quality requirements for RDF output. The timeframe of implementing this option is dependent on the time it takes to establish a local market.	**Physical Contamination** • As above. **Chemical Contamination** • Facilities that accept lower CV RDF are designed to accept materials with higher contamination concentrations.	It is anticipated that this option requires low capital investment for technology acquisition. The key barrier to the economic feasibility of this option is the lack of available local markets.
Two: FOGO input	**1. Compost output meeting the *Compost Order 2016***		• As BAU or simplified processing line (dependent on contamination).	Yes, very similar to BAU.	**Physical Contamination** • The BAU processing line is set up to address higher contamination than what is anticipated in a source separated stream. **Chemical Contamination** • Facilities will be required to meet *Compost Order 2016* chemical contamination specifications.	This option requires low capital investment from a technical perspective. One of the key barriers to the feasibility of this option is the contractual obligations operators have with Councils either directly or indirectly. There may be a lack of sufficient, immediate supply of source separated organics to meet the full operational capacity of the AWT facilities as a limited number of LGAs within the Greater Sydney region offer a FOGO service.
Three: Organics depleted MSW	**1. Do Nothing** Continue BAU process (sort out recyclables, create stabilised organic output).		• As BAU.	Yes, same as BAU	**Physical Contamination** • Potential for higher contamination of the output, where the smaller fraction of glass and plastic are being sorted into the organic fraction. **Chemical Contamination** • Potential for increased contamination if organic fraction of MSW absorbs chemical contamination.	No additional technology required, however lower overall volume of organic input is likely to increase the operating cost per tonne. This option also implies that the process line is operating at less than 100% capacity (dependent on remaining organic content in MSW stream).
	2. RDF output Change technical processing to produce alternative output of refuse derived fuel.		• As, Option 3.2 - Additional of optical sorting for optimising RDF output for particular markets e.g. reducing Chlorine for cement kilns .	Yes, there is a reduced capacity of biological processing which may allow operators to increase annual throughput (as process times are reduced). Timeframes are market dependent.	As for Pathway 3.1 and 3.2	Faster processing time for biological drying means that operators may be able to increase throughput. Available biological processing capacity could be utilised to accept a separate FOGO stream. This would require reconfiguring and may require minor construction dependent on the existing process lines.

6.1 Summary of key findings

General Alignment with AWT process

Each of the alternative pathways generally align with the AWT process and have been proven as long-term solutions in European reference sites. The process options identified under 1.2 Improved MWOO and 1.3 RDF Output involve continuing to process MSW as an input. They require additional technology, re-engineering or facility extensions to be effectively implemented. Each of the alternative processes under Pathway One offers a viable processing option for MSW. Across Europe, MSW typically ends up in landfill or is used for energy recovery, noting that the organic fraction is separated at the kerbside. Pathway Two: FOGO as an input is likely to require a simplified process to current AWT process, dependant on the level of contamination of the source separated stream.

The process of treating or removing chemical and physical contaminants

The current AWT process generally involves the following steps and associated technologies:

- **Material receival**: bobcat, excavator, manual, front-loader.
- **Material stream preparation**: bag openers, pre-shredders, screw mills, crushers, rotating drums, ball mills.
- **Biological treatment**: in vessel aerobic tunnel composting, mechanical agitator.
- **Material separation** (pre and post biological treatment) and Material Refining: trommel screens, ballistic separators, eddy currents, magnets, manual sorting, hammer-milling.

These technologies sort out physical contaminants (glass, plastic, metal and bulky materials) by targeting the contaminants' weight, size and/or density.

Optical sorting technology is also available and uses sensors to detect physical contaminants for sorting. Suppliers confirmed that the sensors most used in the context of sorting contaminants from organics or compost are NIR, laser or x-ray sensors.

Success in removing contaminants

It is acknowledged by operators and suppliers that chemical contamination cannot be detected and removed on its own by commercially available technologies. Mechanical and optical sorting equipment is predominantly designed to detect and remove physical contamination. It is proposed that the removal of physical contaminants as early as possible in the mechanical treatment process will reduce associated chemical contamination in the product. Insufficient sampling data has been sourced to determine this correlation for the chemical contaminants listed as of a concern in the TAC report.

The extent to which physical contaminants can be removed are limited by particle size. It is currently not possible to get a supplier's warranty for the guaranteed removal efficiency of plastic or glass material below 5mm for optical sorting technology. Microplastics (under 2mm) cannot be directly targeted and removed with certainty under a known process option. However, it is also acknowledged that running materials through the sorting equipment several times will significantly reduce the contaminant load. Operators will need to test and verify the extent to which physical and chemical contamination can be reduced as well as making an economic case for the resultant higher operating costs and lower throughput of their respective facilities.

Addressing physical and chemical contamination for Pathway One: RDF Output, and Pathway Three: RDF Output does not require the same level of processing as for Pathway One: Improved MWOO. Chlorine and inert materials such as rocks and gravel are targeted for separation to ensure the output meets the specifications of the market stakeholder for example a cement kiln. Under Pathway Three, the reduced organic fraction may have positive impacts on the ash content of the RDF and open the RDF to new markets. Overseas reference facilities use optical sorting technology to target plastics containing chlorine to achieve these specifications.

The capacity for contamination removal under each alternative Pathway is described in detail in Table 8.

The cost of installing and operating the technology or process change

The cost of installing and commissioning a new process option will be different for each facility. Capital costs for reference facilities and individual technologies have been provided in Table 8. These costs will not be reflective of the total costs associated with the implementation of alternative pathways as there are multiple ancillary and site-specific costs that will be unique to each facility. Some operators have confirmed that they have internally signed off business cases for the implementation of an 'Improved MWOO' pathway, reinforcing the economic viability of this process option.

Economic barriers for Pathway One: RDF Output are not associated with technology acquisition, rather insufficient demand for the product in local markets.

The operating cost per tonne is likely to increase under Pathway Three: Do Nothing, as operational capacity is reduced. The costs of implementing Pathway Three: RDF output will be similar to creating a high CV RDF output under Pathway Two. There may be additional options under this pathway to increase throughput or accept an additional organics stream (for example FOGO). There will be costs to accepting an additional stream, for those operators who are not already set up to accept two or more waste streams.

The timeframe required to install (and commission) the change

The following timeframes have been advised by AWT operators:

Pathway One: Continue to process Municipal Solid Waste (MSW) as an input under the following three process options:

1) *BAU*: Current processing, however this option is not sustainable long term if product is to be applied to landfill. Markets other than land application have not yet been developed.
2) *Improved MWOO*: Timeframe is dependent on the level of investment, which is in turn dependent on the accepted product contamination concentrations which have yet to be determined. Timeframes have been quoted as at least 6 months for reconfiguring of equipment to achieve moderate quality improvement, to up to 24 months for significant re-engineering, acquisition of new technology and planning approvals.
3) *RDF Output*: Timeframes are ultimately dependent on the development of a local market for RDF which could be at least five years away. To implement Pathway One process option 2.2 High CV RDF timeframes are likely to be at least 12-24 months before commissioning.

Pathway Two: Accept source separated food and garden organic (FOGO) as an input to produce compost quality to meet the Compost Order: The timeframe for implementation of this option is dependent on contract negotiations and establishment of a significant supply. Operators have noted that they are engaged in long term contracts to process exclusively MSW and can therefore not accept FOGO without breaching their contract.

Pathway Three: If operators choose to produce an RDF output from accepting an organic depleted MSW stream, the timeline of implementation is dependent on re-configuring process lines to reduce front end processing. If operators choose to utilise the biological capacity for accepting a separate material stream such as FOGO, time is required to reconfigure process flow and controls to avoid mixing of separate streams.

7. References

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Appendix A. Stakeholder Questionnaires and additional material

A.1 Technology Supplier Questionnaire

Subject	**Stakeholder Questionnaire**
Project	Process and Technology advice for treatment of MWOO
Prepared by	Genevieve Daneel
Date/Time	May 8, 2019
Copies to	Insert Stakeholder Name

The EPA has commissioned Jacobs to provide expert advice on the available technologies and processes to address physical and chemical contamination of Mixed Waste Organic Outputs (MWOO) for Alternative Waste Treatment (AWT) facilities and assess the technical feasibility of alternative pathways for AWT facilities in NSW.

Please review the following questions, as a guide for the telephone conversation proposed to be undertaken with a Jacobs representative.

Questions		Response
1	Do you have recent experience in cleaning up chemical and physical contamination for Municipal Solid Waste (MSW) products? Could you provide any case studies or examples with proof of contamination improvements?	
2	What range of level of decontamination can be achieved or is feasible for a mixed waste treatment process for both: - Chemical contamination e.g. metals and metalloids, organic pollutants, others - Physical contamination?	
3	Are there examples of this technology installed and operating at commercial capacity? How long has this technology been installed for, and where has it been installed?	
4	Have you had previous experience with bringing overseas technologies to Australia? What were the barriers and opportunities you faced when trying to achieve this? Was it successful?	
5	Please identify any impediments to a short, medium or long-term alternative pathway to the current process and technology approach.	
6	What would be an alternative approach to treating MSW in a Mechanical and Biological treatment facility? Which alternative outputs or product(s) could you or would you propose for the treatment of MSW?	

A.2 AWT Operator Questionnaire

Subject	**Stakeholder Questionnaire**
Project	Process and Technology advice for treatment of MWOO
Prepared by	Genevieve Daneel
Date/Time	May 8, 2019
Copies to	Insert Stakeholder Name

The EPA has commissioned Jacobs to provide expert advice on the available technologies and processes to address physical and chemical contamination of Mixed Waste Organic Outputs (MWOO) for Alternative Waste Treatment (AWT) facilities and assess the technical feasibility of alternative pathways for AWT facilities in NSW.

Questions		Response
1	Can you please provide feedback on which process and/or technology improvements your organisation would propose, or have investigated to **improve the quality of the MWOO** with regards to: • Reducing or eliminating **physical contamination** of the target materials. To what extent can the technology reduce the amount of glass in the <5mm fraction and plastic in the <2mm fraction? • Reducing or eliminating **chemical contamination**.eg. metals or metalloids, organic pollutants, others. To what degree or amount of de-contamination is achievable? Please provide evidence.	
2	Could you please provide a **process flow chart** of your current process of mechanical and biological treatment of mixed waste? Could you also please provide a mass balance?	
3	What is the estimated **cost** and **timeframe** of the process or technology improvements your organisation would propose to achieve improved outcomes to MWOO quality? Please assume improvement levels at percentage rates chosen by yourself (of what you deem realistic from a technical point of view), i.e. at 25% improvement, at 50% improvement etc. Please provide installation and operational estimates separately, if possible.	
4	What other **challenges** would you face in trying to upgrade or improve the performance of your current facility, i.e. planning, financial, social, etc.?	
5	If you take a medium to longer term view what would be an **alternative approach** to treating residual MSW (rMSW) in your facility? Which alternative outputs or product(s) could you or would you propose for the treatment of MSW? Please consider treating both with or without the organic fraction of MSW.	

Questions		Response
6	Please identify the **top three incentives** for either improving or changing the current pathway of treating MSW within your organisation (provide examples where possible).	
7	As part of the stakeholder engagement process, Jacobs are speaking to the following equipment providers; WTT, Bioelektra, Cemactech and Steinert. Would you recommend we contact any additional suppliers? Could you please provide contact details of a company representative?	

A.3 Additional Material

Leading Separation:
Magnet+Sensor
Sorting Solutions

STEINERT

Use of modern sensor sorting solutions in the field of composting application in Germany

Dipl.-Ing. Patrick Lindweiler

Key Account and Business Development

September 2017

Dear reader,

This document contains information in regard of the use of sensor sorting solutions – particularly UniSort Black – in the field of composting application.

The idea and solution is based on German framework conditions.

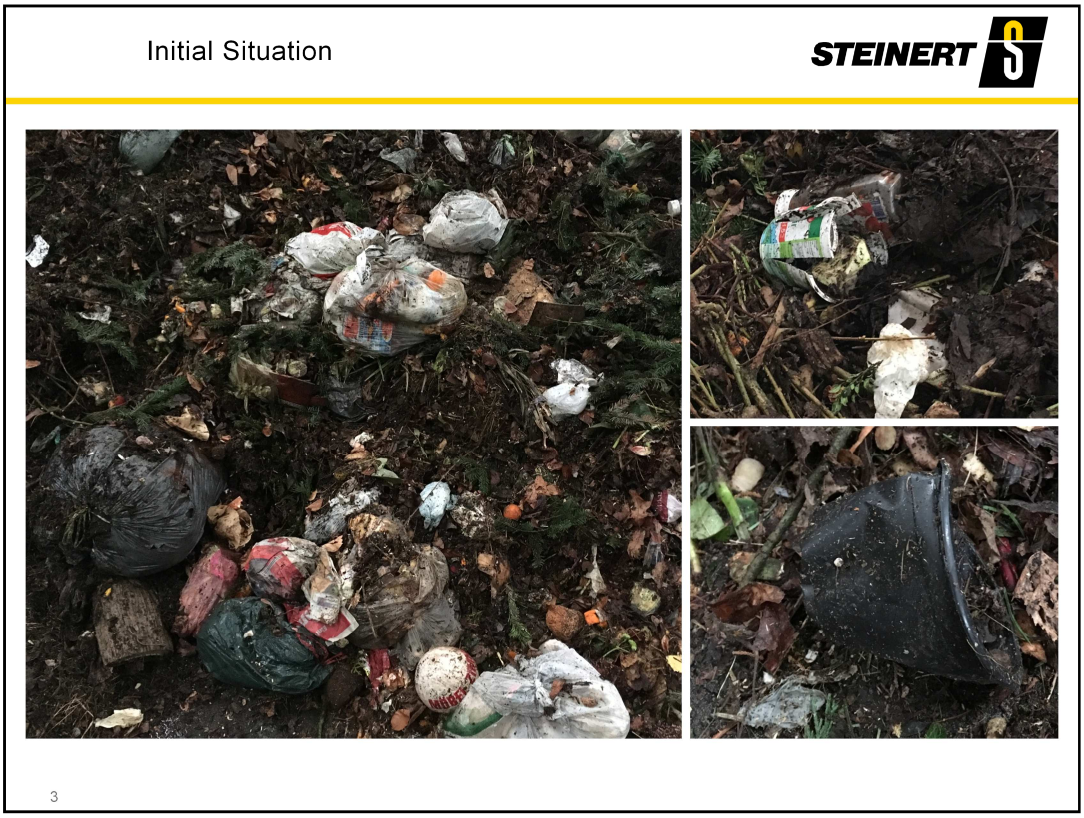
Best regards,

Patrick

AGENDA

STEINERT

- Welcome and introduction
- Sorting concepts in the field of composting application / Examples
- The use of modern sensor sorting solution in the field of composting application
- Tests and results
- Outlook



As entry I'd like to use these pictures because they show briefly the situation with compost material and may give you a short impression for the material that I am talking about in this document.

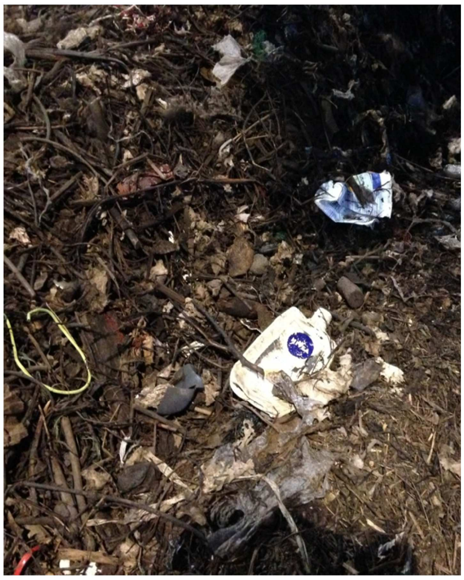
Compost material with more or less contamination in regard of

- stones, glass, ceramics, etc…
- hard plastic
- plastic foil
- black plastics
- composite material e. g. bio material wrapped with plastic foil etc.
- metals *1)

*1)
the following described solution is aiming on optical solution with UniSort Black and optical solution with UniSort Black in combination with wind shifter technology only. The Upgrade of UniSort Black with metal sensor (M) to capture as well the metal is of course an option to discuss with customers.

The tests described in this document were carried out without metal sensor!

Initial Situation



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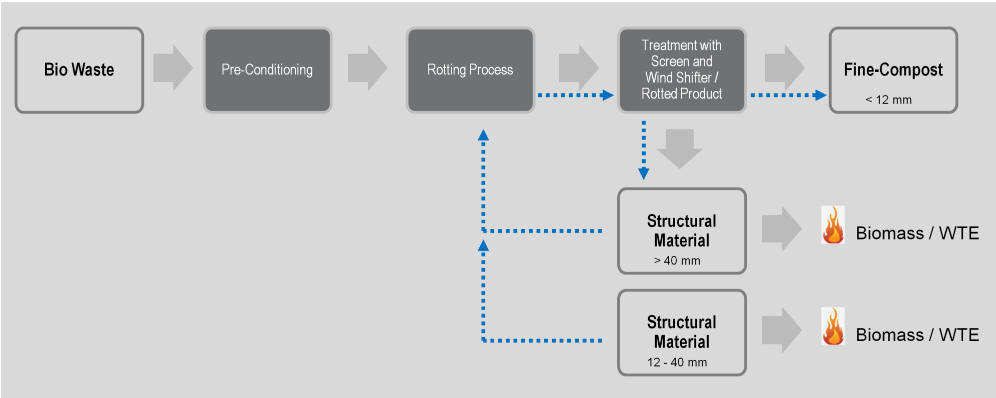
Please see note shown on slide before....

Sorting concepts in the field of composting application / Examples

STEINERT



Simplified concept for bio waste composting with two screening steps for the rotted product

Disposal of structural material (medium / coarse) → incineration / ETW

In case of reuse of structural material for pre-conditioning and rotting procedure
- accumulation of impurities occur in the cycle
- increasing impurities in the fine compost (end product)

5

The concept shows only a rough idea / concept!

After the delivery of bio waste the material is pre-treated with more or less simple technology (depending on operators preferences, mostly only pre-shredder <350, one magnet, homogenisation with structural material).

Homogenised material is forwarded to rotting area / rotting process.

After 6-8 weeks rotting procedure the rotted product is furthermore treated by using screens and stone trap and wind shifter.

Fine-Compost (e. g. < 12mm) achieves most of the time the legal requirements and regulations for quality . This is the main product of the composting plant!

The often high waste-contaminated coarse material / structural material is send to incineration.

In case of reuse of structural material for the pre-conditioning process an accumulation of impurities (plastics, metals, stones, etc.) occur in the cycle and lead to increasing contamination with impurities in the Fine-Compost.

In the end the Fine-Compost does not meet the requirements for quality any more!

The use of modern sensor sorting solution in the field of composting application

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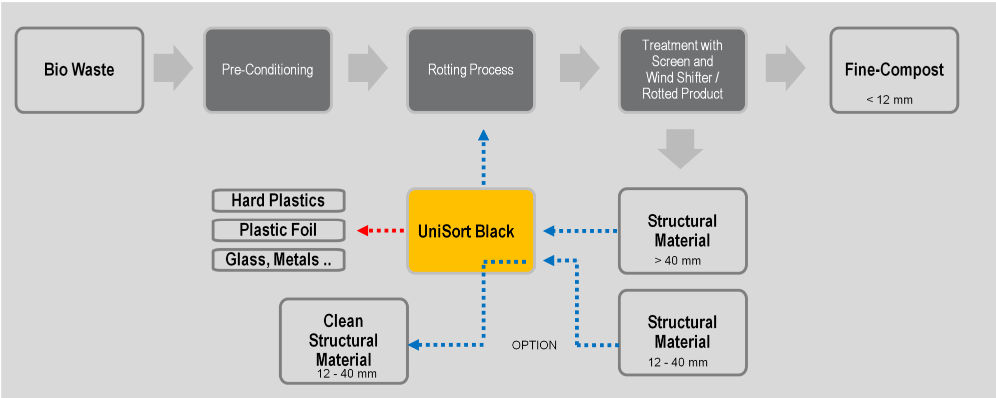


Simplified concept for bio waste composting with two screening steps for the rotted product

Treatment of structural material with UniSort Black and reuse in rotting process

Capture of impurities included in the structural material

- Plastic Foil
- Hard Plastics + Black Plastics
- Glass, Metals etc.

6

Once more the concept with two screening steps and wind shifter as example in front of the UniSort Black.

Now the structural material (coarse) is treated with UniSort Black (in combination with metal sensor) instead of sending material to incineration.

This combination is a solution for capturing the impurities that otherwise may accumulate in the cycle and lead to decreasing quality of the Fine-Compost in the end.

Furthermore the UniSort Black captures as well the black items and dark coloured impurities!

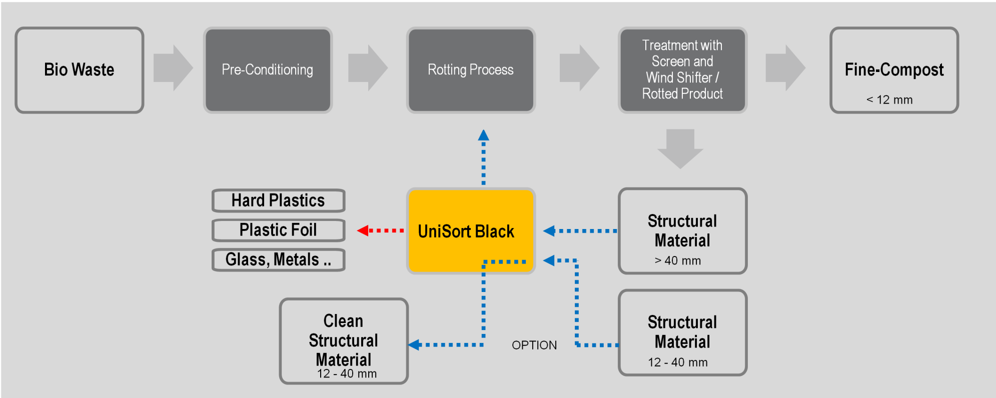
e.g. Flower pots etc.

The "clean" structural material is now ready for reuse in the pre-conditioning and rotting procedure and does not lead to decreasing quality of the Fine-Compost.

The same treatment process is available for the medium size material.

The use of modern sensor sorting solution in the field of composting application

STEINERT



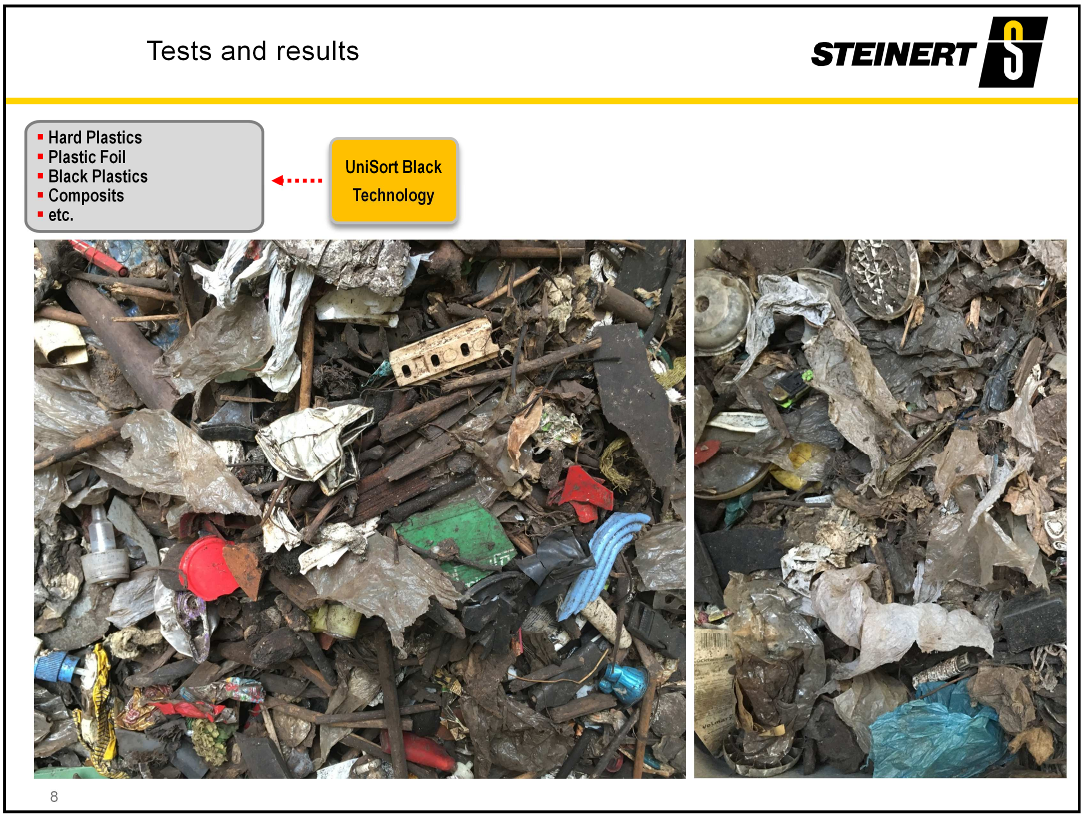
Advantages & positive effects:

- No accumulation of impurities in the cycle and no influence on the Fine-Compost quality
- Reduction of disposal cost (Cost of incineration)
- Reduction of costs generated by purchase of clean / fresh structural material
- Production of structural material (medium size) for the use as e. g. humus in agriculture

7

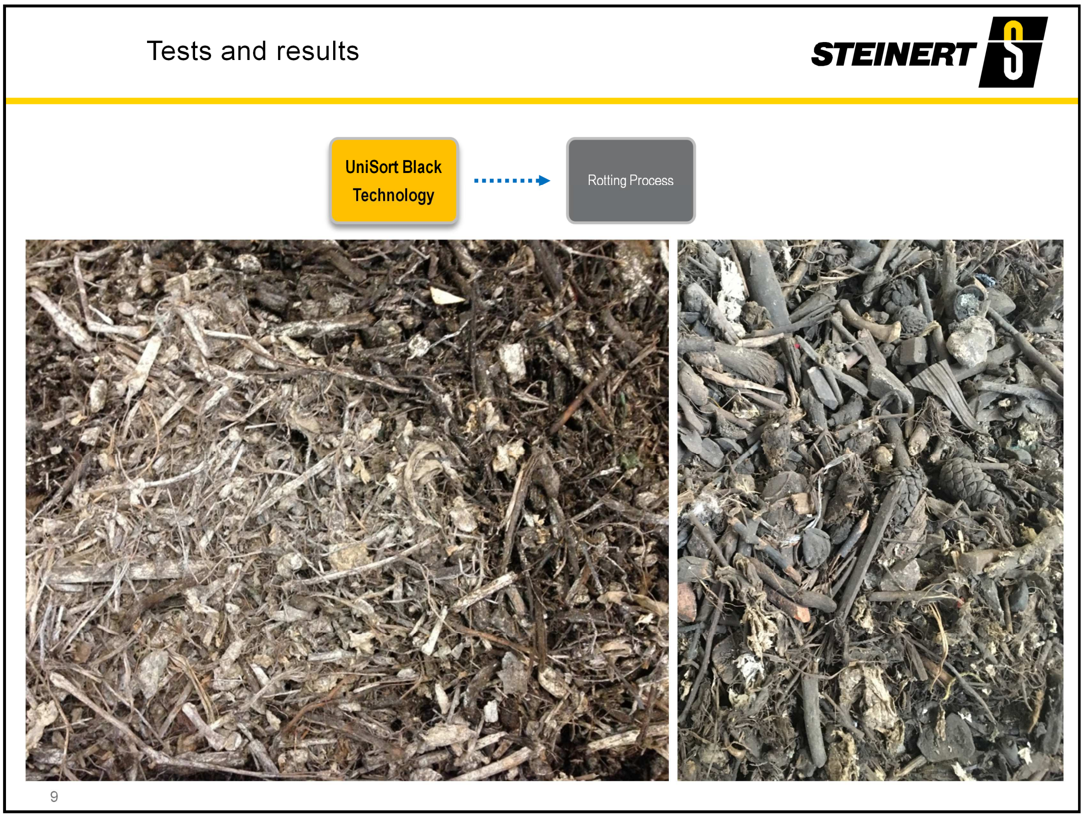
The advantages

- no accumulation of impurities in the cycle and no influence of the Fine-Compost quality
- Reduction of disposal cost (costs of incineration)
- Reduction of costs generated by purchase of clean / fresh structural material
- Production of structural material (e. g. medium size) for the use as e. g. humus in agriculture



Plastic foil material and plastic foil composite material (e.g. structural material wrapped with foil) and particularly hard plastic items and black plastics are captured by the use of UniSort Black Technology!

Picture self-explanatory



The picture shows the clean structural material after the before described sorting procedure with wind shifter and UniSort Black technology.

Picture self-explanatory

Tests and results

STEINERT

Positive side effect due to the use of UniSort Black

- as well a lot of glass and ceramic items are captured …

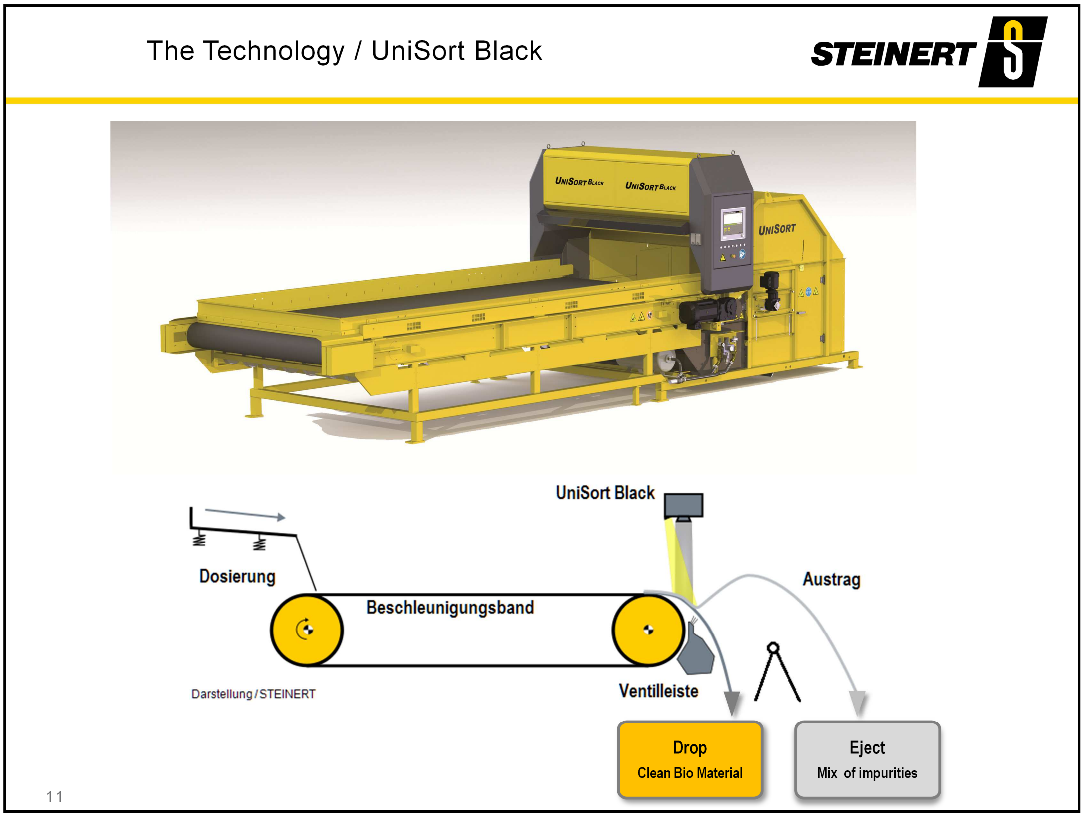
Upgrade with metal sensor in combination with UniSort Black

- as well metals and metal composites are captured ...

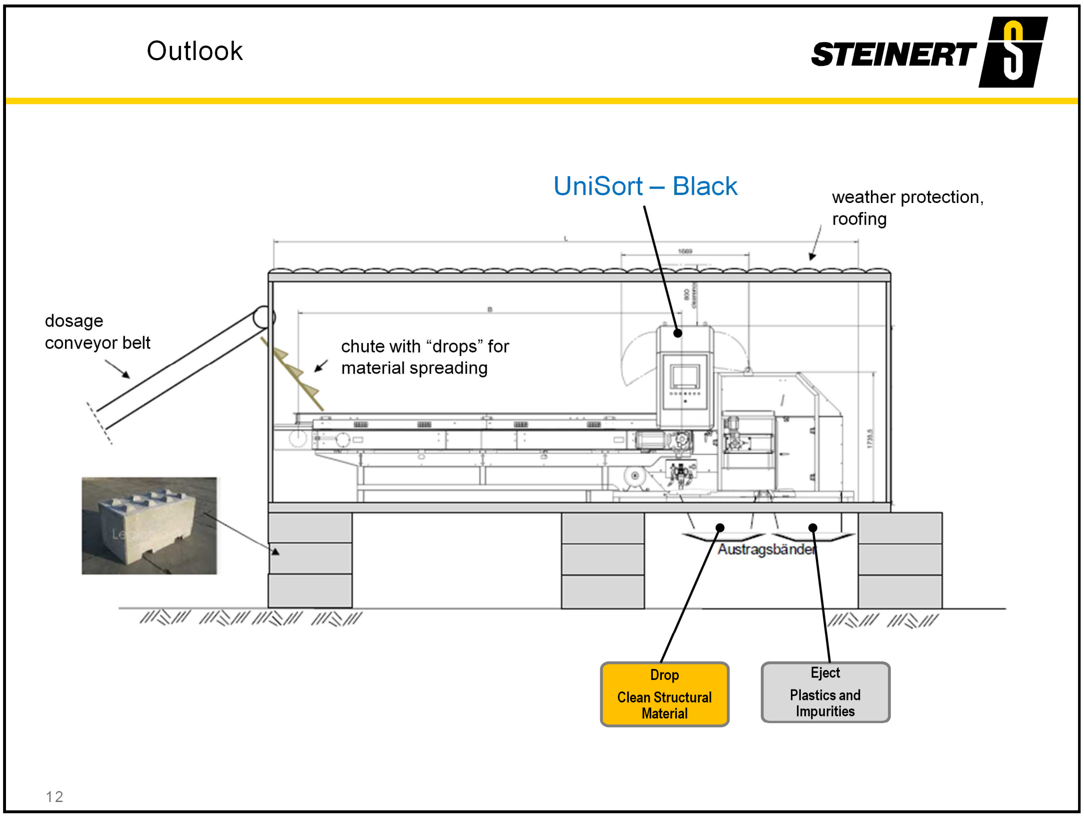
10

Beside the plastics, black plastic items, foil and composite items the UniSort Black captures as well a lot of glass and ceramic items by the use of HSI Technology.

With additional installation of metal sensor together with the UniSort Black (combination of HSI + metal sensor/detector) it is possible to sort as well the metals from the bio material as shown on the picture.


The Technology / UniSort Black
UniSort Black
Dosierung
Beschleunigungsband
Austrag
Ventilleiste
Darstellung / STEINERT
Drop
Clean Bio Material
Eject
Mix of impurities
11

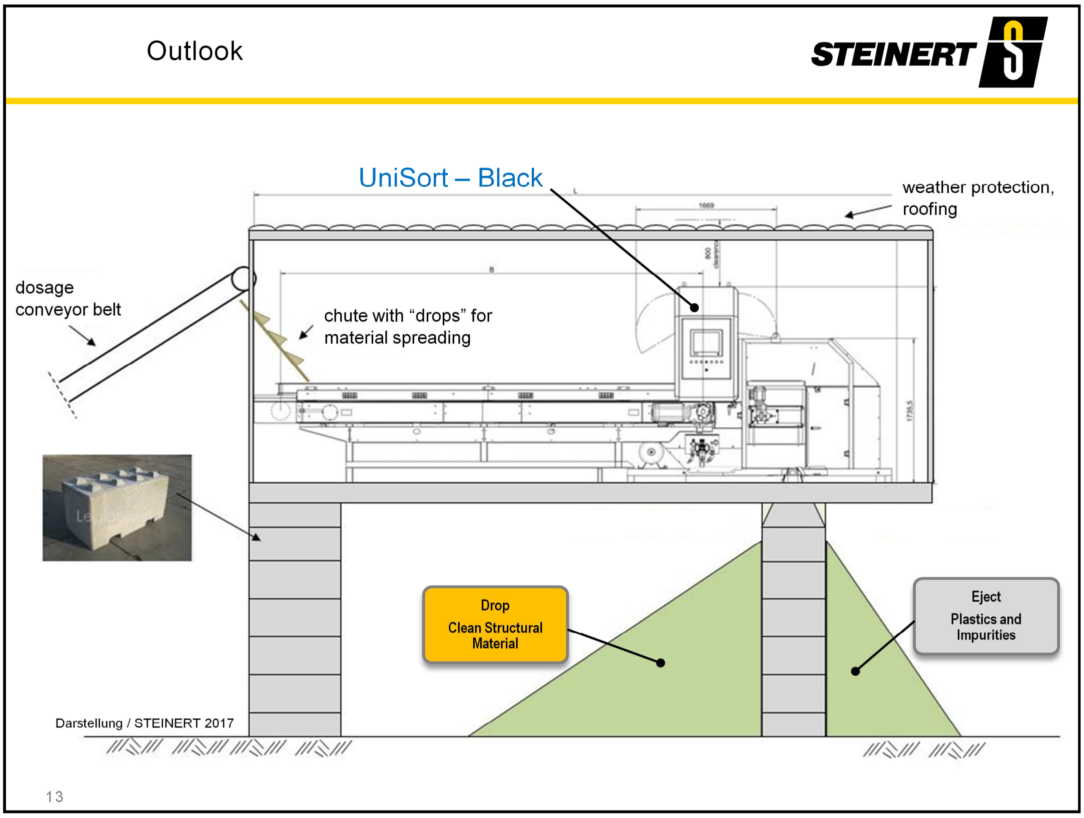
....



Plants with already existing and installed wind shifter technology could be updated and optimised with UniSort Black Technology as this slide shows.

Solution I:

UniSort Black installation as a semi-mobile solution e.g. positioned on concrete blocks with housing.



Plants with already existing and installed wind shifter technology could be updated and optimised with UniSort Black Technology as this slide shows.

Solution II:

UniSort Black installation as a semi-mobile solution e.g. positioned on concrete blocks with housing.

Outlook

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Darstellung / STEINERT 2017

14

Plants with already existing and installed wind shifter technology could be updated and optimised with UniSort Black Technology as this slide shows.

Solution II:

UniSort Black installation as an installation on concrete blocks with inside a hall.

Here disc spreader.

STEINERT

Thank you very much

for your attention

TOMRA SORTING RECYCLING – COMPOST CLEANING

TOMRA SORTING SOLUTIONS | RECYCLING

Oliver Lambertz/ Lisa Höflechner
Mülheim-Kärlich
01.06.2018

CONTENT

Examples of compost cleaning tests

EXAMPLE 1 – AUTOSORT

Input	kg	
Total	14,80	100,0%

throughput: 2,1 t/h/m

Step 1 EJECT

Impurities	kg	
Total	1,80	12,2%

ACCEPT

Organic	kg		kg	
Total	13,00	87,8%		
composition calculated			composition counted	
film	0,03	0,2%	0,031	0,2%
organic	12,91	99,3%	12,700	99,3%
hard plastics	0,01	0,1%	0,008	0,1%
black	0,01	0,1%	0,006	0,05%
textiles	0,02	0,1%	0,016	0,1%
impurity rest	0,03	0,2%	0,028	0,2%
	13,00	100,0%	12,788	100,0%

Test system used during the test

Detection Unit:	AUTOSORT
Working width:	1000 mm
Sensor :	[NIR1]
EM-Sensor:	EM 3 Standard
Resolution:	Standard
Belt speed:	2,7 m/s
Air pressure:	8 bar

Input material:	screen overflow compost
Grain size [mm]:	15 - 60mm

EXAMPLE 2 - AUTOSORT

Input	kg	
Total	138.34	100.00%

2.93 t/h/m

STEP 1

EJECT

Impurities (plastics, metalls)	kg	
Total	6.40	4.63%

Organic	kg	
Total	131.94	95.37%

Test system used during the test

Detection Unit:	AUTOSORT
Working width:	1000 mm
Sensor :	[NIR1]
EM-Sensor:	EM 3 Standard
Resolution:	High Resolution
Belt speed:	3 m/s

Input material:	screen overflow compost
Grain size [mm]:	>40 mm

EXAMPLE 3 - AUTOSORT

Input	kg	
Total	132.19	100.00%

1.70 t/h/m

STEP 1
EJECT

Impurities (plastics, metalls)	kg	
Total	4.19	3.17%

Organic	kg	
Total	128.00	96.83%

Test system used during the test

Detection Unit:	AUTOSORT
Working width:	1000 mm
Sensor :	[NIR1]
EM-Sensor:	EM 3 Standard
Resolution:	High Resolution
Belt speed:	3 m/s

Input material:	**screen overflow compost**
Grain size [mm]:	**24 - 40 mm**

EXAMPLE 4 – X-TRACT

Input	kg	
Total	165.20	100.0%
composition (calculated)		
0-2mm	80.41	48.68%
stones	6.13	3.71%
glass	0.25	0.15%
metals	0.02	0.01%
organic >2mm	78.38	47.45%

Eject

Throughput:

5.9t/h/1.2m

Air consumption:

900l/min/1.2m

Inertes	kg	Step	kg		
Total	18.20	11.0%	1.5520	100.00%	
composition (calculated)			sample counted		Recovery / Loss
0-2mm	5.14	28.25%	0.4385	28.25%	6%
stones	5.93	32.57%	0.5055	32.57%	97%
glass	0.23	1.26%	0.0195	1.26%	90%
metals	0.02	0.13%	0.0020	0.13%	100%
organic >2mm	6.88	37.79%	0.5865	37.79%	9%

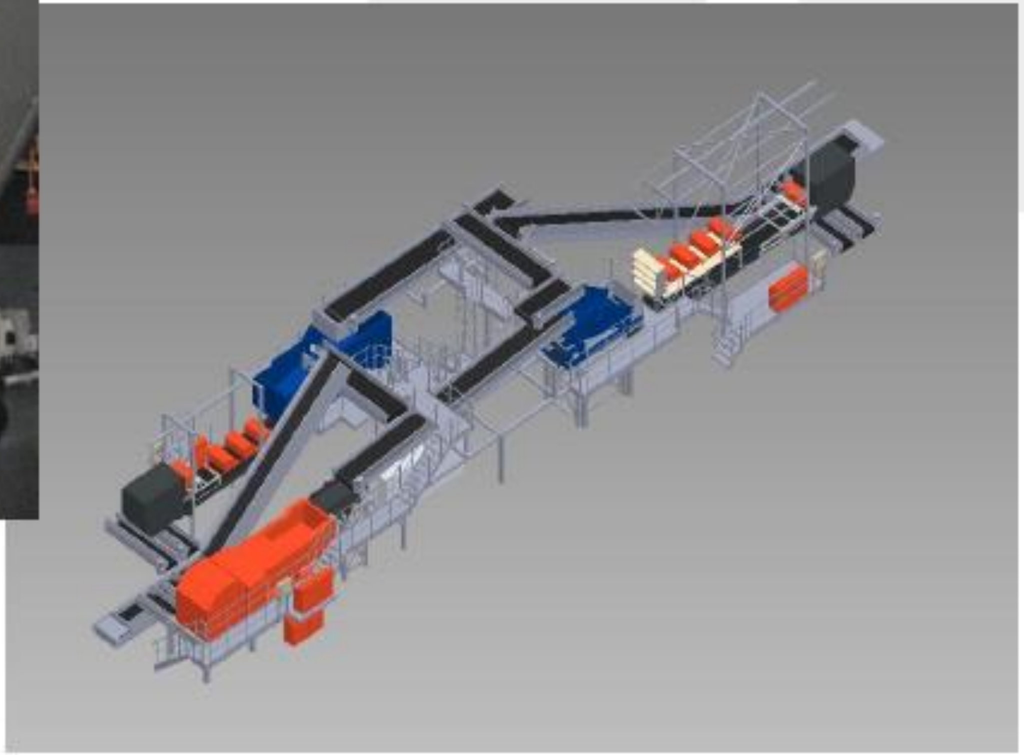
Accept	kg		kg	
Total	147.00	89.0%	8.7415	100.00%
composition (calculated)			sample counted	
0-2mm	75.27	51.20%	4.4760	51.20%
stones	0.20	0.14%	0.0120	0.14%
glass	0.03	0.02%	0.0015	0.02%
metals	0.00	0.00%	0.0000	0.00%
organic >2mm	71.50	48.64%	4.2520	48.64%

Test system used during the test

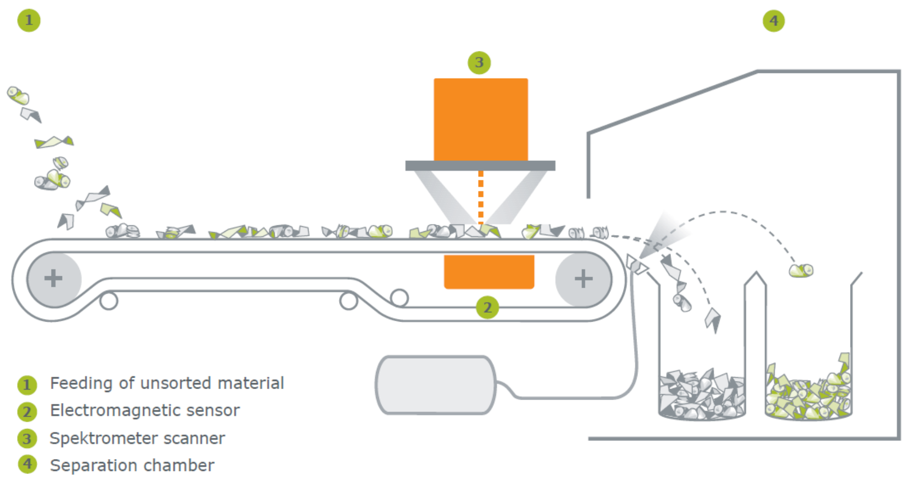
Detection Unit:	X-TRACT
Working width:	1200 mm
X-ray source:	90kV/10mA
Belt speed:	3.15 m/s
Air pressure:	7 bar

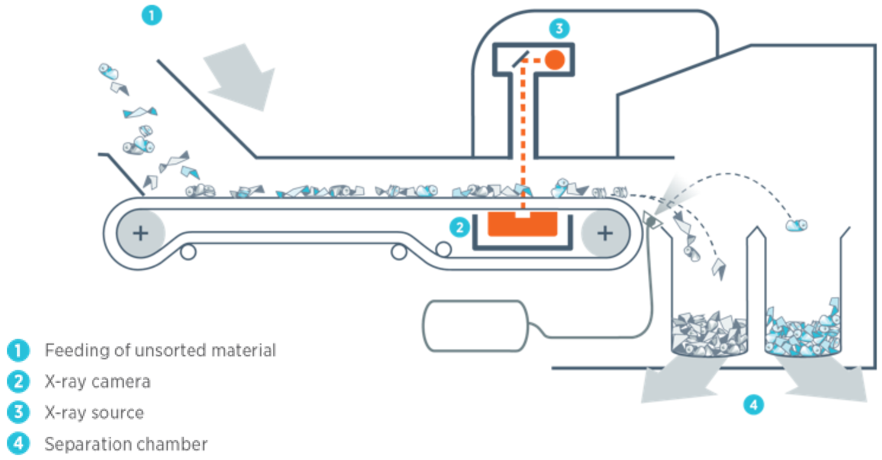
Input material:	compost from organic waste collection
Grain size [mm]:	0 - 50
Bulk density [kg/m^3]:	ca. 300

Sample testing – test facility



Sample testing - Applied advanced sorting technologies





AUTOSORT (NIR/ VIS)

- E.g. sorting of plastics, organic/non-organic, wood from different mixed input materials based on material type and color

EM

- Detection / removal of all metals

X-TRACT (x-ray sensor)

- E.g sorting of inerts (glass, ceramic, stones,..) by measuring density differences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OPPORTUNITIES HISTORY.
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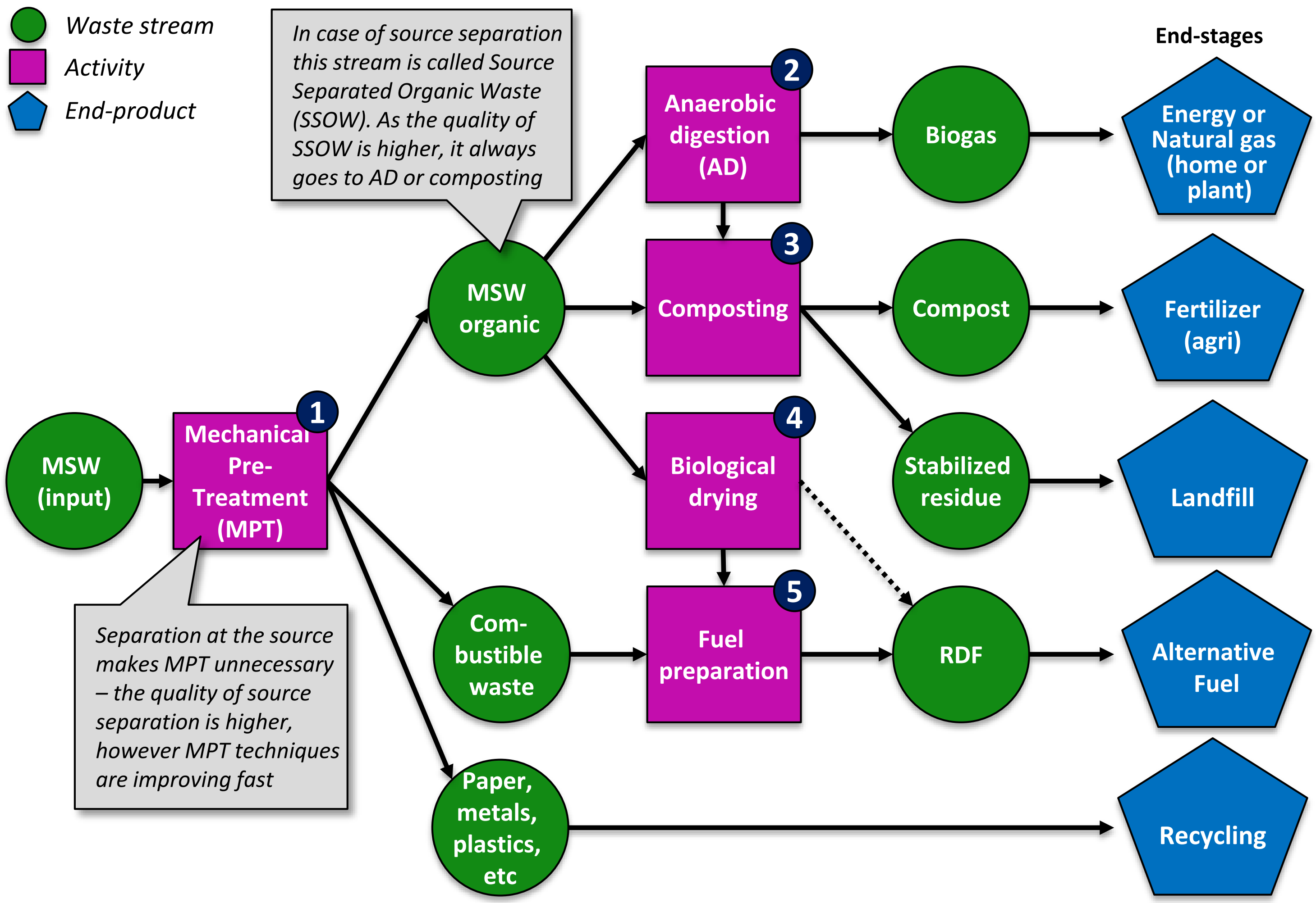
Rethink. Reimagine. Resource.

PRODUCT OFFERING

Integrated Mechanical and Biological Treatment solutions

WASTE TREATMENT TECHNOLOGIES

Simplified overview of an integrated mechanical and biological treatment (MBT) facility



PRODUCT OFFERING

WASTE TREATMENT TECHNOLOGIES

	1	2	3	4	5
Process step	**Preparation/ separation at plant**	**Anaerobic digestion (AD)**	**Composting**	**Biological drying**	**Fuel preparation**
					
Process Description	▪ The "mechanical" element of an MBT plant is either an automated mechanical sorting stage or done by hand picking ▪ It may involve the following techniques: rotating drums, eddy currents, magnets, ball mills, splitters, shredders, air classification, ballistic or optical separation	▪ An anaerobe dry or wet process by which micro-organisms break down bio-waste into biogas and digestate (potential input for step 3 and 4) ▪ It consists of 4 steps: hydro-lyse, fermentation, acido-genesis, methanogenesis	▪ A multi-step, closely monitored process with inputs of organics, water and air that recycles organic matter into fertilizer	▪ Biodrying is the process by which biodegradable waste is rapidly heated through initial stages of composting to remove moisture from a waste stream and hence reduce its overall weight	▪ The production of Refuse-derived fuel (RDF) by shredding and/or pelletising solid waste to be used in cement kilns or thermal combustion power plants ▪ The process may involve the following steps: splitting/ shredding, size screening, coarse shredding, refining separation
Key trends	▪ Continuous innovation in waste sorting (e.g. robotics, zinc baths, near infrared)	▪ EU capacity is expected to double in 2023 from 2014; nr. of plants will increase from 800 to 1,450; primarily in the UK and Germany ▪ Trend towards gas upgrading ▪ New techniques producing bio-chemicals instead of biogas	▪ Urbanisation demands for new and improved odour abatement techniques ▪ Towards combined composting and AD processes	▪ Dependent on the prices of land-fill costs/ taxes: increasing costs will drive the growth of drying ▪ Increasing demand for the treatment of waste water treatment sludge	▪ High fossil energy prices drive the growth of RDF – currently low energy prices which are expected to maintain in the coming years

MBT TECHNOLOGY BLOCK - I

Pre-treatment / Recycling

WASTE TREATMENT TECHNOLOGIES

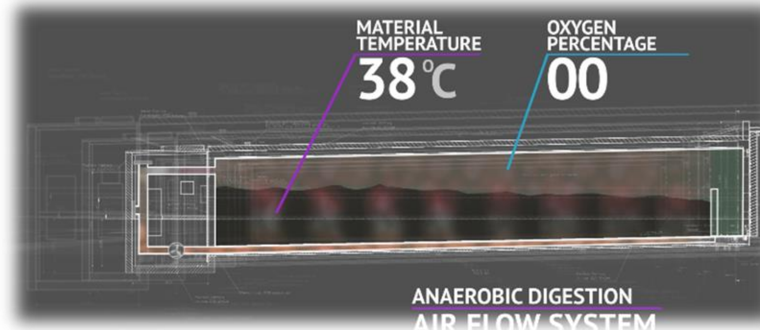
1

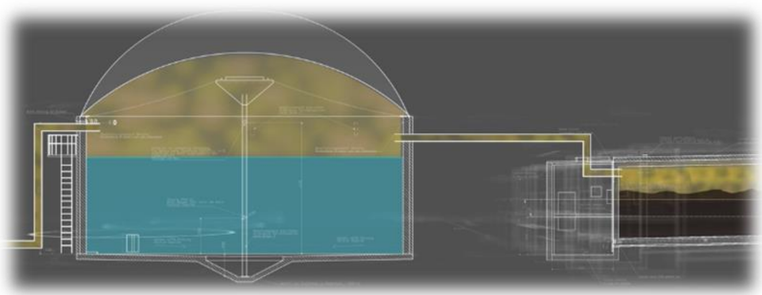
MBT TECHNOLOGY BLOCK - 2

In vessel (dry) batch digestion

WASTE TREATMENT TECHNOLOGIES

2



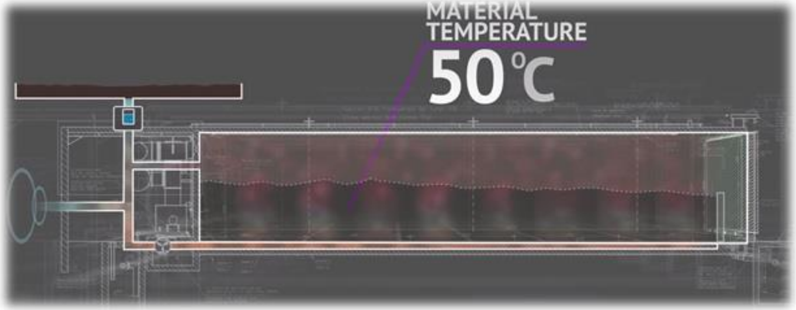


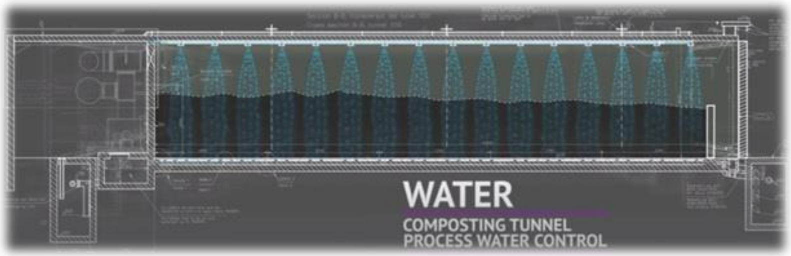
MBT TECHNOLOGY BLOCK - 3

In vessel composting

WASTE TREATMENT TECHNOLOGIES

3





PRODUCT OFFERING

Integrated DRY AD and Composting facility

WASTE TREATMENT TECHNOLOGIES

Green power and heat

OR

Green natural gas

Compost like output (CLO)

Video – WTT Biological Techniques

External

Click on "BIOLOGICAL TECHNIQUES"

Landfill reduction model

Model I – MBT, stabilisation of organics and separation of potential recyclables

WASTE TREATMENT TECHNOLOGIES

households

Collection by city

100%

Pre-treatment

2% Metals

73%

Biological Composting

46% Process losses
(Evaporation of water & Degradation of organic materials)

27%

Refining

25%

RDF / PEF production
(fuel for cement kilns)

15%!

Landfill

12%

Daily landfill cover / land reclamation / highway projects

PROS:

- Recycling metals
- 46% biological mass reduction
- Reduced landfill to only 15%
- Potential profit of RDF/ feedstock MRF
- Daily landfill cover

CONS:

- No electricity/gas production

Landfill reduction model

Model 2, MBT including AD and stabilisation of organics

WASTE TREATMENT TECHNOLOGIES

households

Collection by city

100%

Pre-treatment

2% Metals

73%

Dry Anaerobic Digestion

PROS:

- Eliminating facilities energy bill, potential profit on energy/gas distribution (feed in tariff)

46% Combined Process losses
(Evaporation of water & Degradation of organic materials)

73%

Biological Composting

27%

Refining

25%

RDF / PEF production (fuel for cement kilns)

15%!

Landfill

12%

Daily landfill cover / land reclamation / highway projects

CASE STUDY – BLOCKS 2 & 3

Closing the loop on organics

WASTE TREATMENT TECHNOLOGIES

PROJECT: **Surrey Biofuels Processing Facility**

LOCATION: **Surrey, Vancouver, CANADA**

CUSTOMER: **Orgaworld Design-Builder Limited Partnership (Part of Renewi)**

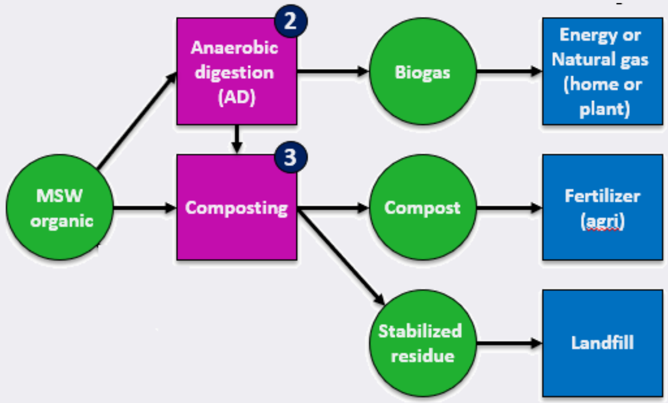
TYPE: **Building block 2 & 3 – Digestion followed by Composting**

INPUT MATERIAL: 115.000 t/a Source Separated Organic Waste and Industrial, Commercial and Institutional Waste (ICI)

SSO-> in Australian terms " FOGO"

OUTPUT MATERIAL:
-Compost for landscaping
-Biomethane fed to natural gas network and used for waste collection trucks

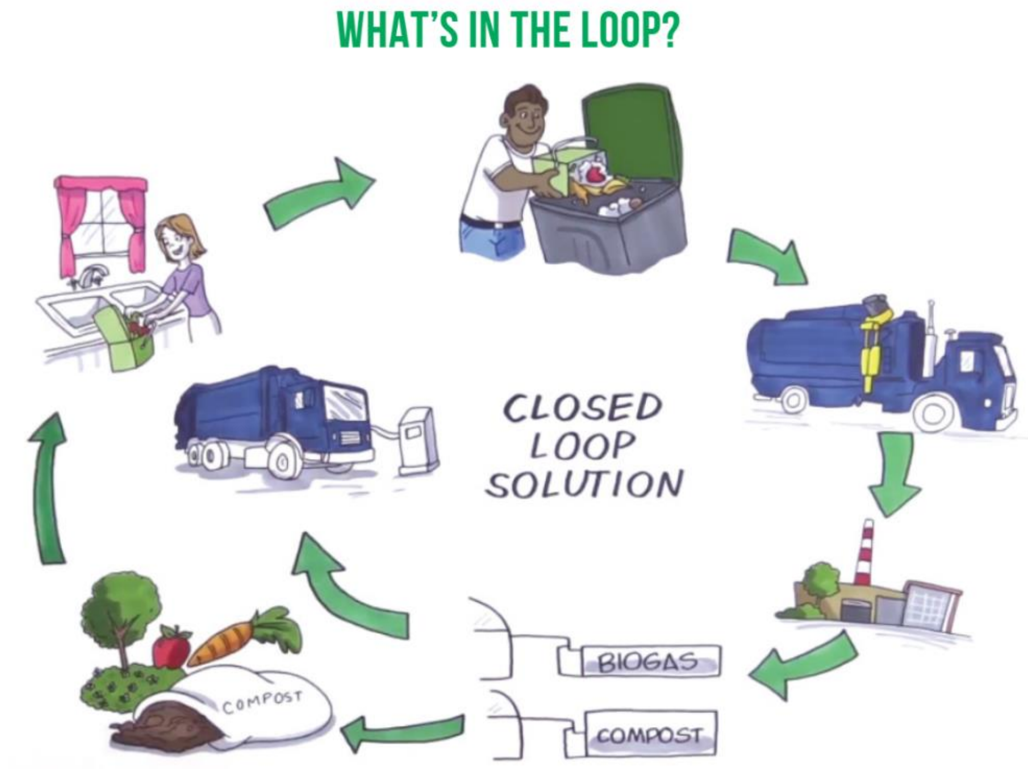
OPERATIONAL : Since late 2017



"When completed, the facility will be the largest of its kind in North America with a capacity to process 100% of the City's organic waste, helping Metro Vancouver achieve its regional 70% waste diversion target."

Mayor Linda Hepner

The **Surrey** Biofuel Facility is the first **closed loop organics** processing operation of its kind in Canada.



Source: http://www.surreybiofuel.ca/loop-and-you

CASE STUDY – BLOCKS 2 & 3

Closing the loop on organics

WASTE TREATMENT TECHNOLOGIES

KEY REFERENCES

Surrey, Vancouver CANADA

PROJECT: **Surrey Biofuels Processing Facility, British Colombia, Canada**

SCOPE WTT: Design and build of the process technique for dry AD-tunnels, hybrid tunnels, composting tunnels, odour abatement system, biofilter, flare, fermentation tank with gas storage.

CUSTOMER: **Orgaworld Design-Builder Limited Partnership (Part of Shanks)**

INPUT MATERIAL: 115.000 t/a Source Separated Organic Waste and Industrial, Commercial and Institutional Waste (ICI)

OUTPUT MATERIAL: Compost for landscaping
Biomethane as fuel for waste collection trucks

KEY EQUIPMENT: 6 Dry AD-tunnels, 4 hybrid tunnels, 7 composting tunnels, odour abatement system incl. biofilter, flare, fermentation tank with gas storage

OPERATIONAL : Late 2017

"When completed, the facility will be the largest of its kind in North America with a capacity to process 100% of the City's organic waste, helping Metro Vancouver achieve its regional 70% waste diversion target."

Mayor Linda Hepner

KEY REFERENCES

Leeds, UNITED KINGDOM

WASTE TREATMENT TECHNOLOGIES

PROJECT:	**Leeds, Great Britain**
SCOPE WTT:	Design, build, start-up and commissioning of complete Mechanical pre-treatment facility including air treatment system
CUSTOMER:	**Veolia Environmental Services**
INPUT MATERIAL:	214.000 t/a MSW
OUTPUT MATERIAL:	Recyclables: PET & HDPE, Paper, Mixed plastics, Ferrous, Non-Ferrous and residual waste to energy for waste
KEY EQUIPMENT:	Shredders, Ballistic separators, Magnets, Eddy current separators, NIR optical sorters, Baler, Facility air treatment
OPERATIONAL SINCE:	2016

PROJECT:	*Braval, Portugal*
SCOPE WTT:	Design, build, start-up and commissioning of Dry AD and conditioning tunnels
CUSTOMER:	*ABB-DST*
INPUT MATERIAL:	*15.000 t/a 0-80mm MSW*
OUTPUT MATERIAL:	First phase compost, Power production: 250 kW electric energy
KEY EQUIPMENT:	Dry Anaerobic tunnels, conditioning tunnels, gas storage, gas engine, flare, Facility air treatment
OPERATIONAL SINCE:	*2014*

PROJECT: *Wiefels, Germany*

SCOPE WTT: Design, build, start-up and commissioning including process technique of Dry AD, Hybrid & conditioning tunnels

CUSTOMER: *AWZ Friesland / Wittmund*

INPUT MATERIAL: *20.000 t/a, mix of 20-40mm coming from pre-treatment wet digestion and screen fraction of 40-120mm MSW*

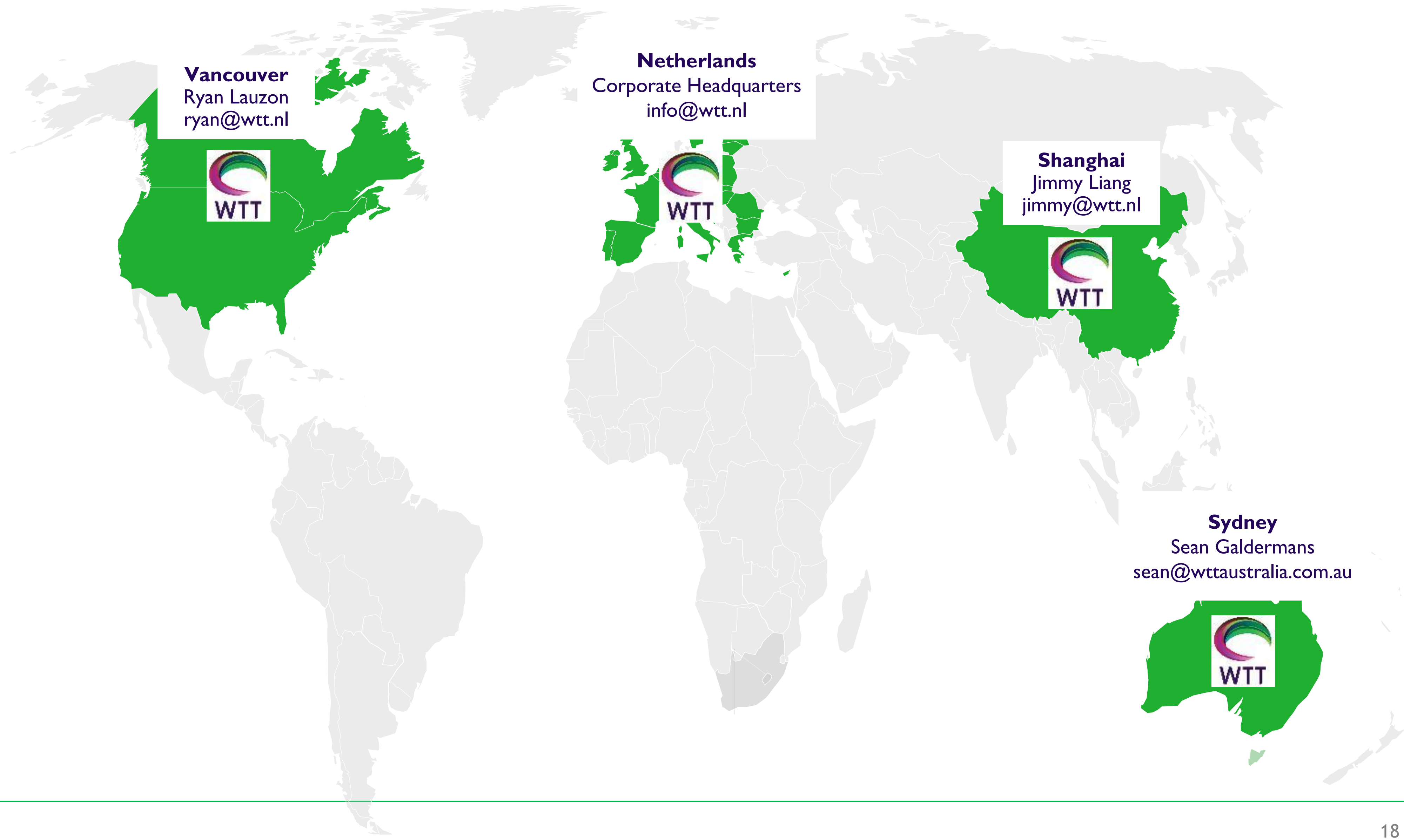
OUTPUT MATERIAL: First phase compost, Power production: 536 kW electric energy

KEY EQUIPMENT: Dry Anaerobic tunnels, conditioning tunnels, gas storage, gas engine, flare, Facility air treatment

OPERATIONAL SINCE: *2011*

PROJECT:	*Alytus, Lithuania*
SCOPE WTT:	Design, build, start-up and commissioning including process technique of Dry AD, Hybrid & conditioning tunnels
CUSTOMER:	*Alytus Region Waste Management Centre*
INPUT MATERIAL:	*21.000 t/a, 0-80 MSW*
OUTPUT MATERIAL:	First phase compost, Power production: 450 kW electric energy
KEY EQUIPMENT:	Dry Anaerobic tunnels, composting tunnels, gas storage, gas engine, flare, Facility air treatment
OPERATIONAL SINCE:	*2015*

WASTE TREATMENT TECHNOLOGIES



Appendix B. Optical Sorting Capabilities Review

Plastic sorting plants in summary:

Automated technologies exist and are being developed to sort different types and grade of plastic polymer. This process allows for the recovery and recycling of different plastic types.

Likely role in achieving circular economy objectives: Plastic sorting plants facilitate the recovery and re-use of plastics and can therefore contribute to the achievement of recovery and recycling targets.

Table 17: Sensor technologies used for sorting complex plastics

Plastic type	Technology applied for automated sorting	Performance
Food grade recycled PET flakes	TOMRA AUTOSORT sensor (UV VIS spectroscopy for colour detection, NIR spectroscopy for polymer contamination detection, metal sensor for metal contamination detection)	Effective sorting > 2 mm particle size. Contamination levels reached: < 10 ppm PVC, < 3 ppm metallic particles, < 200 ppm polymers (coloured or uncoloured)
Food and non-food PE	TOMRA Extended wavelength scanner differentiates two different grades of the same polymer: the homo- (food) and co-polymer (non-food) of PE	>99 % purity
Opaque PET	NIR fingerprint spectroscopy	On-going implementation
Black plastics	Pigment addition (marker technology) to allow for UV VIS or NIR spectroscopy detection	On-going research
	Steinert Hyper Spectral imaging	PP/PE recycled granules reaching €900 instead of €200 due to increased purity
Plastics in WEEE	8 to 80 mm particle size sorting followed by far UV spectroscopy	Ongoing research
Plastic films	NRT's NIR spectroscopy and controlled ejection pattern coupled with high speed cameras	Recovery rate similar to plastic containers
HDPE bottles	Image recognition of particular packaging shape or brand to allow implementation of effective EPR scheme	On-going research Likely packaging deformation hinders access to ~ 100 % detection rates
Food-contact and non-food contact PET mixture	Food-contact approved Polymark chemical marker technology Machine readable fluorescent inks	On-going research Substitute for current NIR technology detection of multiple markers as 'binary code' is still to be developed

Adapted from: Waste Management World, 2015b, 2016a and 2016b, WRAP 2011 and 2014b