Department of the Environment, Water, Heritage and the Arts

Waste Technology and Innovation Study

Final Report

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INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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Acronyms

AWT – Alternative Waste Technology

C&D – Construction and Demolition

C&I – Commercial and Industrial

CBA – Cost Benefit Analysis

COAG – Council of Australian Governments

CPRS – Carbon Pollution Reduction Scheme

DECC – NSW Department of Environment and Climate Change

DEFRA – UK Department for Environment, Food and Regional Affairs

DEWHA – Department of the Environment, Water, Heritage and the Arts

EPHC - Environment Protection and Heritage Council

EPR – Extended Producer Responsibility

ERV – EcoRecycle Victoria

ESD – Ecologically Sustainable Development

GDP – Gross Domestic Product

GRL – Global Renewables Limited

LATS – Landfill Allowance Trading Scheme

LCA – Life Cycle Assessment

MACROC – Macarthur Regional Organisation of Councils

MBT – Mechanical and biological treatment

MCA – Multi Criteria Analysis

MRF – Materials Recovery Facility

NWMRF - National Waste Minimisation and Recycling Fund (UK)

NGERS – National Greenhouse and Energy Reporting Scheme

NPCC – National Packaging Covenant Council

RDF – Refuse-Derived Fuel

RoHS – Restriction of Hazardous Substances

TASi – Technical Guidelines on Municipal Waste (Germany)

WEEE – Waste Electric and Electronic Equipment

WtE – Waste to Energy

ZWSA – Zero Waste South Australia

Executive Summary

Introduction

GHD was engaged by the Department of the Environment, Water, Heritage and the Arts (DEWHA) to prepare a Study into Waste Technology and Innovation. The study is intended to assist DEWHA in developing two vitally important foundation documents for the future of waste management in Australia, the *State of Waste Report* and the *National Waste Policy*.

Together these documents will seek to drive and deliver a successful transition to more sustainable waste management nationally. To date, the lack of a national approach to improving the sustainability of waste management practices has resulted in an inconsistent approach across the country to the introduction of new waste and recycling technologies, an absence of national standards for landfill design and management of emissions, and lack of value adding infrastructure in the recycling industry (such as beneficiation plants), making it more attractive for companies to export recovered recyclables to other countries such as China, instead of performing the value-adding operations in Australia.

The study into waste technology and innovation will be an important foundation resource in the Commonwealth Government's initiative to provide a national waste policy to deliver improved environmental, social and economic benefits associated with waste management. It should guide policymakers in both the Commonwealth and State Governments to work together to provide consistent and effective technology-based solutions.

Scope of Study

The study focuses on the following:

- Identifying key emerging innovations, trends and opportunities in waste and resource-recovery technologies and practices;
- Identifying the market and non-market barriers to the implementation of emerging technologies and innovations; and
- Identifying past and potential future funding models for financing construction and operation.

The study directly addresses a number of elements mentioned in the *Draft National Waste Policy Framework*. A strategic framework of waste management is also presented in this report that includes guideline principles, their application to waste management, the waste hierarchy, limitations and needs, integration of solutions, strategy and markets.

Technologies

A range of systems for processing mixed waste have been examined in this study. These vary from composting processes (which are net consumers of energy) to anaerobic digestion processes, which are net exporters of energy. Many of these are mature technologies with plants operating both in Australia and overseas. The applicability of certain technologies depends very much on a range of issues such as waste stream characteristics, distance to markets, the financial situation of local government and waste quantities.

When a mixed waste composting process is geared towards producing a saleable compost, it becomes more complicated and expensive to operate, and the amount of residual material increases, as contaminants are removed from the incoming waste stream or screened from the raw compost to meet higher standards. Mixed waste treatment processes therefore carry a greater risk as far as acceptance of the resulting compost than composting processes that are based on treating separated food and garden wastes.

Anaerobic digestion processes are more technically complex than composting processes, and therefore have a higher capital cost, but they produce a commodity (green energy) that is in high demand. Generally there is less residual material for landfill disposal than comparable composting processes.

Many emerging technologies such as pyrolysis, plasma arc, hydrolysis and irradiation for the processing of mixed waste are in still in the early development or in pilot plant stages overseas. Some of these technologies are still considered to be commercially risky at a large scale and their widespread adoption in Australia is therefore likely to be delayed until they are proven overseas by a number of years of continuous operation.

Emerging technologies for the processing of toxic or difficult materials such as e-waste, treated timber and tyres among others, include pyrolysis, chemical extraction, electrodialytic remediation and hydrometallurgy. Many of these technologies and their applications to various materials are still in their early stages of development. There are only relatively small quantities of these materials in Australia and few economies of scale compared to Europe, Asia or the Americas, which have much larger volumes to be processed.

However, smaller scale plants could be established in some capital cities if extreme measures, such as banning the landfilling of particular wastes were adopted. The main barrier to introduction of some of these technologies in Australia is that more convenient alternatives, such as landfilling, or exporting the wastes have existed for a long time. Mechanisms such as advanced disposal fees (deposits paid at the point of sale or import) would assist in attracting sufficient quantities of these items to reprocessing facilities.

Adaptability to Local Conditions

It is recognized that some technologies used in other countries may not be suitable for use in Australia. The economic, regulatory and technical environments are much different in Europe and the US than they are in Australia. In Germany, the TASi[1] regulations have very strict criteria on the biological stability of landfilled materials (the tightest in Europe) and they also prohibit the landfilling of high calorific materials. This results in considerable efforts made to prevent high calorific wastes and untreated biological wastes from being disposed of to landfill.

In the UK, the Landfill Allowance Trading Scheme (LATS) results in local authorities incurring high financial penalties if they exceed their landfilling quantity limits. This, and a grant system to regional councils has pushed the development of a number of new and proposed alternative waste technology plants in the UK. In Germany, concerns about air emissions from thermal plants have driven much of the past development of mechanical biological treatment technologies, but there is an active waste to energy sector based on refuse derived fuels, rather than mass burn incineration.

Increases in the cost of landfilling and community pressure to avoid landfilling and increase resource recovery are the driving forces behind innovation in waste management in some parts of Australia and overseas, and new technology is the main means by which this is being achieved. When assessing the applicability of technologies to the local context, consideration must be given not only to the particular

[1] Technical Guidelines on Municipal Waste

local situation for marketing the outputs, but also the affordability and suitability of associated collection and disposal systems.

In regional areas, there is a clear trend towards collecting and processing source separated materials using simple technologies, while in the larger population areas, collection of mixed wastes with limited source separation, and processing them at more complex facilities that use a combination of technologies is a more common approach.

Waste to Energy

It is likely that in the future, some Alternative Waste Technology (AWT) facilities built in Australia will incorporate thermal technologies. Current AWT facilities are successful in removing recyclables such as glass, plastics and metals from the garbage stream, but much of the paper and cardboard is generally too soiled or contaminated to be recycled and is instead converted into low grade compost. This often has limited or zero marketability.

The recent fall in demand for plastics from China resulting from the global financial crisis has made recovery of mixed plastics in AWT facilities much less commercially viable than in the past. New approaches are therefore needed to deal with the recovered plastics from AWT facilities. Over the past few years, the high prices received from exporting these materials have meant that there has been little incentive for local value-adding, by additional sorting into different grades of plastics for example, or converting the mixed plastics into liquid fuels or to other products.

If the prices for recovered plastics remain low in the medium to long term, this may force the development of new products and processes in Australia for these materials, to absorb the increasing amount of plastics recovered from kerbside recycling, commercial recycling, from the various AWT facilities in operation and planned/being constructed. However if commercial organisations invest in such facilities, and the commodity prices rise, the feedstock that they rely on may then be diverted overseas if there are no contracts in place to prevent this. There is a need for financial incentives that encourage local value-adding, and ensure that waste plastic feedstock streams remain available in the face of fluctuating commodity prices.

Production of refuse derived fuel (RDF) from soiled cardboard and paper, plus recovered plastics not suited to higher order uses, textiles and wood, is quite successful in Germany. These processes could be integrated into many of the existing AWT plants. RDF is used overseas in cement kilns, power stations and industrial plants, such as paper mills, requiring significant amounts of steam and hot water. RDF production would be financially viable when existing facilities can be modified and licenced to use the RDF for heat or power production, or new purpose built facilities are able to be established for this purpose.

Commercial Wastes

The heterogeneous nature of the commercial and industrial (C&I) waste stream and the sheer number and diversity of waste generators and collectors presents challenges to the adoption of technology. In addition, waste disposal in the C&I sector is driven largely by economics. Separation plants in the form of 'dirty MRFs' (materials recovery facilities) are the most likely means of recovering significant proportions of this stream. However, there are not likely to be any significant increases in resource recovery from the C&I sector unless there are regulations or enforceable waste targets put into place nationally.

New AWT facilities coming on line in the near future to service municipal wastes should be able to cope with a proportion of their inputs being C&I wastes from offices and some factories (non-industrial wastes from canteens and personnel areas). Indeed, this may be an innovative way of establishing new AWT facilities, to design them with the flexibility to process up to 20-30% commercial wastes.

With long term municipal waste receival contracts underpinning the original establishment of the plants, topping up with suitable commercial wastes could be seen as an opportunity to better utilise the existing plant and equipment, with benefits shared between municipal waste customers (local councils) and the facility operators. The composition of wastes originating from office buildings and commercial premises (being mainly paper and plastics) makes production of RDF, after removal of recyclables and biological materials, a potentially viable approach for these C&I waste streams..

Green Design

New research into the development of novel chemical, biological and other techniques for processing and recovery of hazardous materials is gradually creating safer and more efficient ways to disassemble and extract the valuable components and neutralise the dangerous elements found in these materials. As a net importer of manufactured goods, there is limited opportunity for Australia to apply green design principles directly to manufactured goods. However it may be possible for the Federal Government to impose some sale or import restrictions on those products that do not meet certain green design principles.

Waste from the construction and demolition industry still forms a significant proportion of all waste generated in Australia. Green design principles could be more widely applied in this sector by increasing the weighting given to waste management in green design measurement schemes. This, and accompanying material specifications to cover their application to various situations, would increase the re-processing and recovery of specific C&D wastes.

Role of Waste Transfer Stations

Waste transfer stations were traditionally designed to bulk up and compress wastes in the most efficient way possible, so that they could be cost effectively transported to a landfill site in larger vehicles. This enabled the waste collection vehicles, which are designed for stop/start operation, but not long haul, to continue their collection runs after disposing of their loads. Therefore little thought was given in terms of space or logistics for resource recovery.

This has been changing as recycling has been developing and most new transfer station designs, especially in rural areas, have designated bins and areas for resource recovery activities for. Pricing policies enable residential and some small commercial customers to dispose of separated materials at reduced or zero cost. The price differences between segregated wastes and mixed waste disposal encourage customers to separate their wastes before arriving at the facility. The variety of solutions adopted by regional councils in NSW and elsewhere are outlined in references such as the Handbook for Design and Operation of Rural and Regional Transfer Stations published by the Department of Environment and Conservation (NSW)[182]

Regulations and Policies

Some changes in the regulatory environment have been introduced overseas to accommodate new advances in technology applied to waste management situations. Waste facilities have been prohibited in some local government areas, but AWT facilities and other resource recovery processing facilities have lower environmental impacts than landfills. As a result they can be located in industrial areas, closer to residential and other community areas than new landfill sites. There have been some innovations in the planning area to overcome these restrictions, which arose when landfills were poorly run and many waste recycling facilities were not subject to environmental impact assessments and licencing controls. In NSW, an Infrastructure State Environmental Planning Policy (SEPP) introduced in 2007 can now be used to assist resource recovery facilities being established in industrial areas, close to where they are actually needed.

Some forms of waste technology innovation involving waste to energy, straddle several policy areas; waste, energy, environment and carbon reduction. Existing regulations and legislation, none of which addresses it in a holistic way, prompting a number of new approaches. The European Union has developed several regulatory instruments to deal with waste to energy facilities in particular.

Barriers to Innovation

By far the most obvious market barrier to innovation in waste management is the low cost of landfilling in some states and territories. In areas where landfilling costs are high (such as Sydney), it is noticeable that more AWT facilities are operational and in the planning stages than in locations where landfilling costs are low (such as Brisbane). Overall it is clear that there are no one-size-fits all solutions for increasing the use of technology and level of innovation in waste management in Australia.

There seem to be four main non-market barriers to the uptake of innovation and new waste processing technologies; the requirement for more co-operation between councils, a distrust of new and unproven technologies, a fear of incineration and reservations about making a long term committment to inappropriate or outdated technology. Generally, local government is responsible for waste management, and as a result, the task of implementing new waste technologies has fallen to this sector, whose staff often have limited commercial and technological expertise. Many of the councils themselves are struggling financially and considerable amounts of money are involved in establishing and operating AWT facilities.

In addition, the amount of waste required to make each facility financially viable means that groups of smaller councils potentially need to enter into joint contracts with service providers. This is a major undertaking, as all partner councils need to be satisfied that their interests, as well as the overall interests of the collective councils are being met. A joint waste processing contract was achieved with the MACROC Councils in Sydney, and with the Coffs Coast Councils in northern NSW, but the Hunter Waste project did not proceed partly because of difficulties in resolving issues between the various councils involved. Because of some technical and commercial issues with existing plants in Australia, there is also a degree of distrust of some new technologies. In addition there is often reluctance among councils to commit to a long term contract when they think that the technology may become outdated before the contract period ends.

Overcoming the Barriers

Possible ways of overcoming barriers to innovation include developing means to enable councils to more easily assess new technologies, such as the NSW DECC's AWT Assessment Tool. However, these tools, whilst assisting in decision-making, do not overcome the major issues of perceived or real financial risks for councils that commit to new technologies. In the UK, a system of 'ring fenced' technology grants[2] was provided to local government by DEFRA, to reduce the capital costs associated with building new technology plants, and thereby reduce the costs per tonne of the waste throughputs. This resulted in a massive program of building a wide range of AWT type plants in all areas of the UK. A similar system

[2] Grants to which conditions are attached

of Federal Government grants to Local Government could be considered in Australia, to bring councils in all states and territories to a more equitable level of technological innovation in waste management.

Innovation in waste management is not restricted to new end-of-pipe technologies to treat wastes and divert them from landfill. Tapping into the voluntary resources of the community to assist in streaming and sorting wastes before they reach any form of mechanical processing offers huge potential to recover valuable resources.

Deposit schemes for items like televisions and computers could be a cost effective way of gathering these materials in sufficient quantities to make the setting up of electronic waste reprocessing plants in the major cities a commercial reality. National product stewardship and extended producer responsibility schemes aimed at particular wastes would assist in the implementation of more advanced material processing technologies in Australia.

Due to the distances involved in transporting materials from generation points to the likely location of high technology plants (large regional centres or cities), providing financial incentives in the form of cash or credit vouchers to private individuals or businesses who deliver materials such as computers, computer monitors and other electronic wastes such as televisions would make recovery of these materials more efficient than trying to establishing broad scale collection systems.

Future product stewardship schemes could operate outside the normal waste collection chain or as part of it. Municipal and commercial transfer stations, AWT facilities and other waste disposal facilities are obvious and easy collection points for items subject to Extended Producer Responsibility (EPR) schemes, negating the need for separate purpose-built receiving centres.

Partnerships and joint ventures in industry are also forming to exploit opportunities. Sharp, Panasonic and Toshiba have established a joint venture to manage electronic waste recycling and collection programs. Veolia and Simsmetal jointly run an electronic waste recovery scheme for commercial customers in Australia. Recycling of the E-Waste equipment is performed at Sims E-Recycling, a joint venture set up between Veolia[3] and the Sims Group. Electronic waste collected undergoes a manual dismantling process. The individual materials such as printed circuit boards, cabling, glass and plastics etc., are recovered and then processed so that they can be used as raw materials to produce new products.

Conclusions

In conclusion, much of the progress to date in waste innovation seems to have been in the area of development of new technologies to treat wastes. However, there is evidence of many innovative waste management approaches focusing on waste prevention, waste minimisation, source separated collection and specific technologies for treating particular waste streams. Source separation is much more effective in conserving resources than relying solely on highly complex, expensive end-of-pipe technologies for managing increasing quantities of highly heterogeneous mixed waste streams.

Whilst there is still a need for research into improving recovery and reprocessing technologies, the main challenge in Australia is to improve the access to such technologies across the country. This could be done by providing incentives to efficiently collect and transport materials to strategic locations for reprocessing, develop local and export markets for recovered materials and value added products, and encourage the community and businesses to actively participate in these schemes.

[3] http://www.veoliaes.com.au/commercial-services/waste-collection-and-recycling/electronic-waste-recycling.asp

Further innovation is needed in terms of economic and regulatory drivers to overcome current disincentives to establishing advanced technologies close to the population centres that are producing the wastes. Equally important in terms of resource conservation are enforceable waste targets and green product design/local standards that enhance the recyclability of discarded items.

In addition, there is a need for more programs that encourage sustainable behaviour, to reduce excessive consumption and wastefulness. This would slow down the rate at which waste is generated, and reduce the reliance on innovations in technology as the solution to all waste problems. Innovative thinking beyond the scope of normal waste awareness campaigns, is needed to encourage and reinforce behavioural change at a business and personal level.

1. Introduction

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The study into waste technology and innovation will be an important foundation resource in the Commonwealth Government's initiative to provide a national waste policy to deliver improved environmental, social and economic benefits associated with waste management. It should guide policymakers in both the Commonwealth and state governments to work together to provide consistent and effective technology-based solutions.

The study is to include a focus on the following:

- Identifying key emerging innovations, trends and opportunities in waste and resource-recovery technologies and practices;
- Identifying the market and non-market barriers to the implementation of emerging technologies and innovations; and
- Identifying past and potential future funding models for financing construction and operation.

1.1 Overview of Approach to Study

This study gives both strategic and practical consideration to the issues of technology and innovation in waste management. A wide spectrum of conceivable technology options is considered, and those which are 'incremental' to existing practices are differentiated from those that would be 'transformative' of the way materials are currently managed in Australia.

In undertaking the study, two main tasks have been completed. They are:

- identifying international trends in waste management policy ,and product and technology innovations that are applicable to Australian conditions; and
- documenting the influence of governance structures and regulatory situations in other countries which have resulted in transformative changes, and experiences in technology uptake and performance in various parts of the world.

[4] Plants that improve the quality of recycled materials by removing contamination or separating into constituent materials that are more valuable than the mixed material

Importantly, in seeking to align the assessment of future technology and innovation options with the new National Waste Policy, the role of technology in delivering on the guiding objectives of improving the environmental, social and economic benefits of waste practices are assessed. Performance measures used by state agencies in their waste strategies, such as waste diverted from landfill, favour particular technologies over others, but local barriers such as distances to markets and local value adding of recovered materials are taken into account.

1.2 Innovation Framework

Waste management innovation theory (van Berkel, 2005) can be used to develop a platform for consideration of waste management options that is structured and thereby offers guidance for the consideration of technology and innovation choices, in a way that is as comprehensive as possible. The innovation platform considers that technologies can be classified in to three streams:

1. Near term innovation of operations (technologies that can improve eco-efficiency of existing industry);
2. Medium term innovation of design (technologies that drive and guide the development of new businesses using eco-efficiency targets and tools); and
3. Future technology innovation (application of novel technologies for new outcomes).

The scoping of innovation options in this way will give some balance and perspective to the range of possible technology options.

Issues of governance, as well as a review of opportunities and barriers, are considered in this study from both a strategic and practical perspective.

1.3 Survey of waste and resource recovery related technology and innovation, including products and product uses

This study provides an opportunity to reflect on existing practices, key differences and common elements, and to further research existing and potential technologies and practices. This is conducted within the strategic framework established for the project and involves consultation both locally and overseas with industry, government and academic contacts.

Technologies are further researched by technology review and consultation. Some consultation is conducted on a one-to-one basis as a result of gap analysis, while more general research is through the relevant industry or trade association and stakeholder groups.

1.4 Examination of the applicability of technologies to the local context

Sound waste management practice should be flexible to local conditions including not only environmental conditions such as hydrology and receiving environments, but also existing socioeconomic paradigms, regulatory frameworks and existing infrastructure.

Technology applicability is considered to not only include recycling infrastructure but also examination of the technology and management loops to recover materials, reagents and process residues as potentially valuable materials. Technology options can also include improved process chemistry and process equipment, technology configuration improvements and engineering design. Further, not all innovation is technological as there should be consideration of the community role in waste recovery and reuse models.

1.5 Current and future snapshot of key innovations, trends and opportunities

Emerging opportunities in the waste and resource recovery sectors are outlined in this study. The viability of different resource recovery and management options and technology and innovation options are influenced by knowledge and public information on:

- trends in international commodity prices;
- trends in environmental asset pricing, including carbon and water pricing;
- landfill pricing; and
- land and resource access.

These trend lines are examined for waste streams and individual materials based on current and past practices and data, and data trajectories made on this basis to enable emerging opportunities to be quantified and substantiated.

Waste trends are vastly more complicated than a linear correlation with increases in population or GDP, with resource recovery rates dependent on factors such as the effectiveness of recycling systems and subsequent material processing and marketing systems. International commodity markets undoubtedly affect the commercial viability of recycling, because of past practices in exporting large quantities of partly processed paper and plastics and scrap metals to places like China for further processing and refinement into useful materials and products.

1.6 Market and non-market barriers to the introduction or uptake of emerging technologies and innovations

An assessment of barriers and opportunities to technology and innovation is conducted to span both market and non market barriers including issues of governance, awareness in industry, access to information, product quality and product specifications, technology capacity and use, transport and transfer logistics.

The assessment recognises that technology is just part of the solution to achieving quantum reductions in waste generation and materials and energy intensity. Reducing waste generation can also be the result of improvement in business processes, inputs, products and technology often with multiple environmental and business benefits.

1.7 Examination of current and potential funding options for waste management solutions involving technology and innovation

Different funding models of alternative waste technology plants by private organisations (e.g build, own, operate) and private - government partnerships (e.g build, own, operate, transfer) are reviewed. Research of alternative (more recent) funding models is undertaken.

The funding of technology and innovation needs to be examined based on the cost benefit of solutions implementation. The financing of waste management improvements is discussed case-by-case, however opportunities for funding will be researched and presented, particularly those linking to domestic and international priorities such as climate change.

For example, currently, the proposed national Carbon Pollution Reduction Scheme (CPRS) is expected to shift the economics of production and consumption in a pattern that favours products and services that are less carbon and energy intensive than others. While some elements of the waste and resource recovery sector will benefit indirectly from this, in terms of competing with virgin resource prices, others such as landfill operators will not, and this will reduce their willingness to innovate.

The CPRS does not offer a perfect solution to the internalisation of carbon in the economy and there may be an opportunity to supplement the national scheme as has occurred overseas for some aspects of waste management. For example, carbon sequestration in soil is not rewarded by the CPRS for numerous reasons. Also, recycling and resource recovery services are not directly rewarded and there is no incentive to the 'recyclers', hence the market instrument provided by the CPRS in this case is not targeting the influential party. There may be an opportunity to present a case for a supplementary fund for these activities with the weight of arguments that could cost effectively assist the achievement of carbon abatement targets.

Waste levies have made waste disposal to landfill expensive in Sydney, which has provided significant commercial drivers for introduction of new waste technologies, however the approach in most other states and territories has been adopting the 'lowest cost to meet regulations' approach to waste disposal. In the absence of a Life Cycle Approach, landfilling is the most cost effective approach to meeting sanitary objectives associated with waste disposal.

Therefore there is an urgent need to provide some means of funding the implementation of new technologies to overcome these commercial and financial barriers. This could possibly come through infrastructure grants linked to environmental performance outcomes.

2. Why is there a need for innovation?

2.1 National Waste Policy

The Australian Government is leading the development of a national waste policy for Australia. A recent snapshot of waste and recycling trends in Australia (Waste and Recycling in Australia, 2008) showed that Australia's waste increased by 28 per cent between 2003 and 2007. This occurred in spite of a big increase in recycling efforts, through kerbside recycling programs and actions by the commercial and industrial sectors.

The last national waste policy, the National Waste Minimisation and Recycling Strategy, was published by the Commonwealth in 1992. In the same year the Council of Australian Governments (COAG) agreed to a National Strategy for Ecologically Sustainable Development which included waste objectives. A lot has changed socially, environmentally and in the economy in almost 20 years.

The national waste policy is being developed with the support of Australia's environment ministers, who will contribute through the Environment Protection and Heritage Council (EPHC). The Department of the Environment, Water, Heritage and the Arts (DEWHA) has just release the Draft National Waste Policy Framework, a discussion paper that outlines the background, the results of consultation and the elements of the proposed Policy.

The Draft National Waste Policy Framework puts waste into the national context and provides some point of clarification and update. Points raised that are of relevance to this study include that the policy will focus on 'fit-for-purpose technology, standardised approaches…facilities and business models that enable business development and growth…business certainty for investment, safe handling and disposal of waste materials and hazardous waste…'[5] The policy may set a national target and treat waste as a resource that will provide opportunities for the development of '…new processes, technologies, industries and markets…'[6]

As well as favouring standardised approaches the policy will also promote 'tailoring solutions' that build '…capacity for regional, remote and indigenous communities'.[7] This issue is dealt with directly in this study.

Several points listed in the Framework under The Vision by 2020[8] relate directly to issues covered in this study. These are, as numbered in the Framework document:

Point 3 Australians manage potential waste streams as a resource to achieve better environmental outcomes and overall community benefit including increased agricultural productivity, reducing greenhouse gases, water and energy efficiency and energy production.

Point 4 Access to products, services and capabilities for waste avoidance, resource recovery and waste management is available to all Australians.

Point 6 There will be efficient and effective Australian markets for waste and recovered resources

[5] Page 6

[6] Page 6

[7] Page 10

[8] Page 12

Point 10 The activities of government – including environmental regulation, planning and development and licensing and specification requirements – facilitate waste avoidance and resource recovery.

Elements of the Themes and Directions outlined in the Framework are also particularly relevant. Under Pursuing sustainability,[9] the Framework refers to '…enhancing the recovery and recycling of Australia's waste streams can improve the efficient use of materials, save energy and waste and make an important contribution to reduce greenhouse gas emissions.' and 'Better management and re-use of the organics in Australia's waste streams would offer significant opportunity to deliver sustainability and innovation benefits.'

This section also refers to the '…transition to alternative uses for each major type of organic waste, in particular for non-putrescibles.' and '…the need for facilities to handle the different types of organics for a range of re-use purposes;…and for waste to energy plants and methane to energy.'[10] Under Tailoring solutions,[11] reference is made to '…scalable waste to energy plants, mobile facilities to collect and recycle particular wastes…', guidelines and standards for smaller communities for '…infrastructure for resource recovery, design for waste avoidance, recycling, [and] alternative waste technologies…' and 'For regional, remote and Indigenous communities, explore the potential for small scale energy generation facilities and re-use and recycling facilities, including funding models that would be flexible and provide local employment.'[12]

2.2 Current waste situation – how much is going to landfill?

2.2.1 Nationally

Data from Hyder's Waste and Recycling in Australia Report, 2008, shows the level of total waste generation (disposal and recycling) and diversion rates across the main states of Australia during 2006-07 (see Table 1). About 20 million tonnes per annum is landfilled, and about 20 million tonnes per annum is recycled.

Table 1 Waste generation and diversion rates for the main states of Australia 2006-07

State / territory	Disposed	Recycled	Total Generated	Diversion Rate
		Tonnes		Percent
NSW[13]	7,100,000	6,019,000	13,118,000	46%
Victoria	3,925,000	6,358,000	10,283,000	62%
Queensland	4,286,000	3,381,000	7,667,000	44%

[9] Page 16

[10] Page 17

[11] Page 20

[12] Page 21

[13] Data is for 2004-05

State / territory	Disposed	Recycled	Total Generated	Diversion Rate
		Tonnes		Percent
Western Australia[14]	3,539,000	1,708,000	5,247,000	33%
South Australia	1,144,000	2,434,000	3,579,000	68%
Australian Capital Territory[15]	197,000	567,000	764,000	74%
Tasmania	641,000	[16]17,000	658,000	Not known
Northern Territory	[17]85,000	[18]1,000	86,000	Not known
Total	**20,917,000**	**20,485,000**	**41,402,000**	**49%**

NOTE: All figures have been rounded. Minor discrepancies may occur between the stated totals and the sums of the component items, as totals are calculated using the component item values prior to rounding

Current calculated average diversion rate is 49%, but this hides some significant differences in data reporting between the states (see Table 2 and Table 3). These figures are hard to substantiate, because the Australian Capital Territory has no garden organics separate collection service, for example, yet manages to demonstrate the highest diversion rate from landfill. Similarly, Western Australia and NSW have more alternative waste technology facilities than any other states, yet their reported diversion rates are not as high as the Australian Capital Territory, South Australia and Victoria, none of whom have any AWT facilities.

Table 2 Per capita waste generation and diversion rates for main states of Australia 2006-07

State / territory	Population	Disposed	Recycled	Total Generated	Diversion Rate
			Kilograms per capita		Percent
NSW[19]	6,888,000	1,031	874	1,904	46%
Victoria	5,205,000	754	1,222	1,976	62%
Queensland	4,181,000	1,025	809	1,834	44%
Western Australia[20]	2,106,000	1,680	811	2,492	33%

[14] Extrapolated from municipal data

[15] Includes cooking oil and fat, motor oil, and salvage and reuse

[16] Municipal data only except for plastics recycling which covers all sectors

[17] Darwin only

[18] Municipal only

[19] Data is for 2004-05

[20] Extrapolated from municipal data

State / territory	Population	Disposed	Recycled	Total Generated	Diversion Rate
		Kilograms per capita			Percent
South Australia	1,584,000	722	1,537	2,259	68%
Australian Capital Territory[21]	340,000	581	1,668	2,249	74%
Tasmania	493,000	Unknown[22]			
Northern Territory	215,000	Unknown[23]			
Total	**21,015,000**	**995**	**975**	**1,970**	**49%**

NOTE: All figures have been rounded. Minor discrepancies may occur between the stated totals and the sums of the component items, as totals are calculated using the component item values prior to rounding.

[21] Includes cooking oil and fat, motor oil, and salvage and reuse

[22] Not calculated due to limited data

[23] Not calculated due to limited data

Table 3 Recycling rates by type of waste, by region (Source Hyder, 2008)

State / territory	Recycled *(tonnes)*							Generated *(tonnes)*			
	Municipal		C&I		C&D		Total	Municipal	C&I	C&D	Total
NSW[24]	1,037,000	33%	1,835,000	38%	3,147,000	61%	6,019,000	3,181,000	4,820,000	5,118,000	13,118,000
Victoria	1,055,000	38%	2,947,000	74%	2,947,000	72%	6,358,000	2,782,000	4,007,000	4,086,000	10,283,000
Queensland	1,366,000	44%	1,398,000	57%	617,000	30%	3,381,000	3,133,000	2,451,000	2,083,000	7,667,000
Western Australia[25]	408,000	29%	891,000	60%	409,000	17%	1,708,000	1,424,000	1,476,000	2,348,000	5,247,000
South Australia	408,000	54%	871,000	64%	1,155,000	79%	2,434,000	753,000	1,367,000	1,460,000	3,579,000
Australian Capital Territory[26]	270,000	76%	68,000	43%	229,000	92%	567,000	355,000	160,000	249,000	764,000
Tasmania	15,000	6%	[27]1,000	1%	0	0%	17,000	260,000	146,000	251,000	658,000
Northern Territory	[28]1,000	100%	Unknown		Unknown		1,000	1,000	Unknown	Unknown	86,000
Total	**4,561,000**		**8,011,000**		**8,504,000**		**20,485,000**	**11,887,000**	**14,426,000**	**15,595,000**	**41,402,000**

[24] Data is for 2004-05

[25] Extrapolated from municipal data

[26] Includes cooking oil and fat, motor oil, and salvage and reuse

[27] Only plastics recycling data available

[28] Darwin municipal data only

Hyder notes the inconsistencies in reporting and classification between the states and territories and states that the waste disposal reduction achieved in three states/territories (Victoria, South Australia, the Australian Capital Territory) is likely to be the result of a combination of measures, namely:

- Very active diversion of C&D waste in these jurisdictions;
- Increased opportunity to divert waste at disposal sites (transfer stations);
- Higher level of C&I waste sorting; and
- Smaller residential garbage bins resulting in higher diversion.

These may be contributing factors, but the inconsistency in reporting of data, rather than collection systems, and availability of sorting and reprocessing facilities is likely to be the reason for high performances in some sectors. Hence there is still a need for appropriate facilities even in those states and territories that are reporting high recovery figures.

2.3 Organic materials

The amount estimated by Hyder (2008) of organic and other material disposed of to landfill by each sector is outlined in Table 4 below. It can be seen that paper and cardboard, and food are the most significant organic categories still being disposed of to landfill.

Green organics are also significant, although these can be avoided more easily than other wastes through separate green waste kerbside collections, which are now quite common in most of the major cities.

Table 4 Estimated amount of organic and other material disposed of to landfill, Australia, 2006-07

Waste stream:	Municipal	C&I	C&D	Total
Material		**Tonnes**		
Food	1,905,000	385,000	0	2,290,000
Paper and cardboard	1,905,000	3,528,000	213,000	5,646,000
Green organics	733,000	192,000	142,000	1,067,000
Wood	147,000	898,000	425,000	1,470,000
Other (non-organic)	2,637,000	1,411,000	6,311,000	10,359,000
Total	**7,326,000**	**6,415,000**	**7,091,000**	**20,832,000**

NOTE: All figures have been rounded. Minor discrepancies may occur between the stated totals and the sums of the component items, as totals are calculated using the component item values prior to rounding

It can be seen from above that almost 2 million tonnes of food is disposed of to landfill each year. Despite kerbside recycling systems, almost 6 million tonnes of paper and cardboard is disposed of to landfill each year. Just over 1 million tonnes of garden organics were disposed of to landfill. Technologies required to prevent the bulk of this material from being disposed of to landfill already exist in Australia. Therefore it is not a problem of lack of available technology, rather an issue of lack of implementation of that technology and associated collection or drop-off systems to permit source separation of the feedstock, or prevent it from being entrained in material destined for landfill disposal.

Even in major cities such as Sydney, there are a lack of facilities for recovering and reprocessing food, and paper and cardboard. Garden organics reprocessing facilities are generally well provided, but most cannot cope with food or paper being added to the feedstock as they are open windrow systems that could cause litter and odour complaints.

2.4 Assessment of the Need for Resource Recovery in Australia

The question arising from analysis of the data shown above is, which materials should be recovered, at what cost, and what environmental or social benefit would result from this recovery, as opposed to continuing to dispose of them to landfill? This is essentially what the Productivity Commission set out to try to answer in its 2006 report.

There are many arguments that arise about how much recycling and resource recovery is simply too much - in other words, are the environmental impacts of these activities outweighing the benefits of recovering these materials?

Hyder's analysis (2008) identified a number of key products of 'national significance'. These were products with certain characteristics such as those with high consumption volume or high potential recovery. A number of materials were identified including electronic waste and tyres.

3. Developing a Strategic Framework for Technology Assessment

3.1 Background Information

As highlighted in the consultation phase of developing the National Waste Policy, Australians are more aware than ever of how vulnerable our country is to climate change and to water scarcity. Sustainability has become an important feature of the policy landscape. At the same time, the role of waste management in sustainability is more understood - not only for the role of environmental protection from disposal, but in managing the anthropogenic flow of materials through the economy.

Waste management behaviours and policy have been driven in the past in Australia largely by intuition. There has been a general sense that resources are valuable and that waste has hidden costs. This has helped to drive community pressure for improved waste management and helped to entrench the waste hierarchy as a guiding principle for waste management. More recently, local and international studies have reinforced this message providing environmental and socioeconomic information about the net benefits of recycling and the impact of management options.

Government decision-makers are also increasingly accountable for decision-making in relation to the provision of waste management infrastructure. Accordingly, technology assessment procedures have needed to be robust and more transparent in order to meet expectations and address probity issues.

Of increasing importance is the need to assess proposals in the context of ecological sustainable development, where the relative impacts of proposals are assessed using an agreed set of economic, environmental and social criteria. For most waste treatment technologies, a fourth set of criteria that address technical aspects is also important. The technical performance can vary significantly between technologies and can determine the success or failure of a project.

The new National Waste Policy has a stated intention to reflect these changes in policy, community understanding and the natural environment, and to contribute to broader sustainability outcomes.

All spheres of government in Australia are aware of the need for more informed decision making and the new national waste policy is seeking to provide a strategic framework, based on rigorous assessment, to pave the way to a more considered approach to waste decision making and provide solid foundation for future waste management investment choices.

3.2 The Strategic Framework Introduction

The strategic framework for waste management provides decision support for selection of comparative waste management options. It seeks to foster the objectives of the National Waste Policy as stated in the Consultation Paper (DECC, April 2009) and build on and incorporate key developments in waste management since the National Waste Minimisation and Management Strategy (1992) and the National Strategy for Ecologically Sustainable Development (1992).

The Strategic Framework developed for this study gives regard to the performance categories that enable waste option assessment in order to: 'manage waste more effectively for better environmental outcomes and overall community benefit' (DEWHA, 2009).

Consistent with Best Practice Regulation (COAG, October 2007), which requires public policy makers 'to make judgments based on what is best for the community as a whole by measuring 'social', as opposed to only private, market-based costs and benefits. In the context of waste management, the net community benefit is measured by environmental, social and economic benefits.

The strategic framework for waste management (see Figure 1) seeks to provide decision support across the broad range of possible waste management options. This is achieved in part, by offering Guiding Principles for Waste Management in combination with a sound analytic framework for assessing waste management options and societal preferences.

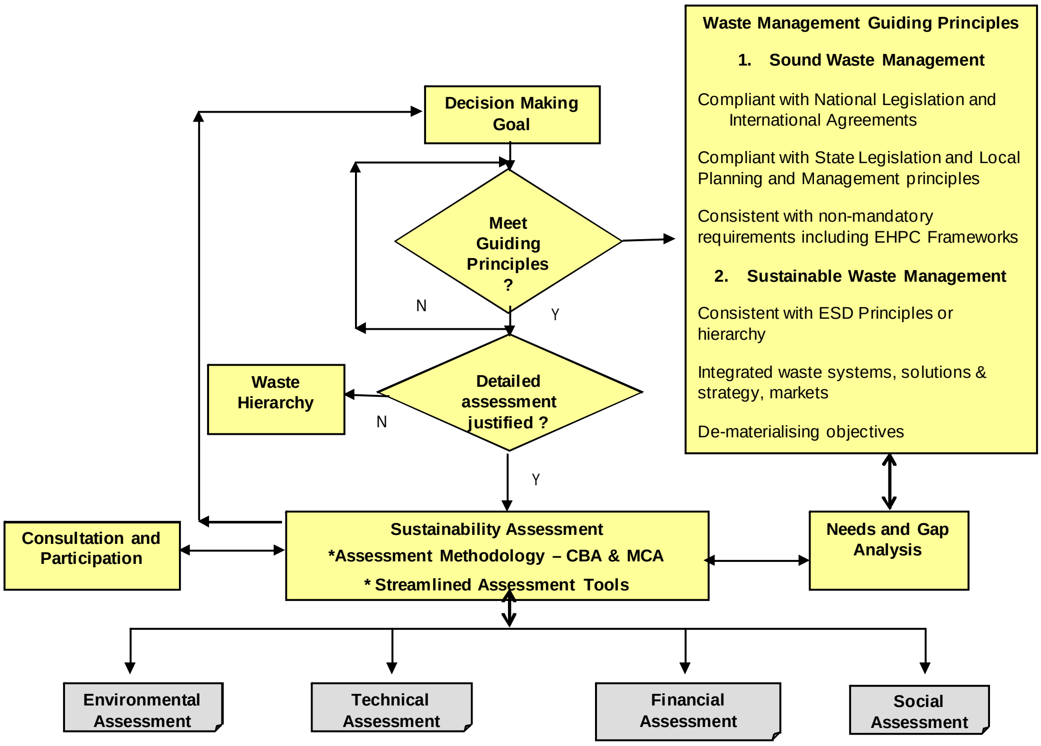

Figure 1 Strategic Framework for Waste Management

In developing a comprehensive framework for waste decision making that meets the selection criteria, there is a need to provide an overarching approach that integrates the *Decision Making Goal* and *Guiding Principles for Waste Management* with the *Assessment Method* for the relevant performance areas. Further, the framework needs to be flexible to avoid unnecessarily complex analysis where it is not warranted and to offer more readily available, streamlined assessment tools.

The Strategic Framework includes:

- An overarching framework that integrates guiding principles and caters for limitations and needs.
- Assessment Methodology - for conducting and integrating a comprehensive performance assessment; and
- Streamlined Assessment Tools - for practical guidance to waste priorities.

The Assessment methodology provides comprehensive guidance for the social, technical, environmental and cost assessment of waste systems. Consistent with the assessment methodology, the streamlined assessment tool uses best available data and approaches to assist with streamlining the assessment process and establishing a relative ranking of available solutions.

3.3 Guiding principles

Guiding principles for waste, in accordance with a preferred hierarchy of waste management, have existed in Australia since the early 1980s. They have been refined since this time, for hazardous waste (Moore, 1995) and waste generally (Moore & Tu, 1995) to incorporate basic aims of waste management and ESD principles.

The guiding principles adopted for this strategic framework to assess waste management technologies and management options are broad and offer a pathway for determining the acceptability of waste management options in terms of, firstly, sound waste management and then secondly for optimising waste management solutions in terms of the Ecologically Sustainable Development (ESD) categories of social, environmental and economic performance. Within the ESD context, additional guiding principles relate to waste innovation and give regard to the need for an integrated approach to waste solutions based on material types and treatment alternatives as well as acknowledging the role of the market in securing solutions. The target of 'doing more with less' through a dematerialised economy is held up as a guiding principle to offer a visionary pathway for waste management that is compatible with the growth objectives of government.

The Guiding Principles for options under consideration include:

1. Sound Waste Management

The first requirement of waste technologies and management options is for sound management as provided in the first instance, by legislation. Compliance at all levels of government is the foremost screening test for waste management options.

At the national and International level, this includes, but is not limited to:

- The Basel Convention;
- The Stockholm Convention on Persistent Organic Pollutants;
- The Montreal Protocol on Ozone depleting substances; and
- Agenda 21.

Waste management options should also be compatible with agreed non-mandatory requirements including voluntary programs under the EPHC, climate change policy and national emissions abatement objectives, and best practice codes and guidelines.

2. ESD Principles

The ESD principle gives rise, within the strategic framework, to the net benefit assessment which is the targeted outcome of the Assessment Methodology and Streamlined Assessment Tools. They seek to enable waste option assessment in order to: 'manage waste more effectively for better environmental outcomes and overall community benefit' (DEWHA, 2009).

In order to meet the environmental aspect of sustainability, it is suggested that waste management strategies must be designed to reduce the net flow of materials and energy associated with the entire waste management system if these efforts are to translate into reduced environmental impacts and prove to be cost effective.

3.3.1 Application of Guiding Principles tor Waste Management

Under the Guiding Principles, net community benefit as measured by the performance categories does not necessarily correlate to a comprehensive interpretation of ESD principles to Waste Management. The guiding principles, as well as playing a determining role in the development of the assessment framework, also provide assistance in determining the gaps associated with this approach if waste decision making is to truly fulfil the goal of delivering on sustainability outcomes.

The application of ESD principles for waste management examined by Moore & Tu (1995), provides concrete expansion of the Guiding Principles, not otherwise provided in this report. Each of five major ESD principles; namely, intergenerational equity, intragenerational equity, biodiversity, the precautionary principle and global issues, are dealt with in turn (refer Moore, 1995 for more detailed treatment) and from this, the limitations of this Strategic Framework may be examined.

3.3.2 The Waste Hierarchy

The environmental assessment procedure has limitations. It provides a means to analyse and quantify, in order to optimise or benchmark. If detailed system analysis is not essential to achieve the preferred outcome, it will not be warranted. A more general approach recognises that study limitations may prevent detailed data acquisition on the material inputs and outputs of processes. If this is the case, the approach in Australia as in Europe (European Commission, 2006) has been to fall back on the waste hierarchy.

3.3.3 Limitations and Needs - Applying Guiding Principles to Waste Management

Limitations and gaps in the Assessment Method may be examined, on a case-by-case basis or holistically, by cross referencing and examining the Guiding Principles. This feature enables the strategic framework to remain flexible to important and compatible principles over time.

Moore & Tu (1995), examined the application of ESD principles to waste including the principle of intergenerational equity. For example, the application of this ESD principle is interpreted by Moore & Tu to be, ‘all waste produced by this generation be managed in such a way that the next generation (taken as 30 years from now) incurs no liability by way of environmental quality degradation’.

Asset preservation across generations would require that minable stocks of certain compounds/materials be retained in long term storage as monofills[29]. Cursory analysis would suggest that elements such as copper justify recovery or immediate temporary storage with flow analysis revealing the copper reserves in landfills and tailings dumps in North America are equivalent to that which may feasibly extracted from reserves (Spatari *et al* 2005).

3.3.4 Managing material and waste to dematerialise the economy

A dematerialised economy, when material, energy and service inputs required for economic processes are reduced, is based on high resource productivity and generating more welfare from less materials. Reducing the material and energy intensity of products and services while maintaining the same utility for society presents a waste management challenge that emphasises upstream management options such as eco design and toxicity phase out or material substitution.

[29] A type of landfill in which only one material is deposited and often seen as a type of long-term storage. Materials deposited in a monofill are not contaminated by other waste and can potentially be ‘mined’ for recovery in the future.

It prompts consideration of solutions outside those typically suited to the assessment methodology, such as a return to a service-oriented economy reliant on new patterns of production and consumption such as: product leasing over private consumption and product repair over replacement (Stahl, 1992).

3.3.5 Integration of waste solutions, strategy and markets

The success or failure of the system will depend on the dynamic context in which waste solutions operate. The integration of technologies and management options at an operational level as appropriate for waste stream components with differing characteristics, the integration of support strategies with solutions and the role of the market place in determining technology and technology innovation success, all require consideration as guiding principles for sustainable waste management.

In practice, waste management solutions are well integrated with no waste management practice, treatment technology and disposal technique suitable for processing the range of materials. The total solution invariably involves transport logistics, collection systems, waste streams, treatment technologies and markets.

3.4 The Assessment Methodology

The Assessment Methodology provides comprehensive guidance for the social, technical, environmental and cost assessment of waste systems. Consistent with the assessment methodology, the streamlined assessment tool uses best available data and approaches to assist with streamlining the assessment process and establishing a relative ranking of available solutions.

The dual approach recognises the limitations on the decision making framework in terms of data availability. While there are advantages from linking to existing data and relevant studies and assessing these in the context of the assessment methodology, issues associated with data quality mean that the outcomes should be viewed as best available at a point in time. As data quality improves a more complete picture of technologies and systems will become available. The framework provides for the incorporation of new information as it becomes available and for changing conditions. As such, the emphasis for this initial stage of framework development is to establish a framework methodology and to capture work to date in the streamlined assessment tool.

3.5 Selection criteria for a strategic framework for waste management decision making

Selection Criteria for a methodology for the sustainability assessment of waste management and technology options include:

Strategically, the framework should:

1. Meet the stated objectives of the new National Waste Policy;
2. Provide for innovation in accordance with Innovation Agenda for the 21st Century set by the Department of Innovation, Industry, Science and Research;
3. Be based on appropriate application of best practice assessment methods; and
4. Require detailed analysis only as necessary not as a prerequisite to decision making.

Operationally, the detailed assessment framework should provide:

1. Transparency of data, assumptions and gaps so that the basis for differentiating between technologies follows a clear, objective and traceable process;
2. Robustness and therefore reproducibility of results so that when applied by different users, the same set of proposals are assessed with similar outcomes;
3. Simplicity and should be meaningful to a wide audience and easy to understand;
4. Embrace and enhance community participation processes by providing transparency to options and facilitating informed decision making; and
5. Results that are readily used but that may be examined in detail.

3.6 Assessment of Performance

Waste management technology and management options require assessment of their environmental, financial, social and technical performance, as well as integration of these assessment results with stakeholder preferences for waste decision making to support sustainability outcomes.

3.6.1 Application to waste decision making in Australia

Various levels of government across Australia have undertaken net benefit assessment or triple bottom line assessment within defined boundaries. For example, Residual Waste Treatment Technologies have been studied in isolation and as part of integrated waste solutions (Resource NSW 1999; South Australia Department of Industry and EPA, 2001; Eco Recycle Victoria 2003, Gold Coast City Council, 2009) and management options for used packaging have been studied (NPCC, 2001; ERV, 2003; NPCC, 2004).

Further, governments have assessed the net benefit of waste stream management (ZWSA, 2007; 2008); collaborated to assess waste management options (Jurisdictional Recycling Group, 2004) or developed decision support tools based on Environmental LCA and Triple Bottom Line Assessment (Western Australian Local Government Association 2001 & 2004; EcoRecycle Victoria, 2003; NSW Department of Environment and Conservation, 2006 & 2007; Western Australia Department of Environment, 2008).

Such assessments have proved useful at the local level for waste decision support (Northern Sydney Waste Board, 2002; Mackay City Council, 2002, South East Queensland Regional Group of Councils 2003, Penrith City Council 2008, Gold Coast City Council, 2008; Orange City Council 2009).

Studies commissioned by government bodies in Australia have contributed to materials accounting decision support capacity and have been influential in regard to policy making in waste management.

The framework methodology for waste management is intended to be applicable to the different levels of decision making from strategic level policy making through to local application of technologies and technology benchmarking.

3.6.2 The Valuation Phase - Multi Criteria Assessment and Cost Benefit Assessment

The framework methodology caters for decision making involving assessment of a wide range of alternatives across numerous evaluation criteria. When confronted with such an array of alternatives and criteria, it becomes difficult to sort, analyse, prioritise and make choices without the assistance of a tool or technique (Annandale and Lantzke, 2001). To assist the decision making process, the decision maker may use a multi criteria assessment framework or attempt to adopt common units between performance categories in order to integrate the financial, economic, environmental and social performance.

Both techniques offer a systematic and structured approach to assist in the analysis of options and hence have the effect of improving the quality of the decision and justifying actions as a result of outcomes. The tools assist comparison across different units such as tonnes of CO_2-e and number of people employed. CBA requires that a further valuation step is undertaken to achieve the common monetised unit.

The act of simplifying complex system into simplified indicators is subject to criticism for failing to engender understanding about the complex issues relevant to the decision (Pickin, pers comms 2008). Further, it is suggested that CBA includes layers of uncertainty and assumption through which bias can enter (Pickin, 2006). He states the elusive valuations of environmental externalities are ripe for this type of bias.

Contra to this, one of the leading environmental economists of our time, David Pearce, has suggested that, despite the criticism, the use of monetary valuation for policy decision support carries less uncertainty than scientific presentation of data (Pearce, 2000). Pearce acknowledges that casual commentators suggest that the monetary valuation stage should be avoided due to uncertainty in the results. He suggests that this is a mistaken strategy and that avoiding the monetary valuation stage may seem like a rational response to the uncertainty embedded in the benefit estimates, but such a response adds at least two other forms of uncertainty.

Firstly, the 'democratic' uncertainty, this is the extent to which any outcome is now responsive to individuals' preferences, and secondly the 'decision-making' uncertainty, i.e. the extent to which rational trade-offs between costs and benefits can be made'. Where the impacts are measured in non-monetary units and compared to costs, there is no apparent guideline on whether a policy is worth undertaking. Monetisation provides the guideline that policies should at least past a test to the effect that benefits should exceed costs.

In Multi Criteria Analysis (MCA), aggregation of performance indicators into common performance scores, may preserve the relative performance within an impact category but it may distort the relative performance across impact categories to the extent that the results are meaningless unless an alternative means for calibration between categories can be arrived at. Normalisation methods may be useful in this regard and used to determine the significance of the performance score with respect to the goal of the study in order to minimise the potential for error.

Two of the most popular decision support tools for waste management in Europe are Life Cycle Assessment (LCA) and Cost Benefit Analysis (European Topic Centre on Resource and Waste Management, 2001). As in Australia, both tools are the subject of debate and criticism. While any method that seeks to assess vast amounts of complex data and simplify it into performance indicators for a non-technical audience will contain assumptions and value judgements that may not suit all stakeholders.

3.6.3 Incorporating decision maker preferences

3.6.3.1 MCA weighting

To undertake MCA, decision-maker or stakeholder community preferences are elicited and used to assign a relative importance or weight to each criterion. This can be done on an individual basis or through focus groups.

Typically, the weighting of each criterion is achieved by assigning a numerical value that reflects the relative importance of that criterion. For this framework, the decision maker is guided to allocate points to each criterion from a total pool of 100 points. The derivation of these weights may vary in sophistication from individual preference selection and is not within the bounds of this study. Weighting is conducted across assessment types and within the assessment for assessment criteria.

3.6.3.2 Monetary Valuation

Monetary valuation of impacts is typically sought by decision makers and often in preference to scientific or other recognised units (Philpott and Partl, 2006).

Two monetary valuation approaches that have been used for CBA of Waste Management (NPCC, 2001 and DEC, 2005 by Nolan-ITU) and (ZWSA, September 2007 by BDA) adopt a similar approach to European methods (Danish Topic Centre on Waste and Resources, 2005) and conduct step wise assessment involving firstly, the quantification of pollutant and resource loads in an inventory and subsequent load valuation by benefits transfer of published valuations using established techniques in environmental economics. Application of these almost mirror image methods has delivered entirely different valuations of landfill disposal due to the range of pollutants included within the analysis. Trace contaminants have been held accountable for the major portion of the environmental cost of waste treatment options (Philpott, 2009).

The valuation of these pollutants, although conducted using an internationally acknowledged scientific assessment method for the benefits transfer, proved controversial in a recent national review of waste management (Productivity Commission, 2006). The method, developed by the Centre for Environmental Studies CML at Leiden University, the Netherlands (Simapro, 2002) was already known to produce inconsistencies for a small number of organic pollutants including Benzene (Grant pers comms, 2007). The distortion brought forward when this method was adopted for the extrapolation of economic values does not reflect on the validity of economic valuation techniques nor on the suitability of the method for other applications.

3.6.4 Financial Assessment

Financial assessment is conducted in accordance with best practice Cost Benefit Assessment as promoted by The Office of Best Practice Regulation and detailed within the methodologies handbook (Department of Finance and Administration, January 2006). In accordance with the handbook, a financial evaluation explicitly compares receipts and expenditures, generating a net cash flow. The net cash flow is then normally discounted to determine the NPV of the proposal.

In tailoring the financial assessment to waste management technology assessment, it is important to expand the assessment scope to include relevant overheads and variables such as:

- land acquisition (at replacement cost);
- contamination and risk;
- residual management costs and project costs based on treatment availability;
- revenue from products at market or substitute prices;
- input costs;
- regulatory costs associated with cleaning technologies;
- abatement or environmental levies and taxes; and
- pricing support by government for political priorities such as;
  - energy generation;
  - renewable energy;
  - greenhouse gas abatement; or
  - other positive environmental outcomes.

A streamlined financial assessment is provided in Table 5 to assist decision-making.

Table 5 Streamlined Financial Performance Assessment

Performance Category		Objective	Evaluation Criteria (Scoring)
1	**Financial**		
1.1	Capital Cost	Ensure prudent expenditure and appropriate cost to community for waste treatment and disposal.	5. Lowest cost capital investment 4. Low to moderate cost of capital investment 3. Moderate cost of capital investment 2. Moderate to high cost of capital investment 1. Highest cost capital investment
1.2	Operating Cost	Ensure prudent expenditure and appropriate cost to community for waste treatment and disposal.	5. $50 - $100 per tonne 4. $100 - $150 per tonne 3. $150 - $200 per tonne 2. $200 - $250 per tonne 1. $250 + per tonne
1.3	Energy Consumption	Consumption of energy and ability to offset energy costs.	5. Net energy producer, net profit from energy production 4. Net energy producer, break even with cost offset from energy production 3.Net consumer of energy, moderate production of energy moderate offset of energy consumption 2.Net consumer of energy, little energy production little offset of energy consumption

			1. Net consumer of energy, no energy production
1.4	Imposed levies, taxes or remunerated benefits	Seek to complement net income from government environmental initiatives such as climate change and renewable energy or infrastructure grants and minimise taxes and levies.	5. Entitled to government funds for one-off infrastructure grants and on-going performance such as renewable energy or carbon credits 4. Entitled to government funds for on-going performance such as renewable energy or carbon credits 3. May be entitled to government funds for one-off infrastructure grants and on-going performance such as renewable energy or carbon credits 2. May be entitled to government funds for on-going performance such as renewable energy or carbon credits 1. Unlikely to be entitled to government funds for on-going performance or one-off infrastructure.
1.5	Market availability for products	Readily available markets for by-products within Australia or with existing trading partners (eg high grade or low grade compost, energy or recyclables)	5. Very stable, viable market (over 20 years) 4. Stable viable market (over 20 years) 3. Viable market (over 20 years) 2. Variable market (over 20 years) 1. No viable market (over 20 years)
1.6	Post closure costs	Ensure actual costs of waste process / disposal are accounted for	5. No ongoing post closure cost very low risk of cost 4. No ongoing post closure cost and low risk of cost 3. Moderate ongoing post closure cost moderate risk of cost 2. Potentially high ongoing post closure cost and high risk of cost 1. Potentially very high ongoing post closure costs risks to more than one aspect (e.g. water, soil, land use, greenhouse gas) * Not considering decommissioning requirements rather ongoing costs associated with monitoring, contamination, cleanup, land use constraints etc.

3.6.5 Social Performance Assessment

International Principles for Social Impact Assessment offer some guidance to Social Performance Assessment for waste management (International Association for Impact Assessment, 2005) suggesting an approach that embodies the evaluation of all impacts on humans and on all the ways in which people and communities interact with their socio-cultural, economic and biophysical surroundings.

The approach has strong links with a wide range of specialist sub-fields that might potentially be involved in the assessment with relevance to waste management such as: aesthetic impacts (landscape analysis), archaeological and cultural heritage impacts (both tangible and non-tangible), community impacts, cultural impacts, demographic impacts, development impacts, impacts on indigenous rights, infrastructural impacts, institutional impacts, leisure and tourism impacts, political impacts, psychological impacts, resource issues (access and ownership of resources), impacts on social and human capital, and other impacts on societies.

Typically in waste decision making, the most controversial social costs are those arising from stakeholder perceptions based on private costs and their distribution, conceptions or misconceptions of nuisances and impacts, acceptability of different technologies and the effectiveness or perceived effectiveness of policies (Weidema, 2007).

While reference to specialist sub fields offers a broad view of the social impacts of waste management systems, more common impacts have been summarised to include (Wassermann *et al*, 2005):

- Odour;
- Noise;
- Visual Impact;
- Convenience;
- Complexity;
- Urban space;
- Private Space;
- Traffic;
- Risk Perception;
- Final destination;
- Distribution and Location;
- Employment Quality; and
- Employment Quantity.

A streamlined social assessment scoring method is provided in Table 6 to assist decision-making.

Table 6 Social Performance – Streamlined Assessment

Aspect		Objective	Evaluation Criteria (Scoring)
2	**Social**		
2.1	Consistency with the National Waste Policy	Fosters the goals and objectives of National Waste Policy	5. Directly achieves the Policy's stated waste management goals and objectives
			4. Directly achieves Policy's waste management goals and objectives
			3. Indirectly supports the Policy's waste management goals and objectives
			2. Has no impact on the Policy's waste management goals and objectives
			1. Contravenes the Policy's waste management goals and objectives

2.2	Deliver innovation based on sound science.	Develop Innovation platform to drive and guide the development of novel technologies to new businesses and emerging infrastructure needs.	5. Technology innovation is based on the application of novel technologies applied to emerging practice 4. Technology innovation based on novel technologies applied within the same models of waste management operation 3. Innovation based on incremental technological applications to emerging infrastructure needs 2. Innovation based on incremental technological applications to existing infrastructure. 1. No innovation
2.3	Employment Opportunities	Increased employment opportunities for skilled and unskilled local labour - construction and operation including multiplier industries.	5. 20+ new construction jobs and 20+ new operational jobs or labour intensity spanning multiple sectors compared with alternative management. 4. 10-20 new construction jobs and 10-20 new operational jobs or labour intensity within the nominated sectors compared with alternative management. 3. 1-10 new construction jobs and 1-10 new operational jobs or significantly more labour intensive than alternatives 2. 1-10 new jobs (construction and/or operational). 1. No new construction or operational jobs
2.4	Community Acceptance	High level of community support for the proposed project including perceived and real nuisances and convenience levels.	5. High level of community support (regional level) 4. Low level of community support (local level / special interest groups) 3. Community acceptance (neutral) 2. Low level of public objection (local level / special interest groups) 1. High level of public objection (regional level)
2.5	Quality of People's Living Environment	Quality of people's living environment is enhanced (highly linked to perception)	5. Positive impact on visual amenity, air quality, odour, traffic 4. No impact on visual amenity, air quality, odour, traffic, or residential/community land acquisition 3 .Low level of impact on visual amenity, air quality, odour, traffic or residential/community land acquisition 2. Moderate level of impact on visual amenity, air quality, odour, traffic or residential/community land acquisition 1. High level of impact on visual amenity, air quality, odour, traffic or residential/community land acquisition

3.6.6 Technical Performance Assessment

The technical or operational performance of a waste technology is highly specific to the waste or material under treatment, the performance characteristics of the system and the performance requirements of the end product. Features of the waste management system that may contribute to greater certainty regarding technical performance have been assessed (Resource NSW, 1999; NSW EPA, 2002; European Commission, 2007, DECC, 2008; Gold Coast City Council, 2009) to include:

3.6.6.1 The demonstrated operational reliability of the technology

The operational reliability is influenced by the facility concept and the selected equipment and configuration. Contributing factors include: the experience of technology suppliers as well as the range of potential equipment breakdowns and their consequences on the overall facility operation.

One aspect of known operational experience is measured as 'availability', - the actual operating time over a year for a facility against the scheduled operating time (NSW EPA, 2002).

3.6.6.2 Flexibility to handle different streams and materials

- Capacity to accept both municipal and commercial waste; and
- Capacity to accept waste unlike that from municipal sources

3.6.6.3 Flexibility Regarding Feedstock Material

The range of suitable feedstock materials can be evaluated with examination of the following indicators:

- Experience available regarding feedstock material variation in existing facilities (past and current);
- Technology limitations concerning moisture content;
- Ability to influence decomposition rates and output/product qualities;
- Required amounts of additives to adjust feedstock properties to suit process conditions or required cleansing and beneficiation and potential effects on cost efficiency.

3.6.6.4 Modularity and extension services

- Capacity for modular extension to take account for potential increases in feedstock; and
- Capacity to shutdown and start up for short-term facility shutdown or failure or for routine maintenance.

3.6.6.5 Process Control

This assessment compares the extent to which the process can be controlled to cater for variations in waste input quality and quantity, extent of controls to manage the decomposition process and environmental emissions, and to manage the output product quality.

3.6.6.6 Staff Requirements

Number of staff and required qualifications are an indicator of facility operating costs and likelihood of success. High-tech facilities require higher staff qualification for process control, maintenance work and risk management.

3.6.6.7 Area Requirements

Area requirements for biological processes as well as for additional infrastructure such as waste water treatment and energy recovery facilities.

3.6.6.8 Efficiency in delivering on waste reduction targets

The effectiveness of the technology in reducing and stabilising (minimising the environmental releases from) process residuals that remain for disposal.

3.6.6.9 Proven Technology /reference facilities

The degree to which a technology is proven may be indicated by the number and operating history of commercial scale facilities using the technology around the world or reference facilities.

Regard may be given to the degree to which a proponent has demonstrated a commitment to continuous improvement including incorporation of best practice elements arising from technical assessment.

A streamlined technical assessment scoring table (Table 7) is provided to assist decision-making.

Table 7 Technical Performance – Streamlined Assessment

Criterion		Objective/Description	Evaluation Criteria (Scoring 1-5)
3	**Technical Performance**		
3.1	Proven Technology	Proven and reliable operation for the waste stream / material under consideration (low operational and investment risk)	5. Used successfully at commercial scale in Australia for many years 4. Used successfully at commercial scale internationally for many years 3. Used successfully at commercial scale in Australia or internationally for 1-2 years 2. Successful operation of pilot plant in Australia or internationally 1. Concept or operation of experimental plant in Australia or internationally
3.2	Process Control Requirements	A system with low process control requirements. For example, thermal processes have high PC while more robust processes such as landfill and composting do not. Further, a bioreactor landfill has a higher process control requirement than conventional landfills. More elaborate process control requirements introduce risk and maintenance loads.	5.Low process control requirements relative to throughput with automated monitoring 4.Low process control requirements relative to throughput no automation of monitoring 3. Medium process control requirements relative to throughput. 2. High process control requirements with automated and integrated monitoring. 1. High process control requirements relative to throughput.
3.3	Input Quality Flexibility	A system that can readily handle changes in waste stream characteristics over time.	5. Can readily process the nominated materials/waste streams with current or projected contamination rates. 4. Can readily process the bulk of the nominated materials/waste streams and can be easily adapted to process the bulk of MSW and can be adapted to process some C&I waste with moderate additional expenditure 2. Can process a portion of the MSW stream (eg separated organics) and can take some input of C&I waste with little additional expenditure 1. Can process only a single waste stream (eg separated organics) and can not accept C&I waste

3.4	Feedstock Quantity Flexibility	A system that can readily handle increases or decreases in waste quantities over time	5. Able to handle large variations in waste input quantity with little additional expenditure 4. Able to handle moderate variations in waste input quantity with little additional expenditure 3. Able to handle moderate variation in waste input quantity with moderate additional expenditure 2. Able to handle moderate variation in waste input quantity with significant additional expenditure 1. Unable to handle variation in waste input quantity
3.5	Modularity	A system that can be readily modulated	5. System can be modulated and effectively achieves economy of scale, capital cost and risk reduced 4. System can be modulated, economy of scale not reached however capital cost and risks are reduced 3. System can be modulated at moderate additional expenditure 2. System can be modulated at high additional expenditure 1. No modulation, high capital cost, no reduction in risk.

3.6.7 Environmental Performance Assessment

In accordance with the ESD Guiding Principles, it has been suggested that waste management strategies must be designed to reduce the net flow of materials and energy associated with the entire waste management system if these efforts are to translate into reduced environmental impacts and prove to be cost effective.

In order to measure if waste management systems reduce the net flow of materials and energy associated with the entire waste management system, Environmental assessment of waste management options should be based on an understanding of the physical system that characterises the waste stream or material management option, as well as all significant changes associated with the management option (from a cradle-to-cradle, cradle-to-grave or life cycle perspective).

3.6.7.1 Available Assessment Methods

Materials accounting approaches that may be used to define the physical waste system are based on the techniques of mass balance and input-output assessment. Depending on nature of the decision and the system boundary of the study, materials accounting methods employed to undertake this work include:

- Life Cycle Inventory Analysis and input/output analysis;
- Substance Flow Analysis /Material Flux Analysis;
- Footprinting;
- LCA, Environmental CBA/ Full Cost Pricing;
- Materials Intensity per Unit Service;
- Greenhouse gas assessment (this equates to a scope-limited LCA); and
- Energy balance and entropy indicators (this equates to a scope-limited LCA).

Further, if enough is known about the fate of materials through a treatment option, then elemental composition analysis may be sufficient on its own to assess the environmental performance of processing options.

3.6.7.2 Recommended Assessment Method

The recommended method for environmental assessment of waste management options is Life Cycle Assessment. In Australia, LCA has been used to assess the environmental performance of national and state based waste management options for more than 10 years. Similarly in Europe, it is generally accepted that LCA concepts and techniques provide solid waste planners and decision makers with an excellent framework to evaluate MSW management strategies (Obersteiner, 2007).

The LCA approach recommended for the environmental assessment requires the decision maker to conduct or oversee the development of life cycle inventory data. This may be requested from the waste industry, LCA software providers or waste management assessment models. Data should be collected in accordance with a data collection protocols and may need to be peer reviewed and independently validated. After inventory data is complete, impact assessment is performed. Categories used to conduct this vary. Multicriteria analysis and economic valuation or CBA is recommended.

3.6.7.3 Assessment Method

The Assessment Method is summarised below and more information is provided in Appendix A.

1. Physical system defined in an inventory

   The recommended approach for identifying physical data flows in an inventory is life cycle inventory analysis. Other materials accounting tools may be used to develop inventory data as long as a system-based approached is used and data sets are gathered for the physical system in terms of material and energy inputs and pollutant outputs.

2. Inventory data assessed for impact categories of:

   - Global Warming Potential (CO_2-e); Measured in accordance with a life cycle framework and national greenhouse energy and reporting guidelines, NGERS (DEC, 2008)
   - Water Use (fresh water delivered kL)
   - Air Toxicity (critical volume Nm^3 - measured as the critical volume of air required to dilute pollutant loads to regulatory standards using National Ambient Air Quality, National Environmental Protection Measure (NEPC, 2000) and the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (DEC, 2005).
   - Water Toxicity (critical volume Nm^3- measured as the critical volume of water required to dilute pollutant loads to regulated limits using *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000)
   - Solid Waste – amounts to landfill (m^3)

3. Optional data interpretation by normalisation of data or economic valuation

4. Relative ranking of assessment options or economic valuation.

3.6.7.4 Environmental Performance Assessment Tables

The following tables (Table 8, Table 9, Table 10, Table 11 and Table 12) provide energy benefits, water and greenhouse gas emissions savings for various material types from recycling.

Table 8 Energy benefits from recycling

Material	Energy benefit from recycling (kWh/t)[30]	Source
Aluminum cans	47.5	DECC, 2007
Steel cans	9.1	DECC, 2007
Copper wire	22.9	USEPA, 2006
Glass	1.1	DECC, 2007
HDPE	13.0	DECC, 2007
LDPE	15.6	USEPA, 2006
PET	13.8	DECC, 2007
Corrugated cardboard	7.6	DECC, 2007
Magazines/third-class mail	0.2	USEPA, 2006
Newspaper	4.2	DECC, 2007
Office paper	5.9	DECC, 2007
Phonebooks	3.2	USEPA, 2006
Textbooks	0.1	USEPA, 2006
Timber	2.0	DECC, 2007
Medium-density fiberboard	0.2	USEPA, 2006
Food Discards	0.2	USEPA, 2006
Yard Trimmings	0.2	USEPA, 2006
Mixed Paper		
Broad Definition	7.4	DECC, 2007
Residential Definition	6.4	USEPA, 2006
Office Paper Definition	5.9	DECC, 2007
Mixed metal	20.8	USEPA, 2006
Mixed plastics	14.6	USEPA, 2006
Mixed recyclables	4.7	USEPA, 2006
Mixed organics	-0.2	USEPA, 2006
Carpet	29.3	USEPA, 2006

[30] Numbers are based on different LCA methods and take into account different assumptions. They should be considered indicative only.

Material	Energy benefit from recycling (kWh/t)[30]	Source
Personal computers	0.1	DECC, 2007
Concrete	0.03	USEPA, 2006
Fly ash	1.3	USEPA, 2006
Tires	14.4	USEPA, 2006
Televisions	0.1	DECC, 2007

Table 9 Water and greenhouse gas emissions savings from recycling

Material	Recycling water savings		Recycling greenhouse gas emissions savings	
	kL/tonne[31]	Source	tCO_2-e/t	Source
Aluminum Cans	233.2	DECC, 2007	15.18	DECC, 2007
Steel Cans	1.1	DECC, 2007	0.81	DECC, 2007
Glass	2	DECC, 2007	0.33	DECC, 2007
HDPE	-10.4	DECC, 2007	0.49	DECC, 2007
PET	-12.1	DECC, 2007	1.43	DECC, 2007
Corrugated Cardboard	30.66	DECC, 2007	1.29	DECC, 2007
Newspaper	21.08	DECC, 2007	0.57	DECC, 2007
Office Paper	15.58	DECC, 2007	1.54	DECC, 2007
Timber	0.07	DECC, 2007	0.15	DECC, 2007
Personal Computers	0.28	DECC, 2007	0.04	DECC, 2007
Clay Bricks	1.88	DECC, 2007	0.01	DECC, 2007
Televisions	0.46	DECC, 2007	0.2	DECC, 2007
Lead	47.5	Mudd, 2009		
Silver	47.5	Mudd, 2009		
Zinc	47.5	Mudd, 2009		

Table 10 shows the energy benefits associated with source reduction of various material types.

[31] Numbers are based on different LCA methods and take into account different assumptions. They should be considered indicative only.

Table 10 Energy benefits from source reduction

Material	Energy benefit from source reduction (kWh/t)	Source
Aluminum Cans	77,119	USEPA, 2006
Steel Cans	11,780	USEPA, 2006
Copper Wire	39,805	USEPA, 2006
Glass	2,612	USEPA, 2006
HDPE	22,673	USEPA, 2006
LDPE	24,794	USEPA, 2006
PET	23,473	USEPA, 2006
Corrugated Cardboard	8,639	USEPA, 2006
Magazines/Third-class Mail	10,734	USEPA, 2006
Newspaper	13,133	USEPA, 2006
Office Paper	12,032	USEPA, 2006
Phonebooks	12,871	USEPA, 2006
Textbooks	11,406	USEPA, 2006
Dimensional Lumber	1,140	USEPA, 2006
Medium-density Fiberboard	3,716	USEPA, 2006
Mixed Paper		
Broad Definition	10,415	USEPA, 2006
Residential Definition	10,415	USEPA, 2006
Office Paper Definition	23,709	USEPA, 2006
Carpet	29,397	USEPA, 2006
Personal Computers	308,868	USEPA, 2006
Clay Bricks	1,656	USEPA, 2006
Fly Ash	1,540	USEPA, 2006
Tyres	28,464	USEPA, 2006

Table 11 Greenhouse gas emissions

Waste stream			Source waste stream options	Greenhouse emissions (tCO_2-e/t) [32]	Source
Residual MSW	MBT		MBT Aerobic	-0.05	
Residual MSW	MBT		MBT Anaerobic	-0.104	AEA, 2002
Residual MSW	Disposal		Eng. Landfill	-0.1-1.0	
Residual MSW	Disposal			0.98	USEPA, 2006
Residual MSW	Disposal		Bioreactor landfill	-0.1-1.0	
Residual MSW	Disposal		Stabilised/inert landfill	-0.25	
Residual MSW	Disposal		Ash landfill	-0.25	
Residual MSW	Thermal processing	Mass burn	Excludes biogenic carbon, based on US energy mix	-0.08	USEPA, 2006
Residual MSW	Thermal processing	Mass burn	No energy recovery	0.181	AEA, 2002
Residual MSW	Thermal processing	Mass burn	Energy recovery as electricity (with metals recovery), assume coal fired	-0.225	AEA, 2002
Residual MSW	Thermal processing	Mass burn	Energy recovery as electricity (with metals recovery), assume wind power	0.177	AEA, 2002
Residual MSW	Thermal processing	RDF	Excludes biogenic carbon, based on US energy mix	-0.04	USEPA, 2006
Residual MSW	Thermal processing	Gasification	Energy recovery as electricity, assume coal fired	-0.195	AEA, 2002
Residual MSW	Thermal processing	Gasification	Energy recovery as electricity, assume wind power	0.163	AEA, 2002
Source separated organics	Composting		Includes transport and sequestration	-0.2	USEPA, 2006
Source separated organics	Composting		Includes transport and sequestration and avoided product credit	-0.41	Calculated. Incorporated DEC, 2008 process default with life cycle based emissions including process energy, sequestration, avoided product credits for peat substitution. Avoided Landfill excluded.

[32] Numbers are based on different LCA methods and take into account different assumptions. They should be considered indicative only.

Note: Data published prior to NGERS guidelines mean that directly referenced values may include outdated carbon accounting approaches such as including biogenic emissions. Indicative of performance as a more reliable would plot performance against assumptions.

Table 12 Energy balance factors

Waste stream		Source waste stream options	Energy balance (net electrical energy) (kWh/t) [33]	Source
Residual MSW	MBT treatment	MBT Aerobic	-24	Nolan ITU, 1999
		MBT Anaerobic	160	Nolan ITU, 1999
		Incineration	220-400	Nolan ITU, 1999
		New Thermal	320-400	Öko-Institut, 1998, Nolan ITU, 1999
	Disposal	Eng. Landfill	233	Nolan ITU, 1999
Source separated organics	Composting	Open	-10	Nolan ITU, 1999
		Enclosed	-24	Nolan ITU, 1999

3.6.7.5 Environmental priority assessment Tables

Guidance on the identification of policy or funding priorities from the broad spectrum of waste streams and materials that exist is not immediately possible from published studies. Studies vary in term of the indicators that they report against, the terms of reference and functional unit of the study, goal and scope of the original study, the system boundaries, data quality etc. These variations mean that comparison of results should proceed only with regard to the study context.

Material stream priorities need to be ranked by the waste stream from which they originate as well as by the **end-product** that is recovered if they are to reflect the environmental performance variations that exist at this level.

Examples are provided in Table 13 for a material stream (office paper) and waste stream (residual MSW). To define categories in a more streamlined way would fail to capture system variables that are influential in determining the overall performance of the system.

[33] Numbers are based on different LCA methods and take into account different assumptions. They should be considered indicative only.

Table 13 Paper waste (office paper) definition - priority assessment matrix

Material stream		Technology characterisation / End product recovery options	Greenhouse benefit (tCO_2-e/t)	Water Savings (kl/t)	Energy Balance (GJ/t)
Paper waste Office paper	MSW	Cardboard/Packaging fibre	1.13	30	27
		Tissue			
		Recycled office paper	1.54	29	21
		Newsprint	0.57	21	15
		Compost	0.24	37	.09
	C & I	Fuel (mass burn combustion) to gasification	-0.078		3.8
		Landfill	-2.5		1.4
		Stabilate for landfill	-0.25		
		Stabilate for RDF or energy recovery			3.2

Note: The absence of a toxicity assessment has the potential to bias the results as a measure of sustainability. For waste treatment, toxicity impact is one of the most significant impact categories (NPCC, 2001, ERV 3003). For example, LCA data reveals the toxicity impact savings from recycling paper into recycled office paper is notably higher than for other grades due to the materials intensity of producing writing paper grades.

4. Survey of waste and resource recovery related technologies and innovations

4.1 Introduction

A survey of waste and resource recovery related technologies and innovations are conducted for this study. The survey has been conducted within the strategic framework established for the project. Information has been obtained from consulting locally and overseas with industry, government and academic contacts.

The survey considered a range of possible technologies and innovations including:

- Reuse, recycling and resource recovery;
- Waste transport, collection systems and sorting;
- Best practice transfer station management (including design and operation);
- Landfill management (including design and operation);
- Management of organic wastes;
- Alternative waste treatment; and
- Waste to energy;

The wastes and material types to be assessed, and the technologies assessed are summarised in Table 14.

Table 14 Technology types to be assessed - Mixed waste streams

Stream	Technology Type				
	Mechanical separation	**Biological**	**Thermal**	**Chemical**	**Other**
MSW	Improved sorting techniques	Anaerobic and aerobic digestion, composting, biofuel production, bioreactor landfill	Pyrolysis, gasification, plasma arc, incineration, autoclaving, fuel production (RDF)	Hydrolysis	Irradiation
C&I	Improved sorting techniques	Anaerobic and aerobic digestion, composting, biofuel production, bioreactor landfill	Pyrolysis, gasification, plasma arc, incineration, autoclaving, fuel production (RDF)	Hydrolysis	
C&D	Improved sorting techniques		Fuel production (RDF)		
Kerbside recyclables	Optical sorting				
Mixed plastics	Optical sorting		Fuel production (RDF)	Pyrolysis and plasma arc	
Timber		Biochar	Biochar		Radiation
Concrete	Improved sorting techniques				

Stream	Technology Type				
	Mechanical separation	**Biological**	**Thermal**	**Chemical**	**Other**
Paper and cardboard	Improved sorting techniques and reprocessing to same plastics	Anaerobic digestion, composting	Fuel production (RDF)	Pyrolysis	
Liquid paperboard	Improved separation of components	Anaerobic digestion, composting	Fuel production (RDF)	Pyrolysis	
Food organics	Dry processes (Trommels) and wet processes	Anaerobic digestion, composting			
Garden organics	Shredding and final screening	Composting	Biochar	Pyrolysis	
Glass	Optical sorting for improved recovery and re-use applications				
Rigid plastics	Reprocessing into same or other plastic products	Conversion to polyhydroxyalkanoates	Fuel production (RDF)	Depolymerisation to fuels	
Plastic films	Reprocessing		Fuel production (RDF)	Depolymerisation to fuels	
Textiles	Reprocessing into other cloth		Fuel production (RDF)	Tyre components	
Carpets	Reprocessing into other carpets	Fertiliser			
Mixed recyclables	Near infrared and other identification and separation techniques				
Electronic waste	Automated disassembly and handling, reprocessing of components		Pyrolysis	Extract metals by supercritical water oxidation process	Extract metals by electrokinetic process
Treated Timber	X-Ray fluorescence and laser sorting	Bioremediation	Plasma arc, pyrolysis, combustion with other fuels	Extraction using bioxalate solution	New wood composites, electrodialytic remediation
Tyres	Crumbing, civil engineering uses		Fuel production (RDF), steam gasification, gas phase halogenation, pyrolysis	Devulcanisation, plasma, fuel production, continuous reductive distillation,	Microwave, high pressure water
Fluorescent light bulbs and tubes	Batch crushing and separation, dense medium centrifugation		Thermal retort, thermal desorption		

Stream	Technology Type				
	Mechanical separation	Biological	Thermal	Chemical	Other
Dry cell batteries	Handling and disassembly systems, super cooling and shredding			Neutralised electrolytes, hydrometallurgy	Magnetic separation
Wet cell batteries	Handling and disassembly systems, crushing and screening		Refining and smelting	Electrolytes filtering, paste desulphurisation, leaching	
Hazardous waste	Big Oversized Blender	Bioremediation, phytoremediation	Molten metal catalytic extraction, plasma arc	Molten metal catalytic extraction	
Building waste	Dry separation sorting				In-place recycling

4.2 International trends

4.2.1 Why have particular technologies been selected overseas?

Technology is currently available to deal with most waste materials and convert them to useful materials, energy, or to detoxify them so they can go to landfill. There are a variety of reasons why such technology might be used in one place, and not another. Often they relate to regulatory or cost drivers, or absolute shortages of landfill space but other influencing factors include institutionalised inertia or cultural reasons[34], rather than a desire to embrace new technology for its own sake.

4.2.1.1 Germany

In Germany, the high diversion from landfill is a result of a combination of advanced collection systems and technologies, which have been put in place because of the German TASi regulation.

This regulation requires all waste to be treated prior to landfilling, and for high calorific waste to be extracted for energy production, and biologically active waste to be stabilised for landfill disposal. Agricultural use of the composted or digested materials from mixed waste processing is not permitted by law.

In this case, the technology selection is a function of the technical requirements, more than any other factor. When the TASi regulation was introduced, incineration technology was widely adopted as it would most easily meet the criteria. However, there was a community backlash against incineration, and as a result, MBT (mechanical biological treatment) was promoted as an alternative. Thus there are now about 76 MBT plants in Germany. Many anaerobic digestion plants exist because of the energy benefits of such plants (they are net energy exporters and there are schemes in place that provide financial incentives to generate electricity from renewable sources).

[34] Some cultures are uncomfortable with practices where human waste is handled or mixed with other material no matter how hygienically safe.

4.2.1.2 France

In France there is a different view about the material produced by composting. The French believe that the material produced from mixed waste composting can be refined to the extent that it is suitable for use in agriculture. Hence there are many plants that use rotating drums to do the initial bag opening and sorting of the waste, then compost and refine the residual materials.

4.2.1.3 UK

In the UK, the view of the authorities is that compost from mixed waste plants should not be used for agricultural purposes, and this has guided the technology selection accordingly.

England's household recycling rate was just 10% 1999-2000, one of the lowest in Europe. To deal with this, the National Waste Minimisation and Recycling Fund (NWMRF) was established to assist recycling and waste initiatives through local authorities and help them deliver their legal obligations to increase recycling. It was hoped that this approach would both reduce waste generation and break reliance on landfill as a disposal method.

In 2002 local councils in England (not including London Councils) submitted bids to the Department of Environment, Food and Rural Affairs (DEFRA) for a share of the fund to help them meet their targets for 2003-2004 and 2005-2006. A proportion of the fund, known as the London Recycling Fund (LRF), had already been quarantined for London councils. The LRF was distributed for the same strategic objectives as the rest of the NWMRF and its allocation administered jointly by the Greater London Authority, the Association of London Government and London Waste Action.

More recently the LRF has been decoupled from the NWMRF, renamed the London Waste and Recycling Fund and will be administered by a new London Waste and Recycling Board.

The fund, at £140 million (approximately A$288 million), was not big enough to distribute equally among all 400 local authorities so a challenge approach over three rounds was adopted and priority given to areas where a large turnaround in performance was needed. Bids for funding were judged by an expert panel and some grants had conditions attached, such as spending or facility operation deadlines.

In the first round, £42.4m (approximately A$87 million) was allocated to councils outside London and £7.6m (approximately A$15.6 million) to London authorities. Almost half the funding (47%) was allocated to turnaround low performers (many by extending kerbside and household recycling and green waste collections), 30% to partnership projects, with the balance split among high performance, innovation and best practice, general projects and developing community initiatives. Subsequent rounds distributed £76.3 (approximately A$157 million) million and £135m (approximately A$277 million).

The partnership projects referred to above were projects in involving more than one local authority, such as council groups co-operating in a joint kerbside collection and processing system. These Partnership Projects were eligible for up to £5m (approximately A$10.2 million) each of funding.

Other sources of Local Authority Funding include the Waste Infrastructure Capital Grant which is also administered by DEFRA. This is an 'un-ringfenced' capital grant, that's is, it has no conditions or strings attached, and will be paid to local authorities in recognition of the need to get front-end waste infrastructure, operational in time to help England meet landfill targets imposed by the European Landfill Directive.

4.2.2 Separated Organics

4.2.2.1 Supermarket food wastes

The major supermarket retailers have in place a range of initiatives to minimise waste to landfill from their operations. Generally they are well advanced in diversion of cardboard from landfill however, the level of diversion of organic waste is still lacking. Innovations in packaging have extended the shelf life of some food products but there is also growing interest diverting food organics from landfill to composting or alternative waste treatment facilities.

This is largely in the trial phase at this time and/or is subject to availability of facilities. For example, 53 Woolworths stores in Sydney send source separated food waste to a facility that processes the material into compost, fertiliser and electricity. The lack of such facilities outside Sydney and Melbourne and long lead-times for new facility development is a barrier to expanding this program.

4.2.2.2 Small Scale Organics Processing

- **Bio Bins**[35] is a new small-scale organics processing system that consist of in-vessel composting bins of 4.5-m^3 or 9-m^3 capacity that are used to collect putrescible organic waste and turn them into more stable, more useful, disease free by-products. The bin is made of steel and includes a blower, to provide adequate aeration of the waste, preserving aerobic condition for the material's decomposition, and a biofilter containing organic compost and woody material for controlling leachate waste. The organic waste is stored into the bin for seven days until the waste is stabilised. In most cases when the bins are full they are taken to an organics composter, emptied and returned to the site. Each unit consumes some electricity to run the blower, however, it is a single-phase engine that works on the AC power current. The engine can be plugged into a standard household power socket. BioBins have been used in permanent situations such as at Flinders University and for temporary applications such as at the Moomba Festival in Melbourne and at Womad in Adelaide. Both McDonalds and Coles have conducted trials. Figure 2 shows some examples of Bio Bins.

[35] BioBin - http://www.biobin.net/

A 9m³ BioBin

Inside a 4.5m³ BioBin

A 4.5m³ BioBin being transported

Figure 2 Examples of BioBins

- **Hot-Rot** is a New Zealand technology that processes small to medium scale quantities of organic waste in highly controlled, continuous flow, agitated composting units. The technology consists of enclosed drums in which rotating paddles mixed and move organic waste placed in one end to the other end where it is removed as compost. Quantities as little as 400 kg (two or three 240 litre wheelie bins per day up to 8-11 tonnes per day of material can be processed through off the shelf units. Large quantities require a tailored solution. Typical applications include universities (a unit is in operation at the Australian National University in Canberra), shopping centres and sewage treatment works.
- **Vermiculture** or vermicomposting refers to the breakdown of organic material that, in contrast to microbial composting, involves the joint action of different species of earthworms and micro-organisms and does not involve a thermophilic (that is, high heat) stage. As the agents of turning, fragmentation and aeration, the worms consume organic wastes such as food waste, animal waste, greens and sewage sludge to produce a soil conditioner. Vermiculture systems are a simple technology, particularly when compared with in-vessel composting technologies, and are suitable for processing a much smaller range of food organic material (primarily fruit and vegetable scraps). They also require specialised management to achieve successful and consistent processing performance. The 'mid-scale' technologies and systems have processing capacities between 20 and 250 kg (fresh weight) per day (over a seven day week). Batch-flow (or box systems) units are a simple design and suitable for small-scale vermiculture applications. They require very little initial capital expenditure and can be popular for this reason. Continuous flow systems are considered to be the high-tech options

for vermiculture. More sophisticated mid-scale vermiculture systems recirculate leachate back on top of the bedding. Figure 3 shows an example of a continuous-flow vermiculture unit.

Figure 3 Examples of continuous-flow vermiculture unit

- **In-vessel composting units** are generally made up of an insulated, reinforced plastic, fibre glass or stainless steel vessel with a capacity in the range of 1-3 m3. The majority of off-the-shelf systems are batch-flow type units – where materials are loaded into the top of the vessel, and pasteurised materials are harvested from a grate on the bottom of the unit. A motorised auger is sometimes provided to mechanically mix the compostable organic material and assist in size reduction. The major advantage of in-vessel composting system is that the key parameters affecting the rate of composting can be controlled and optimised.

  In addition, the odour control units allow the systems to be stored in locations closer to people. Batch-flow units do require at least two units to be installed on-site to deal with a continuous organics feedstock. Figure 4 shows two different styles of induced aeration in-vessel batch-flow composting units. The in-vessel composting units are tolerant of a wider range of feedstocks than vermiculture systems, but still require specialised management to ensure consistent processing performance.

Figure 4 On-site in vessel composting units

4.3 Mixed Waste Technologies and Innovations

Broadly termed Alternative Waste Technology (AWT), technologies for processing mixed waste generally concentrate on separating and treating the organic (often the food) fraction. With recyclables and green waste commonly removed from the domestic waste stream, the largest remaining proportion is food waste. Concerns about greenhouse gas emissions and the rising costs of building and operating modern landfills, has pushed the development of AWT facilities which can process waste streams with high levels of putrescible content.

4.3.1 Definition of AWT

There is more than one definition of the term ‘AWT’. The expression itself is reported as Alternative Waste Technology, Advanced Waste Technology,[36] Alternate Waste Treatment Technologies[37] and Advanced Waste Treatment.[38]

AWT commonly refers to any technology that is applied to mixed waste other than traditional methods such as disposal to landfill. Separate green waste processing is now so prevalent that it is not considered an alternative processing technology. AWT is more specifically ‘a combination of mechanical, biological and in some cases thermal processes to recover resource value from mixed municipal waste.’[39]

AWT covers a multitude of processes. Those known in Australia include:

- Mechanical biological treatment – mechanical separation of waste stream components followed by biological treatment of the organic fraction;
- Anaerobic digestion – biological treatment of organic waste in the absence of oxygen;

[36] Department of Sustainability and Environment (Victoria) - Specification for Victorian Advanced Resource Recovery Initiative (VARRI) Engineering Services Advisor and Australian Council of Recyclers Submission to Department of Climate Change on the Proposed Carbon Pollution Reduction Scheme

[37] Department of Environment and Climate Change (NSW) - http://www.environment.nsw.gov.au/warr/AWT.htm

[38] SITA Environmental Solutions’ ‘SAWT’ stands for Sita Advanced Waste Treatment (AWT)

[39] Ritchie, Mike (President, Waste Management Association NSW Branch) 2008 Letter to Climate Change Group Department of Prime Minister and Cabinet dated 15 January

- Gasification – the partial oxidation of organic materials that are converted to a synthesis gas (or syngas), typically a mixture of carbon monoxide, hydrogen, carbon dioxide and methane;
- In-vessel composting – biological composting of organic waste in an enclosed container;
- Pyrolysis - the chemical decomposition of a material by heat in the absence of oxygen; and
- Tunnel composting – biological composting of organic waste in a purpose built enclosed or semi-enclosed tunnels.

It also includes technologies used elsewhere or in development, such as:

- Plasma arc waste disposal – breaking waste down into elemental gases and solid residue using high voltage, high current electricity;
- GasPlasma gasification - a hybrid plasma arc and gasification system;
- Alcohol/ethanol production – syngas from gasification is converted to ethanol[40];
- Bioconversion to alcohol fuels – the action of certain micro-organisms and enzymes converts waste to alcohol;
- Waste to energy – converting solid waste to energy by either anaerobic digestion and burning the resulting biogas, combusting waste directly as a fuel for steam generation or converting solid waste to syngas by pyrolysis or gasification which is then combusted to generate power;
- Biodrying – drying waste to produce RDF; and
- Autoclaving – steam treatment of waste to kill pathogens, separate components and recover useable materials.

4.3.2 Descriptions of AWT

AWTs are generally large scale and mostly designed to process municipal solid waste using a variety of techniques. Most ultimately produce a compost type material and some have the capacity to extract recyclable materials left in the residual waste stream. Food, and sometimes other organic waste, is processed either aerobically (with oxygen and therefore avoiding the generation of methane – a greenhouse gas) or anaerobically (without oxygen and with methane gas capture and electricity generation).

AWT facilities require significant capital investment, depending on the type and scale of the technology, along with ongoing operation and maintenance costs. For this reason, the gate fees for disposal of material at these types of facilities can be higher than the equivalent disposal fee at a landfill. As a result AWT facilities are mainly established in areas where landfilling costs are high, such as Sydney. High landfill charges make capital-intensive AWT facilities more economically viable.

Some AWT systems have MRF-like processes for separating recyclables and other materials from the incoming waste stream before organic processing. Because the separation is by mechanical means, these systems are termed Mechanical Biological Treatment (MBT) systems. The separation of these inorganic materials serves three main purposes:

- Recover recyclable materials for sale;

[40] *Turning Waste into Ethanol* (2008) Science Daily August 14 - http://www.sciencedaily.com/releases/2008/08/080813164640.htm

- Reduce levels of visible contaminants such as plastics and glass; and
- Reduce levels of chemical contaminants such as heavy metals.

The processing of separated organics produces a moderate to high quality soil conditioner, which can be used in a wide range of markets, including horticulture, viticulture and agriculture, and in specialist landscaping applications such as mine rehabilitation.

4.3.3 AWT Issues

Despite AWT facilities becoming more common in Australia, there is still a high degree of scepticism about the claims made by many technology providers about the performance of AWT facilities generally. The technical and commercial failure of technically complex plants such as the SWERF gasification plant in Wollongong (see section 4.6.2) has created a lack of trust in AWT facilities. Even plants using relatively mature technologies such as the Bedminster process have had technical issues.

Local councils are conservative by nature and therefore wary of new technologies of any type. They are inclined to select technologies that are either well proven either in Australia or overseas. As a result, there is a general lack of awareness in Australia of more than the handful of technologies that are currently used in this country. There are opportunities for European technology providers with a strong track record of many years of successful operations in Germany or other countries with a large number of operating facilities to enter the Australian market, especially if they partner with local waste companies already involved in landfilling or waste collection.

Due to issues faced by plant operators who are trying to market mixed waste compost, the likely future trend is towards energy production, rather than composting technologies. There are, therefore, likely to be more anaerobic digestion plants built to serve the major cities. In regional centres, it is more likely that food and garden waste composting plants will be adopted, because of their simplicity, lower costs and reliable local markets for high grade agricultural compost.

Because commitment to AWT is largely driven by the municipal sector, it has been difficult to direct commercial waste to AWT facilities without legal imperative. One possible solution is for operators of municipal waste facilities to ‘top up’ their plant throughputs with commercial waste.

Some facility agreements with councils already allow this, with Councils receiving royalties or a share of the profit associated with commercial customers using their facilities. Businesses with corporate sustainability objectives are interested in increasing waste diversion from landfill, and maximising their recycling achievements, so there are a number of potential customers in the market.

In Europe, a large number of the waste processing plants produce refuse derived fuels (RDF) for energy production. None of the current AWT plants in Australia do this. There are commercial reasons such as lack of markets for the material and lack of purpose-built facilities for these fuels.

As explained in section 4.6.1 there is considerable reluctance to build and operate any type of thermal waste treatment plant in Australia with concerns that dioxins and other pollutants could increase health risks to surrounding populations. Siting of such a facility would be extremely problematic. As a result it seems more likely that small-scale co-firing in cement kilns and power stations will be the main application for RDF from waste facilities in the future.

Details of the numerous groups of technologies for the treatment of mixed municipal and or commercial wastes are provided below.

4.3.4 Digestion (Anaerobic and Aerobic)

Digestion is the reduction of solid organic materials through decomposition by microbes, which results in the production of liquids and gases. The digestion process may be aerobic or anaerobic – depending on whether air (containing oxygen) is present in the process.

These processes are often conducted 'in-vessel', that is enclosed in a container or vessel. Although a simple process, in-vessel systems generally require high capital outlay for complex equipment. They have the advantage however, of a high level of control over the organic material. Other advantages include a reasonably small operational footprint and short processing time.

The in-vessel design makes exposure of the feedstock material to high temperatures for the requisite time easier to achieve, reducing the risk of producing an unacceptable product. High temperatures also kill weeds, seeds and plant pathogens, making this kind of system suitable for use in environmentally sensitive areas.

4.3.4.1 Anaerobic digestion

Anaerobic digestion is the decomposition of organic matter by microbes in the absence of oxygen. This process results in a solid by-product (digestate) and a gas (biogas). Historically, anaerobic digestion has been used extensively in the wastewater treatment industry for stabilisation of sewage sludge. It has more recently been adapted and applied to process the organic fraction of municipal and commercial wastes.

Anaerobic systems are generally more complex and more expensive than aerobic systems. They often require more space for larger digester vessels and to aerobically-mature processed material. Small plants require several thousand square metres of land.

As with the aerobic process, pre-sorting is also required to remove contaminants. Some technologies use water for separating contaminants. Heavy contaminants sink, light contaminants float and the organics are suspended in the water.

Anaerobic digestion is commonly a component of MBT technologies. These technologies generally incorporate a mechanical sorting process and a biological digestion process such as that shown in Figure 5.

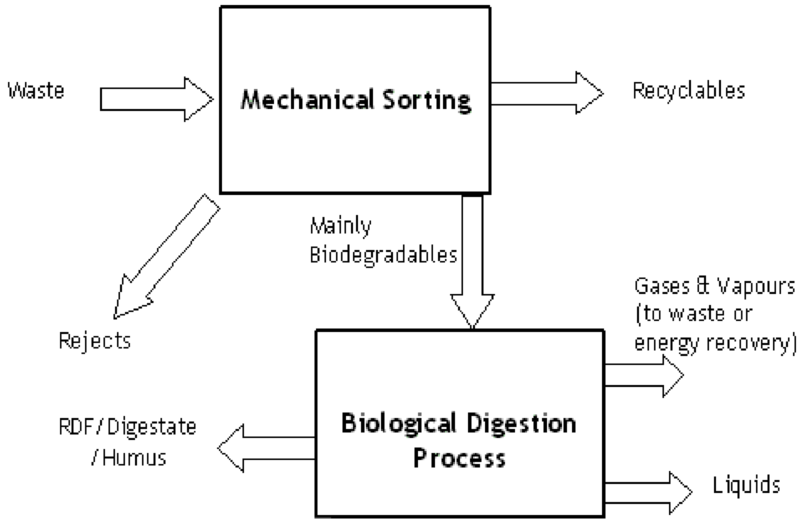

Figure 5 Typical MBT process[41]

Decontaminated feedstock is added to the digestion vessels with water. The anaerobic digestion process may be either 'wet' or 'dry', depending on the proportion of solids to liquids in the digester (reactor). Sometimes bacteria are also added to start the process. The vessel is sealed and the process allowed to take place for between 10 and 20 days. Once processing is complete, the solid digestate product is removed from the vessel and dewatered to produce solid and liquid fertiliser. Several weeks of additional aerobic processing outside the vessel may also be required. Processing is mostly done by batch although there are some continuous flow systems.

In an anaerobic process the bacteria absorb heat so less heat is generated. Heat may even need to be applied to ensure digestion. The process temperature can vary, and is generally controlled in order to promote the growth of a specific type of microbe population. Mesophilic anaerobes proliferate at temperatures in the order of 35°C and thermophilic anaerobes are dominant at temperatures around 55°C.

The process produces 'biogas' and a liquid fertiliser (digestate). The biogas produced in the anaerobic digestion process comprises mostly methane and carbon dioxide with some impurities such as moisture, H_2S, soloxane and particulate matter. Methane and carbon dioxide are both greenhouse gasses. This biogas can be burned in an internal combustion engine to generate electricity. This can be done on-site in 'co-generation' plants where the gas is used as a fuel for internal combustion engines that drive electrical generators. Some of the electricity generated can be used to run the facility and the remainder sold into the grid. Heat from the engines can also be used in drying processes. The biogas may need to be purified to certain extents depending on its use.

Biogas is a clean burning fuel, producing only carbon dioxide as a by-product. However, it has a lower calorific value compared to other fuels as shown in Table 15 below.

[41] Juniper Consultancy Services - http://www.juniper.co.uk/services/Our_services/what_is_MBT.html

Table 15 Comparative Calorific Value of Fuels

Fuel Type	MJ/kg
Coal	26-30
Natural gas	37-43
Biogas	20

Table 16 below shows the amount of electricity that may be generated from different tonnages of organics.

Table 16 Possible Electricity Generation

Tonnes of Organics	MW	Number of Homes This Could Power
77,000	2.6	2600
50,000	1.7	1700
40,000	1.4	1400

There are also other uses for biogas if it is scrubbed of carbon dioxide (such as for alternative fuels). The digestate can be beneficially reused as a soil conditioner or compost (after a period of aerobic stabilisation).

There are a number of variations and combinations of anaerobic systems including:

- Pond (lagoon) based;
- Completely mixed stirred tank;
- Anaerobic filter;
- Upflow anaerobic sludge blanket;
- Upflow fluidised bed;
- Dry continuous digestion;
- Dry batch digestion;
- Leach-bed process;
- Wet continuous digestion; and
- Multi-stage wet digestion.

Examples of technologies using anaerobic digestion are the ArrowBio, BTA, BIOCEL, and DRANCO processes.

4.3.4.2 Aerobic digestion

During aerobic digestion of municipal and commercial waste, the organic fraction is metabolised by microbes in the presence of oxygen. During aerobic digestion, temperature and pH increase and carbon dioxide and water are liberated and pathogens are destroyed. Anaerobic processes operate at much higher rates than aerobic processes, but generally do not produce useful fuel gases. The digestate can be used as compost. The aerobic digestion process may also be either ‘wet’ or ‘dry’. The Conporec, Remondis and Bedmister technologies are examples of technologies that incorporate aerobic digestion.

Digestion systems mostly require the removal of inorganic contaminants from the feedstock and most also require some size reduction. If the feedstock has a high moisture content, bulking agents such as woodchips, garden organics, sawdust or fresh made compost may need to be mixed with the food waste to improve structure and ensure efficient processing. In some cases a suitable bulking agent may be available. For example, if the facility is located at a landfill, green waste delivered by residents or the landscaping industry may be available. Green waste collected as part of a kerbside service may also be available where a service like this exists. If a suitable material is not available, it will have to be obtained at additional cost. If the feedstock is not moist enough, water will need to be added. The high moisture content of food waste makes it particularly suitable.

Viable feedstock for both systems includes wood waste, crop wastes, sewage sludge and food such as fruit and vegetable scraps, bread and pasta, meat and seafood, lawn clippings, small branches, prunings, tea bags, paper bags and paper towels, flowers and tissues.

Vessels may consist of concrete bays or tunnels which are filled with the required amount of feedstock and sealed. The climate inside the bay is controlled to manage temperature, oxygen and moisture levels, which reduces pathogens and meets the processing objectives.

Air is pushed through the composting material by a pipe system that collects and recirculates it. The material is kept moist by overhead sprays and all water flowing out of the compost is collected and recirculated or used to humidify exhaust airstreams.

Air temperature, humidity, oxygen and carbon dioxide concentration and pressure are measured and water flows and airflow changed to maintain the required conditions. In ‘non-agitated systems’ the material is left as it is without any mixing. In an ‘agitated’ system the material is turned or broken up by an auger or drum mechanism.

Figure 6 An agitated bay system showing the bay full of compost and the turner at one end

Figure 7 Agitated bay system showing bays empty of compost

Systems can generally be varied to suit particular clients, environments or situations. For example:

- The process can be set to be simple or more complex;
- Waste processing can be fully or partially automatic;
- Tunnel loading and unloading can be fully or partially automatic;
- Biofilters can be open or closed;
- Processing can be continuous or in batches;
- Different waste streams can be composted together; and
- Different quality waste streams can be processed separately.

The aerobic process produces pasteurised or composted soil conditioners or mulches. The anaerobic process produces a solid digestate. In both cases these materials, particularly those from anaerobic processing, require further maturation in piles or windrows to produce a mature stable product and especially if it has to comply with AS 4454-2003 Composts, soil conditioners and mulches.[42] The anaerobic digestate will not be pasteurised if it has not reached a sufficient temperature during the digestion process.

The final product from both processes has the following applications:

- Extensive Agriculture – Pasture farming, broadacre farming, forestry;
- Intensive Agriculture – Nurseries wholesale production, fruit and orchard growing, market gardening, cut flowers growing, mushroom farming, turf grass growing, viticulture;
- Rehabilitation – Landfill cover and rehabilitation, erosion stablisation, land reclamation, restoration, revegetation and rectification;
- Urban amenity – Landscape, local government, retail nurseries, special projects, state and territory government, sport leisure and recreation;
- Bio-fuels – Gasification, pyrolysis, power stations, ethanol, incineration, anaerobic digestion, bioreactive landfills, firewood;
- Bio-remediation – Contaminated sites and soils, water purification, biofiltration; and
- Export – Australasia and Asia.

4.3.5 Hydrolysis[43]

Hydrolysis is a chemical reaction whereby water reacts with another substance to form two or more new substances. It involves the biological or chemical partial breakdown of the complex molecules within the waste. Hydrolysis technologies for the treatment of municipal and commercial waste incorporate acid-catalysed reaction of the cellulose fraction of the waste (e.g. paper, food waste and garden organics) with water to produce sugars and is normally only used in conjunction with other methods. Interest is growing however, in the potential of this technology to produce alternative fuels such as bio-oil, bio-diesel

[42] This standard specifies the physical and chemical requirements for composts, soil conditioners, mulches and vermicast (the product of worm farms) that need to be met before a product can be labelled as a composted or pasteurised product. It also specifies the health warnings and other information to be supplied to the consumer. Guidance is also given on best practice for composting and vermicast systems designed to produce a quality product achieved by following an approved process.

[43] Juniper Consultancy Services - www.juniper.co.uk

and ethanol from wastes. The CES OxyNol plant is a good example and has been operating in the US since 1987.[44]

4.3.6 Autoclaving

In autoclaving, waste is sealed in an autoclave and treated with steam at 140-160°C. The process kills pathogens, can be used to separate various components (such as metals, plastics, glass, organic fibre etc) and recover various useable portions of the incoming waste stream. Some of the wastes can be recovered for aggregate material – such as the glass and grit. The organic fraction could have a number of uses depending on the quality of the material and the markets available. It may be suitable for land-spreading, making into a fibre to be used in the construction industry, or made into refuse derived fuel. Residual material from the process is sent to landfill. Autoclaving has been used extensively for clinical or medical waste, but only in pilot stage of development for use with municipal or similar wastes. One such example of autoclaving technology is the Vantage Waste Processor system.[45,46]

4.3.7 Irradiation[47]

This experimental technology involves the high energy destruction of waste and encompasses many types of systems such as microwave, ultraviolet light and ultrasound.

4.3.8 Waste to Biofuel

At the pilot/testing stage is a bioreactor process that uses microorganisms to create ethanol from waste developed by US-based Coskata Inc which in 2008 entered into a program with General Motors to develop the fuel on test vehicles.[48]

4.3.9 Microwave Technology

New Zealand company Carbonscape uses industrial microwave technology to convert wood and other biomass to biochar. Each industrial microwave unit converts 40–50% of wood debris into charcoal, which can be added to soils.

4.3.10 Bioreactor Landfills[49]

A bioreactor landfill is a conventional sanitary landfill that uses enhanced microbiological processes to transform and stabilise the readily and moderately decomposable organic waste constituents more quickly than a conventional landfill. The most significant element of a bioreactor landfill is the addition and recirculation of water (as leachate) through the accumulated waste. Other management strategies include waste shredding, pH adjustment, nutrient addition and temperature management. This process

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[44] Masada Resources Group - http://masadaonline.com/_wsn/page2.html

[45] Friends of the Earth New Technologies – what they are and what we think - http://www.foe.co.uk/resource/briefing_notes/acronyms_for_waste_technol.pdf

[46] Reclaim Resources Limited - http://www.reclaimresources.com/index.html

[47] Juniper Consultancy Services - www.juniper.co.uk

[48] *GM and Coskata to develop fuel from waste* (2008) Waste Management World January 21 - http://www.waste-management-world.com/display_article/317661/123/ARTCL/none/WTENE/1/GM-and-Coskata-to-develop-fuel-from-waste/

[49] Pacey, J., Augenstein D., Morck.R., Reinhart, D. and R Yazdani (1996) The Bioreactor - An Innovation in Solid Waste Management EMCOV, San Mateo, CA http://www.swana.org/pdf/swana_pdf_295.pdf

speeds up microbiological activity, hence waste decomposition, and gas generation providing the advantages of a significantly shorter decomposition process, rapid settlement and stabilisation of the site, better leachate processing and control and better energy recovery through gas capture.

There are three types of bioreactor landfills:

- Aerobic - leachate is removed from the bottom layer, piped to storage tanks, and re-circulated into the landfill in a controlled manner. Air is injected into the waste mass, using vertical or horizontal wells, to promote aerobic activity and accelerate waste stabilisation;
- Anaerobic - moisture is added to the waste mass in the form of re-circulated leachate and other sources to obtain optimal moisture levels. Biodegradation occurs in the absence of oxygen (anaerobically) and primarily methane, can be captured to minimise greenhouse gas emissions and for energy projects; and
- Hybrid (Aerobic-Anaerobic) - employing a sequential aerobic-anaerobic treatment to rapidly degrade organics in the upper sections of the landfill and collect gas from lower sections. Operation as a hybrid results in the earlier onset of methanogenesis compared to aerobic landfill.

Because the nature and density of the waste is a critical element in the management and success of a bioreactor landfill, it is not a technology that is easily applied to existing landfills. The way waste has been deposited at existing landfills does not normally allow water to contact and move uniformly through it. As a result injection and drainage systems become fouled and large volume of leachate are required for flushing. This in turn requires treatment and disposal.

Bioreactor landfills do not recover or recycle any materials but the accelerated biological activity produces a greater quantity of gas more quickly which can be used for electricity generation. There are two bioreactor landfills in Queensland, the Ti Tree facility operated by Veolia, and the Swanbank facility operated by Thiess, and one in NSW, the Woodlawn Facility near Goulburn operated by Veolia.

4.3.11 Baled Waste Landfills

As the name suggests, a baled waste landfill accepts waste material that has been compressed and wrapped either with wire or in plastic film. The baling process increases waste density from typically less than 0.2 tonne/m^3 up to 0.75 – 1.0 tonne/m^3 reducing truck movements and making transport more cost effective. It also assists in the control of leachate, litter, and odour during transport and landfilling as well as reducing access to the waste by insects and vermin.

Other advantages include the ability to temporarily store bales outside (subject to licensing approval) if, for example, immediate transfer off site is not possible. Specialised handling equipment and transport vehicles are not required as bales can be moved by forklift and transported on either conventional flat-bed trucks or in open trucks and dog trailers.

Figure 8 Stored bales of waste

Figure 9 Bales of waste loaded into a truck

When bales of waste are delivered to the landfill they are unloaded from the transfer trucks using a loader with a specially modified clamp. Once unloaded, the bales are placed progressively in the landfill cell in a brick-like pattern with an excavator or forklift. Cover is applied at the end of each day, on compromised bales and on unbaled waste. Normal leachate collection systems are used.

There are four baled landfill operations currently in Australia. Two are in South Australia. Baled waste is transported by IWS from its Wingfield baling plant to its Dublin landfill, after being enclosed in large plastic sacks. The Northern Regional Waste Management Authority (NRWMA), operates a baling plant at Elizabeth West, and a baled waste landfill at Uleybury.

Two other baled landfills are operating in NSW. At Moree, a baling plant was established on the site of the existing landfill avoid the need for a compactor at the landfill and to increase resource recovery opportunities. At Ballina, the baling plant is also at the existing landfill, as was established to avoid bird strike at the nearby airport. A baled landfill is also proposed for Orange in NSW. In this case it is to manage biosecurity issues relating to beekeeping near the site, but it has the added benefit of providing resource recovery opportunities at the baling plant, increasing transport efficiency and preventing roadside litter.

4.4 Operational Facilities for Municipal Wastes in Australia

Mixed waste composting systems (such as Bedminster) were the first types of alternative waste technologies to be introduced to Australia. However, marketing of mixed waste derived compost for agricultural applications proved to be difficult, because of concerns about product contamination.

In 2001, a tunnel composting plant to process separately collected garden waste into high grade compost products was commissioned by the waste company Rethmann (now Remondis) at Port Macquarie, on the North Coast of NSW. Later, food waste was also separately collected, and composted at this plant, with good results. The compost product from this plant is successfully marketed to residential and commercial customers.

This same plant also used its tunnel composting technology to treat the residual waste from the residential collections, with an intention of producing a refuse-derived fuel (RDF). However, this initiative was never commercially viable, since there were no obvious customers for the RDF, and the treated residual waste is simply landfilled.

Anaerobic digestion of separately collected commercial food wastes had been undertaken since approximately 2001, at the EarthPower plant in Western Sydney. Initially this plant struggled to attract commercial wastes, due to low costs of landfilling at the time and much of the material that the customers delivered was highly contaminated with non-organic wastes. The plant is currently operating successfully and accepts only contamination-free feedstock. A range of customers deliver this type of material including the Sydney Markets and a number of Coles and Woolworths supermarkets.

The largest AWT facility to be built in Australia to date has been the Global Renewables UR-3R plant at Eastern Creek in western Sydney. This is an anaerobic digestion plant with a mixed municipal waste feedstock. This plant was highly engineered, and very sophisticated, but there were issues with large quantities of lead acid car batteries received in municipal waste deliveries until GRL added additional processes at the beginning of the plant to screen these from the in-feed. While the plant produces green energy to feed into the electricity grid, the mixed waste compost it produces has proved difficult to market at various times.

The most recent AWT facility to be commissioned in Australia is the Ecolibrium facility at the Macarthur Resource Recovery Park in south western Sydney. This uses the Arrow Bio technology from Israel, which incorporates wet waste separation techniques and a patented anaerobic digestion process for organics processing, Another AWT facility, the SITA Advanced Waste Treatment (SAWT) facility at Kemps Creek, in Sydney's west is now being commissioned. This uses mixed waste composting technology to produce a waste compost type product to be used for rehabilitation of the Elizabeth Drive landfill site, where it is located.

4.5 Comparative Mixed Municipal Waste Technologies

A number of technologies that are being applied to mixed municipal waste streams in Australia and elsewhere have been highlighted in this report. They vary from composting processes (which are net consumers of energy) to anaerobic digestion processes, which are net exporters of energy.

Costs associated with municipal waste processing are closely related to the complexity of the processes used. Composting processes that are used simply for volume reduction and stabilisation of municipal waste prior to landfilling are the lowest cost, and carry the lowest risk, but have the lowest landfill diversion rates. These processes are widely used in places like Germany, where experience has shown that it is difficult to produce composts that meet agricultural standards.

When a mixed waste composting process is geared towards producing saleable compost, it becomes more complicated. Contaminants need to be removed from the incoming waste stream or from the raw compost to meet standards for agricultural uses. These types of processes carry the greatest risk as far as sale of the resulting compost. Marketing of mixed waste-derived compost, when green waste-derived compost is available in the same market, has proven difficult in parts of Australia.

The trend in some parts of Europe (such as Germany), where waste incineration is not favoured, is towards plants that remove recyclables, remove the high calorific fraction, then use anaerobic digestion of the organic components of mixed wastes, with composting then used to stabilise the residuals from these plants before landfill disposal. Very often there are additional processes to remove combustible (but not easily recyclable) items and materials from the residuals (such as plastics) and produce refuse derived fuels.

Anaerobic digestion processes are more technically complex than composting processes, and therefore have a higher capital cost. However they produce a commodity (green energy), which is in high demand, and less stabilised material for landfilling than composting processes. To assist in understanding the differences between the various technologies currently used in Australia and selected technologies currently used Europe and North America, their features are shown in Table 17 and Table 18 below. Other technologies used outside Australia are compared in Table 19 and Table 20.

Table 17 Comparison of technologies used for municipal waste streams in Australia – (1)

	UR-3R[50]	ORRF	Bedminster			BioMass Solutions	EarthPower
Operator	Global Renewables Limited (GRL)	Remondis	Sita	Sita	SMRC	BioMass Solutuions	EarthPower, joint venture between Veolia and Transpacific
Location	Eastern Creek, Sydney, NSW	Port Macquarie, NSW	Port Stephens NSW	Cairns, Qld	Canning Vale, Perth, WA	Coffs Harbour, NSW	Camellia, Sydney, NSW
Commenced Operation	2004	2001	1999	2003	2004	2008	2001
Inputs	MSW	MSW and source separated organics + biosolids (optional)	MSW + biosolids (optional)			MSW and source separated organics + biosolids (optional)	Clean organic food waste and biosolids. Accepts only commercial waste
Type of technology	MBT, anaerobic digestion and composting.	Tunnel composting and static aerated pile composting.	Rotating drum digesters and static aerated floor maturation			Agitated aerated composting and autoclave process for mixed waste	Anaerobic digestion
Capacity	Up to 260,000 tonnes per year	Processes approximately 30,000 tonnes per year	Approximately 30,000 tonnes per year through single drum.			30,000 tonnes per year of mixed waste and 20,000 tonnes per year of food and garden organics	
Size of existing facilities compared to expected throughput	High – modular process.	High –modular process. Each tunnel can process ~3,000 to 5,000 tonnes per year.	High – modular process.			High – modular process.	
Technology maturity	Eastern Creek plant the first of this type but similar plant proposed for Lancashire, United Kingdom to process 600,000 tonnes.	Successfully operating since 2001. Many similar plants operating overseas.	Nine plants operating in North America and Japan and three in Australia are in Port Stephens. Technology in use for over 30 years			Similar plants in operation overseas, although none use both autoclaving and enclosed composting technologies together.	

[50] Global Renewables Limited - http://www.globalrenewables.com.au

	UR-3R[50]	ORRF	Bedminster	BioMass Solutions	EarthPower
Site area required for 40,000 – 50,000 t/yr facility	Approx 5.6 ha for the Eastern Creek site in Sydney	Approx 2 ha for Port Macquarie (estimated as no published information available).	Approx 2 ha for Pt Stephens plant (estimated as no published information available).	Approx 1.1 ha for buildings plus operational areas for Coffs Harbour plant. Total area of 3.5ha reportedly required for Coffs Harbour RRC.	
Produces	Stable organic products such as organic growth media – compost or average daily cover. Also produces recyclables and/or inert material.	High quality compost from source separated organics and landfill cover from mixed waste.	Low grade compost.	Lower grade compost.	Energy and soil conditioner
Diversion Rate	About 70%	Not reported	Not reported	Organics fraction, 96%, mixed waste 80% - 85%.	
Energy production and consumption for 40,000-50,000 t/yr facility*	Generates 100kWh of electricity per tonne of input but also requires energy for its operation	0.3 M-0.45MW of energy used for 30,000 t/yr plant (not including recyclables recovery)	Approx 0.6MW to operate plant.	Approx 0.6 MW needed to operate plant at peak load, plus 78kW of gas.	
Water production and consumption for 40,000-50,000 t/yr facility*	Zero net water requirement	10 ML/yr to produce marketable compost	Not reported – however is a net consumer of water	30 ML/yr to produce marketable compost	
Approximate capital cost (based on current operating plants)	$100 million for 200,000 tonnes per year plant	$15 million for 30,000 tonnes per year plant	$80 million for 100,000 tonnes per year plant	$20 million for 30,000 tonnes per year plant	

Table 18 Comparison of technologies used for municipal waste streams in Australia – (2)

	Ecolibrium	SAWT	Conporec[51]	AnaeCo DiCom[52]	Atlas
Operator	WSN Environmental Solutions	Sita Environmental Services	Mindarie Regional Council	EMRC	Atlas and City of Stirling
Location	Narellan, NSW	Kemps Creek, NSW	Perth, WA	Perth, WA	Balcatta, Perth, WA

[51] Conporec - http://www.conporec.com

[52] AnaeCo - http://www.anaeco.com/

	Ecolibrium	SAWT	Conporec[51]	AnaeCo DiCom[52]	Atlas
Commenced Operation	2009 (commissioning)	2009 (commissioning)	2009	2009	2000
Inputs	MSW and garden organics + biosolids (optional)	MSW and source separated organics + biosolids (optional)	MSW plus other organic waste	MSW	MSW
Type of technology	MBT and wet digestion for organics in MSW, tunnel composting for separated organics	Recyclables recovery followed by Aerated composting in biocells	Aerobic digestion and composting with agitated forced aeration	Hybrid anaerobic/aerobic biological system	Mixed waste composting
Capacity	90,000 tonnes per year of MSW and 30,000 tonnes of separated garden organics and biosolids.	120,000 tonnes per year	100,000 tonnes per year	30,000 tonnes per year	100,000 tonnes per year
Size of existing facilities compared to expected throughput	High – modular process.	High – modular process.			
Technology maturity	Similar plant operating in Tel Aviv since 2003, after 10 year development program with pilot plant at Hadira.	Similar plants operating overseas. None in Australia processing MSW. One plant in WA using the organics process.	Well established. Facilities operating in the US and Canada and under construction France.	One 50,000 tonnes per year facility in WA and one 75,000 tonnes per year facility commissioned in Victoria	This plant has closed
Site area required for 40,000 – 50,000 t/yr facility	Approx 2 ha for proposed plant at Narellan in SW Sydney.	Estimated by GHD at approx 4 ha (estimate based on scaling down of 120,000 t/yr plant which reportedly requires 10ha).	Not known	20,000m^2	Not known
Current uses of end products at existing plants	High quality compost and biogas for energy production, digester sludge sold as fertiliser.	Compost product	Soil conditioner	Organic fertiliser and renewable energy	Spreading over farmland
Material diverted from landfill *	Approx 70%.	Up to 70%.	Greater than 70%	Claimed to be 80-85%	Not known

	Ecolibrium	SAWT	Conporec[51]	AnaeCo DiCom[52]	Atlas
Resource / energy recovery revenues	Revenue from high grade compost (Grade A) Revenue from renewable energy credits / green energy Revenue from recovered recyclables.	Revenue from compost (separate processing of garden organics may result in some Grade A compost being produced for sale). Revenue from recovered recyclables.	Compost can be sold as a soil conditioner	Compost, biofuel[53]	Low grade compost and recyclables.
Energy production and consumption for 40,000-50,000 t/yr facility*	Approx 1 MW of electricity produced and 0.6MW of this consumed in operating the plant.	0.9 MW reported to be required for 120,000 t/yr plant	Not reported	1MW	None.
Water production and consumption for 40,000-50,000 t/yr facility*	Arrow Bio plant produces 15 kL/day of waste water Estimated 10 ML/yr of water needed to produce marketable compost from separately received garden waste	Not reported – however is a net consumer of water	Not reported	140 L per tonne (7 million litres per year)	Not known.
Approximate capital cost (based on current operating plants)	$60 million for 90,000 tonne per year plant	$50 million for 120,000 tonne per year plant	$US15.8M for 35,000 tonne per year plant (in 1992)	Not known	Not known.

[53] *ABB System 800xA helps AnaeCo deliver Alternative Waste Technology* (2007) ABB in Australia 10 December - http://www.abbaustralia.com.au/cawp/seitp202/afccc27872d1927548257372000964cc.aspx

Table 19 Comparison of technologies used for Municipal waste streams in Europe and North America – (1)

	Valorga[54]	Citec[55]	GvoA[56]	ZAK	Linde
Inputs	MSW and biowaste	MSW (or Biowaste, sewage sludge)	MSW, commercial, sewage and other sludges	Residual MSW	MSW
Type of technology	MBT and anaerobic digestion using Valorga™ technology and post-composting, turning and air treatment.	Waasa process (anaerobic digestion technology)	MBT using fermentation	MBT using ZAK technology - mechanical treatment and biological percolation, biological drying and final mechanical material separation.	Anaerobic (wet) digestion
Material input requirements	Moisture content of input waste to be < 75%	Additional pre-treatment required if dry solids content is > 15%	None reported	Source separated residual MSW	Fine screen fraction only
Size of existing facilities compared to expected TWL's throughput	Bassano Plant in Italy 44,200 tonnes per year MSW and 8,200 tonnes per year biowaste.	MSW plants have digester capacities of 15,000 - 90,000 tonnes per year	Pohlsche Heide capacity is 55,000 tonnes per year MSW and 25,000 tonnes per year commercial waste	100,000 tonnes per year	Ecoparc 1 capacity of 300,000 tonnes per year of MSW.
Technology maturity	Well established. The Bassano Plant in Italy was commissioned in 2003.	MSW plants commissioned in 1994, 1999, 2002 and 2003	Recent, commercial plant operating since January 2005	Demonstration plant operating from 2001 to 2003. Full scale plant in 2006	Operational since 2002
Site area required for 40,000 – 50,000 t/yr facility	Not known	Not known	3 ha for Pohlsche Heide plant (80,000 tonnes per year MSW and commercial waste)	Not known	Not known
Current uses of end products at existing plants	Compost is used in agriculture, and biogas is used for electricity production	Compost in agriculture	Not known	Refuse derived fuel (RDF)	Compost for agriculture and landfill remediation.
Material diverted from landfill *	Not reported	Weight reduction of 50 – 60%.	Not reported	Not reported	Not reported

[54] Valorga - http://www.valorgainternational.fr/

[55] CiTEC - www.citec.fi

[56] GvoA - www.pohlsche-heide.de

	Valorga[54]	Citec[55]	GvoA[56]	ZAK	Linde
Energy production and consumption	The net electrical output is estimated at 1,320 kWe at the Bassano plant.	Groningen plant in Netherlands produces 1,920 KWe from 85,000 tonnes per year of MSW.	Not reported	Not reported	Not reported
Approximate capital cost (based on current operating plants)	$22M for a 52,000 tonnes per year plant	Not known	Not known	$9M for 100,000 tonnes per year plant	$110M for 300,000 tonnes per year facility

Table 20 Comparison of technologies used for Municipal waste streams in Europe and North America – (2)

	Plasco	BTA	BIOCEL[57]	DRANCO[58]
Inputs	MSW	Organic fraction of MSW	Source separated MSW	Organic waste
Type of technology	Plasma Arc	MBT and three-stage anaerobic digestion process	Dry anaerobic digestion	MBT and anaerobic digestion
Material input requirements	None reported	Sorted MSW is pulped and non-digestible inorganic removed. Pulped organic material is degritted before digestion	Source separated MSW	Source separated organic waste or organic fraction of MSW after mechanical separation
Size of existing facilities compared to expected TWL's throughput	Approx 30,000 tonnes per year	Not known	Not known	Not known
Technology maturity	Commercial-scale evaluation and demonstration plant commissioned in July 2007	Operating commercially in Europe since mid-1980s and in Canada since 2000. More than 30 facilities operating worldwide.	Pilot plant operated in the Netherlands in the 1990s and two commercial plants have been operating since 1997.	Six demonstration plants operated before the first commercial plant came on line in 1992 in Europe. At least nine commercial plants are now operating in Europe. Two plants are processing mixed MSW, one of which has been operating since 2002.

[57] Orgaworld - http://www.orgaworld.nl/installations.html#biocel

[58] Anaerobic Digestion - http://www.anaerobic-digestion.com/html/the_dranco_process.php

	Plasco	BTA	BIOCEL[57]	DRANCO[58]
Site area required for 40,000 – 50,000 t/yr facility	1.2 hectares	Not known	Not known	Not known
Current uses of end products at existing plants	Vitrified residue potential as construction aggregate.	Biogas used to generate electricity and a compost product.	Compost	Soil compost called Humotex
Material diverted from landfill *	Not reported	Not known	Not known	Not known
Energy production and consumption	Over 1 MWh of net power per tonne of waste processed or 4 MW per day.	Not known	Not known	Not known
Approximate capital cost (based on current operating plants)	$34M for the 30,000 tonnes per year plant	Not known	Not known	Not known

4.6 Waste to Energy

4.6.1 Incineration

Incineration is a simple technology that involves passing waste over reciprocating or inclined roller grates, which allow air to be blown both through and over the top of the waste. The organic component of the waste is oxidised into carbon dioxide and water. The unburnt ash or slag is cooled in water and disposed of. Flue gas contains water, combustion gases, oxygen and nitrogen. The process generates heat, which is used for to generate steam or hot water for local heating and/or as electricity.

Incineration is not a very efficient way to generate power, as most of the energy is lost as heat and in flue gas. There is also significant potential for air pollution with flue gases containing particulates, dust, NOx, acid gases, dioxins, furans, polyaromatic hydrocarbons and heavy metals. Reducing the emission of these materials into the atmosphere adds significantly to the cost of this technology.

Additionally, incineration has been criticised for discouraging recycling due to it being more economically viable to simply combust all the waste than spend effort and resources in sorting and reprocessing recyclable materials. These factors and the risk of pollution have led to decreased social acceptance of this form of waste disposal.

Incineration is a mature technology, long used all over the world and still widely used in Europe, among other places. In Australia the last solid waste incinerator, the Waverley Woollahra facility in south Sydney closed in 1997. At the time, community and government concern over stack emissions and the availability of relatively low cost landfilling made continuation of waste incineration a politically unpalatable option. Since then, acceptance of other forms of AWT has all but eliminated mass burn incineration as a viable waste processing option.

4.6.2 Pyrolysis and Gasification[59]

Pyrolysis and gasification, like incineration (combustion), are forms of thermal treatment that convert waste into energy-rich fuels by heating waste under controlled conditions in contrast to incineration where waste is fully converted into energy and ash. The processes deliberately limit the conversion to energy and ash so that combustion does not take place directly. Rather, waste is converted into valuable intermediates that can be further processed for materials recycling or energy recovery. These technologies promise to extract more energy from waste than is possible with traditional incineration, and to do it more cleanly.

Pyrolysis and gasification plants can deliver about 1MW/hr of electricity for every tonne of waste and can be twice as efficient as incineration, depending on the waste used. The basic technology is not new and generally, specific processes have been developed and optimised for feedstocks of varying properties and quantities such as for waste tyres, sewage sludge or mixed municipal waste.

Both methods potentially produce fewer environmental emissions and higher levels of energy than incineration although the technology is largely unproven. Most pyrolysis and gasification systems developed to date have not been fully demonstrated for mixed (unsegregated) municipal or commercial waste but several proprietary processes have been developed in recent years. More than 150 companies around the world now marketing systems based on pyrolysis and gasification for waste treatment. Some

[59] Juniper Consultancy Services - http://www.juniper.co.uk/services/Our_services/P&GFactsheet.html

examples of proprietary technologies include WasteGen, TwinRec, GEM Thermal Cracking and Thermal Convertor among others. A gasification plant that uses municipal waste to generate electricity became fully operational on the Isle of Wight (UK) in March. It is operated by the Norwegian firm Energos, which already has four plants in Norway and one in Germany. The British plant apparently generates electricity at a rate of 2.3MW per hour for sale to the national grid.

4.6.2.1 Pyrolysis

Pyrolysis refers to the thermal degradation of waste in the absence of air, that is, waste is cooked to about 800C without oxygen. The waste falls apart, separating into a compact residue (char), pyrolysis oil and syngas, which can be turned into transport fuels or can be burnt for heat, electricity or both.

A full-scale version of the WasteGen process has been operating in Germany since 1987. In this facility materials and energy are recovered from the incoming waste stream in a conventional materials segregation process, followed by a pyrolysis gas production process using a steel kiln rotating inside an insulated jacket clad in metal. The gas is subsequently burnt in either a gas turbine or a burning chamber to raise steam to drive a steam turbine. The materials segregation is designed to remove the unsuitable material, the material for composting and the recyclable materials both mechanically and if required, by manual selection. The resulting char product is not used and is sent to landfill. The dust and fly ash recovered in a baghouse gas cleaning system is considered hazardous and must be disposed of appropriately.[60]

Australian company Crucible Carbon is developing its own pyrolysis unit that aims to generate about three megawatts of electricity from 24,000 dry tonnes per annum of municipal solid waste derived-biomass[61].

4.6.2.2 Gasification[62]

Gasification is similar to pyrolysis but uses a small amount of air in the heating process. Hydrocarbons are broken down into a syngas by carefully controlling the amount of oxygen present. Gasification technology appears to be subject to significant research and commercial effort and investment, perhaps due to the possible synergies with sequestration of clean char in soil.

The advantages gasification has over incineration include:

- Flue gas cleaning can be performed on the syngas instead of flue gasses after combustion of which there are much larger volumes;
- Electric power can be generated in engines and gas turbines, which are cheaper and more efficient than the steam cycle used in incineration.

A significant amount of energy is required to process the waste and clean the gas and this offsets to a significant extent the high efficiency of converting syngas to electric power. Although several waste gasification processes have been proposed, the few that have been built and tested processing real

[60] WasteGen UK - http://wastegen.com

[61] Manning, Paddy (2009) *Burn, bury and bargain with it: biochar ticks the green boxes* The Land June 1 - http://theland.farmonline.com.au/news/nationalrural/agribusiness-and-general/general/burn-bury-and-bargain-with-it-biochar-ticks-the-green-boxes/1527966.aspx

[62] New York City Economic Development Corporation (2004) Evaluation of New and Emerging Solid Waste Management Technologies

waste are doing so using fossil fuels. As an example, a plant in Chiba, Japan, has been operating since 2000, but has yet to produce any documented positive net energy.

Some examples of those operating in the gasification area include the Indian-based Ankur Scientific Energy Technologies. This company made 120 gasifiers in 2005 and has them operating in Italy, Germany, Russia, Vietnam, Sri Lanka among other countries. Its wood-fuelled gasifiers have electrical power outputs ranging from 3 kW to 850 kW. A 200 kW demonstration system is being established in Pokeno, New Zealand.[63,64]

The SilvaGas process developed by Future Energy Resources Corporation is being used by Biomass Gas & Electric (BG&E) in the US to produce energy from wood-waste. This process has been designed specifically for biomass, unlike other gasification processes which are based on coal gasification designs. This particular project is projected to be in commercial operation in June 2011.[65,66]

Commercial gasification plants using the Twin Rec process have been operating in Japan (six plants) while thermal converter technology has been used in commercial plants in Japan and Europe. GEM Thermal Cracking Technology has been running in pilot plants in Europe and the UK and pilot testing in the US has taken place using briquettes of dewatered sewage sludge, with coal as a binder.[67]

4.7 Plasma Arc[68]

This technology works by passing relatively high voltage, high current electricity between two electrodes, spaced apart, creating an electrical arc. Inert gas or air under pressure is passed through the arc into a sealed container of waste material. Temperatures more than 13,800°C are reached in the arc column. At these temperatures most types of waste are broken into basic elemental gases and solid waste (slag). The device in which this takes place is called a plasma converter.

A good example of a full-scale commercial plant is the Canadian Plasco Conversion System.[69] The GasPlasma process, a hybrid plasma and gasification system, is in operation in a pilot plant in the UK.[70]

Depending on the input waste (plastics tend to be high in hydrogen and carbon), gas from the plasma containment can be removed as syngas, and may be refined into various fuels at a later stage.

One of the disadvantages of trying to use biomass, particularly food waste, as an energy source is that the high moisture content of the waste requires a significant amount of energy to remove before combustion can begin. However, a new radiation technology under development in Brazil removes water from biomass using electromagnetic radiation. This is done without having to carbonize the wood, as might occur in a high temperature furnace. The process also energizes the biomass with higher calorific power.[71]

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[63] Energy Efficiency and Conservation Authority (NZ) - http://www.eeca.govt.nz

[64] Ankur Scientific Energy Technologies - http://www.ankurscientific.com/

[65] Biomass Gas and Electric - http://www.biggreenenergy.com/

[66] Checkbiotech - http://www.checkbiotech.org/green_News_Biofuels.aspx?infoId=16491

[67] Solid Waste Conversion; IWM-C0172 http://www.ebara.ch

[68] Juniper Consultancy Services - www.juniper.co.uk

[69] Plasco Energy Group - http://www.plascoenergygroup.com

[70] Advanced Plasma Power - http://www.advancedplasmapower.com

[71] Technical Association of the Pulp and Paper Industry (TAPPI) - http://www.tappi.org/s_tappi/doc.asp?CID=183&DID=557891

The electromagnetic dryer does not need high temperatures to work but uses simple molecular agitation so that water is removed but not the inner hydrocarbons of the wood. The process avoids the production of residual ashes in thermoelectric boilers and reduces air pollution.

4.8 Organic Waste Technologies and Innovations

4.8.1 Open Windrow Composting

This is a simple ‘low-tech’ aerobic process that requires the mixing and turning of chipped green waste and other organic material to produce a stabilised product. Material is stored and processed on an open flat area in long rows. The rows can be handled in one or a combination of ways:

- Passive – no action;
- Turned – windrow is turned by mechanical action; and
- Forced air - air is forced though the windrows from underneath.

Turning and forced aeration speeds up the composting process. Processing times range from three to five weeks up to 14-20 weeks.[72]

This system can be operated with quite low capital costs compared to other composting systems, but a degree of attention is required to ensure the compost rows are properly and regularly turned. As a result this system may require a larger labour force and greater running costs. Purpose-manufactured windrow turners are available; however, a front-end loader would suffice in relatively small operations.

Disadvantages of this system include a relatively large amount of space is required and the inability of the window technique to generate high temperatures during the composting process, which may result in health and safety issues if bio-solids, food and manures are to be processed. There is less process control compared to other systems and greater potential for leachate runoff, as well as attracting flies and vermin and emitting odour. Typically odours are released when turning the windrows and this is most often the cause of complaints by members of the community living near these facilities.

[72] Recycled Organics Unit 2007

Figure 10 Open windrow composting

Figure 11 Windrow composting using a windrow turner[73]

[73] Cornell University College of Agricultural and Life Sciences - http://www.cals.cornell.edu/cals/public/comm/pubs/ecalsconnect/vol13-1/features/photo-page.cfm

Windrow composting can process garden organics but it is not really suitable for processing food, which in this open system emits odour and attracts vermin.

The process produces pasteurised or composted soil conditioners or mulches, similar to other systems, although they take longer to produce. These materials have applications in agriculture, landscaping and domestic retail markets.

4.8.2 Vermiculture

Vermiculture or vermicomposting refers to the breakdown of organic material that, in contrast to microbial composting, involves the joint action of different species of earthworms and micro-organisms and does not involve a thermophilic (high heat) stage. As the agents of turning, fragmentation and aeration, the worms consume organic wastes such as food waste, animal waste, greens and sewage sludge to produce a soil conditioner. Waste materials that are high in moisture content are best treated by vermicomposting, as various worms can tolerate between 40% and 85% humidity levels.

Vermiculture systems are a simple, relatively inexpensive technology, particularly when compared with in-vessel composting technologies, and require little space in which to operate. Although they require specialised management to achieve successful and consistent processing performance, they are not labour intensive.

Studies have shown that vermicomposting is an effective method of treating pathogen-rich waste materials and domestic solid and liquid wastes. Composting worms can consume 50%–100% of their body weight in organic matter. Depending on the volume of the waste matrix, filtration of wastewater through vermicomposting matrix has yielded pollutant removal. Depending on the waste stream, vermicomposting can also be semi-enclosed (windrows) or in-vessel (continuous flow or tray systems).

There are a number of disadvantages to vermicomposting. It will process a much smaller range of food organic material (primarily fruit and vegetable scraps) than other systems and may not be suitable in particularly dry or cold climates.

Worms have quite specific food requirements. They like wet food high in nutrients and relatively low in carbon. This system is best suited for vegetative food materials such as fruit and vegetable scraps, some animal manures, garden waste and compost, and cardboard. It is generally not suitable for processing other types of food waste such as meat, fish, liquids and egg and nut shells, onion, garlic, shallots or materials with high ammonia or nitrogen levels, or large quantities of fats and oils.[74]

The vermiculture process produces vermicasts, a high quality soil conditioner, and a nutrient rich liquid. Both are worm waste products and have uses in the agriculture, landscaping and domestic retail sectors.

4.8.3 Terra Preta/Biochar

Terra Preta is an ancient Amazonian agricultural technique that restores soil fertility, sequesters carbon and provides carbon-neutral or even carbon-negative energy. This 'emerging' technology for the treatment of wood waste involves slowly burning unwanted organic matter and adding the charred

[74] City of Lismore - http://www.lismore.nsw.gov.au

remains ('biochar') back into the soil. Not only does the technology sequester carbon but making biochar releases heat, meaning that biochar production can also constitute a fuel source. Cornell University is testing the technology by heating a poultry house using poultry litter.

Biochar is made by combustion of biomass in a low oxygen environment. These conditions can be found in several processes including fast pyrolysis[75], slow pyrolysis[76] and gasification. [77] A New Zealand company is making biochar using industrial microwave technology (see 4.3.9). Biochar quality is affected by the type source material (wood, food or municipal waste for example), and processing conditions such as temperature and time. There are indications that biochar provides some agricultural benefit when injected in the soil but this varies depending on its quality as well as other variables such as soil type, climate and crop type.[78]

Australian company Crucible Carbon has partnered with the Western Australia Agriculture Department in a project to convert agricultural residues and woody crops into biochar and renewable energy. Application of biochar to wheat crops is reportedly already demonstrating agricultural benefits.[79]

4.8.4 Radiation

In this technology water is removed from biomass by electromagnetic radiation without apparently carbonising the wood, which would occur when drying biomass in a high temperature furnace. At the same time, the process energises the biomass with higher calorific value. This technology can be applied prior to gasification or combustion to maximise the energy that can be produced from the biomass or waste wood.

4.9 Other Waste Technologies

4.9.1 Glass

Waste glass processing technologies generally require the glass to be ground into cullet. This cullet can then be used for the production of new glass bottles and products, as is as an aggregate in the construction industry or in the production of new products. [80] New technologies include the decolourisation and colourisation of molten glass to increase cullet availability and enhance the economics of the glass value chain[81] and crushing and remelting cullet to produce decorative glass and other glass grades for other purposes such as a blasting, a filter media for swimming pools[82] and as a sand substitute in golf course bunkers[83] and on beaches in the US, New Zealand and the Caribbean.[84]

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[75] High temperature and short residence time

[76] Lower temperatures and longer residence time

[77] Sohi, Saran; Lopez-Capel, Elisa; Krull, Evelyn and Bol, Roland (2008) Biochar, climate change and soil: A review to guide future research CSIRO Land and Water Science Report 05/09, 64 pp

[78] Sohi *et al* 2008

[79] Manning, Paddy 2009

[80] *Glass recycling information sheet* Waste Online - http://www.wasteonline.org.uk/resources/InformationSheets/Glass.htm

[81] Green Mountain Glass - http://www.greenmountainglass.com/

[82] *Novel Size Reduction and Classification of Recycled Glass Yields Profitable Products, Eliminates Landfill Costs* Kason - http://www.kason.com/TechnicalLibrary/index.php?sType=1&ArticleID=648

[83] *TerraNova Wins Award for Crushed Glass Projects* Terra Nova - http://www.terranova.org.nz/terranova/events/

[84] ABC (US) News - http://abcnews.go.com

4.9.2 Plastics

4.9.2.1 Current technologies

The thermoplastic nature of many plastics makes them relatively easy to recycling with the application of heat. The low cost and high quality of virgin material however, often makes plastic recycling uneconomical. Many types of consumer plastics including bottles, containers, bags and film are currently recycled into many different products. Individual and mixed plastics can be recycled into composite 'timber' and can also be reprocessed into pellets, or post consumer resin, which can be used as feed stock for a variety of products such as new bags and films, pallets, containers, crates, pipes, household and electrical goods, textiles and toys.[85,86]

4.9.2.2 Emerging technologies

New technologies for the sorting of rigid plastic waste include optical systems that identify and separate plastics by density and opacity. New technologies for the conversion of specific or mixed grades of plastic to other useful products include:

- **Plastofule** - The Plastofule technology uses a hot water boiler heating system to burn pea-sized pellets made from waste mulch film plastic. Film plastic items, rigid plastic items, or both are forced through a heated die, melting the dirt in the extruded material. A hot knife cuts the material into dense fuel nuggets that can be easily stored and transported. The simple process densifies waste plastics into the Plastofuel fuel nugget. Originating in the agriculture sector, the process is in the pilot stage and hopes to reduce the amount of plastic waste on farms;[87]
- **T-Technology** - This technology breaks down plastic waste into component liquid fuels by polymerizing the waste through catalytic processing. Heating the plastic waste in this environment 'cracks' the long polymers that make up plastic, thus generating hydrocarbon vapours which are cooled. There are two main outputs; hydrocarbon vapours and a solid residue of impurities such as metals, glass, paper and food. This by-product is similar in consistency to sand and has its own calorific value. Ten years of research resulted in the technology being commercialised in 2003. There are now seven installations in Poland, one under construction in Slovakia and other projects being prepared in Spain, Italy and Sweden.[88]
- **ThermoFuel** - The ThermoFuel system uses a pyrolysis chamber, a patented catalytic converter and a series of specially built condensers to produce energy-rich diesel fuel from unsorted waste plastics. Plastics that are unsuitable for other recycling purposes because of an undesirable or contaminated mix of polymers are no problem. ThermoFuel plants can produce about 9000 litres of high-grade diesel fuel from 10 tonnes of almost any type of waste plastic by employing liquefaction, pyrolysis and catalytic breakdown. Developed by Melbourne-based environmental technology manufacturer

[85] Plastic Bag Recycling - www.plasticbagrecycling.org/

[86] *China keen on paper and plastic waste: UK survey* (2009) WME - http://www.environmentalmanagementnews.net/StoryView.asp?StoryID=1003031

[87] Lamont, William J. and Garthe, James W. (2006) *Recycling and Recovery of Energy Stored in Used Plastics* The Vegetable & Small Fruit Gazette 10 (4) , published by Penn State University at the American Society for Plasticulture - http://www.plasticulture.org/history_recycling.htm

[88] Oleszkiewicz, Agniezka (2008) *Plastic Power – Waste management in Poland* Waste Management World September-October - http://online.qmags.com/WMW0908/?sessionID=CB3167FCBECB094A74B6B03B3&cid=681583&eid=12960#

Ozmotech up to 30 ThermoFuel systems are hoped to be installed and commissioned in Britain and Europe in the next seven years;[89] and

- **Thermal/Biological Conversion** – This Irish/German/US technology is only at the research stage but it is looking at the possibility that bacteria could help transform a key component of disposable polystyrene plastic cups, plates and utensils into a useful eco-friendly biodegradable plastic. The process works by heating plastics in the absence of oxygen to convert the polystyrene into styrene oil which is then fed to the bacterium that then converted the oil into a biodegradable plastic known as PHA (polyhydroxyalkanoates). PHA has numerous uses in medicine and can be used to make plastic kitchenware, packaging film and other disposable items. The biodegradable plastic is resistant to hot liquids, greases and oils, and can have a long shelf life. Unlike polystyrene however, it readily breaks down in soil, water, septic systems and backyard composts.[90]

4.9.3 Mixed recyclables

4.9.3.1 Current technologies

The comingled collection of mixed recyclables is common in many western countries. This system requires recyclables to be sorted in materials recovery facilities (MRFs) which use an array of screens, trommels, magnets, eddy currents, rotating discs, vibrating conveyors and air classifiers of some complexity. Optical sorting technology, which separates materials by colour, density and opacity, is now commonplace for many already separated streams of small particles.

Figure 12 An optical sorting unit above a conveyor[91]

[89] *Local recycler ignites Euro fuel market* (2009) WME - http://www.wme.com.au/categories/waste_managemt/feb6_05.php

[90] *Styrofoam converted into biodegradable plastic* (2006) Sustainability Matters - http://www.sustainabilitymatters.net.au/news/3864-Styrofoam-converted-into-biodegradable-plastic

[91] Titus Services - http://www.titusservices.com/media/gallery/photo

Figure 13 Diagram showing how an optical sorting unit scans and separates materials

4.9.3.2 Emerging technologies

New technologies for the automatic sorting of recyclables include:

- **TiTech** – This commercial Norwegian technology includes several techniques including;
  - NIR (near infrared), which recognizes different materials based on their spectral properties of reflected light;
  - CMYK (cyan, magenta, yellow, key) sorts paper or cartons that have been printed using CMYK;
  - VIS (visual spectrometry) recognizes all colours that are visible and works for both transparent and opaque objects;
  - EM (electromagnetic) sorts metals with electromagnetic properties, as well as sorting metals from non-metals and recovers stainless steel or metallic compounds;
  - RGB sorts specifically in the colour spectrums of red, green and blue for specialized applications; and
  - X-ray sorts by recognizing the atomic density of materials.[92,93]

  These technologies can be used for both source separated materials such as paper, plastics and metals or as a combined system for comingled wastes. High levels of purity result regardless of particle size, amount of moisture or contaminants in the streams.

- **MIR (mid infrared)** – This technology works on a similar principle to NIR, but projects light in the mid infrared range onto materials to be analysed. French company Pellenc ST has been piloting this technology as a more efficient way to separate paper and cardboard claiming efficiency levels up to 90%, an improvement of around 30%.[94]

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[92] *Paper Sorting - Alton, UK showing TITECH's ability to work on single stream systems, sorting both plastics and paper* – TITECH - http://www.titech.com/case-studies/paper-sorting-alton-uk-10926

[93] Capel, Claudine (2009) *Waste sorting - A look at the separation and sorting techniques in today's European market* Waste Management World 10, 5 May - http://www.waste-management-world.com/display_article/339838/123/ARCHI/none/none/1/Waste-sorting---A-look-at-the-separation-and-sorting-techniques-in-todayrsquo;s-European-market/

[94] Pellenc Selective Technologies - MIR Technology - http://www.pellencst.com/en/21/54/mir-technology

- **BOREAS** - Pellenc ST also has commercialised this near infrared technology-based on using infra-red detection to determine the weight of the paper, or more exactly the length of the fibres in the celluloid materials. The length of the fibres enables the paper to be identified without any possibility of error and determine if it is of good quality or not.[95]

4.9.4 Carpets

4.9.4.1 Current technologies

Carpets have long been subject to recycling technologies of various kinds including shredding, melting and depolymerisation to produce caprolactum, which can be used as a feedstock to produce new material and recycling waste vinyl backing for use as a new carpet backing product.[96]

4.9.4.2 Emerging technologies

Emerging technologies include:

- **Vinyl Reprocessing** - Recycle vinyl-backed carpet to produce a new carpet backing; [97] and
- **Fertiliser** – A New Zealand study showed that ground wool carpet can be used as a fertiliser, producing elevated levels of essential elements such as nitrogen, sulphur and magnesium in grass grown using the wool carpet fertiliser.[98]

4.9.5 Clothes and textiles

4.9.5.1 Current technologies

Scrap and waste clothes are already sold to the 'flocking' industry where items are shredded for fillers in car insulation, roofing felts, loudspeaker cones, panel linings, furniture padding among other applications. Wool is sold to specialist firms for fibre reclamation to make yarn or fabric.[99]

The fibre reclamation process starts with the grading of incoming material into type and colour at mills. Colour sorting means no re-dying has to take place which saves energy and reduces pollutants. Initially material is shredded into 'shoddy' (fibres) and depending on the end uses of the yarn, for example as a rug, other fibres are chosen to be blended with the shoddy. The blended mixture is carded to clean and mix the fibres, and spun ready for weaving or knitting.[100]

4.9.5.2 Emerging technologies

Japanese company Teijin Fibers, has developed the world's first technology for chemical recycling of polyester. The process decomposes polyester for conversion into new polyester raw materials that offer purity comparable to those derived from petroleum. Registered apparel and sportswear manufacturers make products from the recyclable materials as well collecting them for recycling at the end of their

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[95] Pellenc Selective Technologies – Near Infrared Technology http://www.pellencst.com/en/21/12/near-infrared-technolgy

[96] Shawfloors - http://www.shawfloors.com/Environmental/RecyclingDetail

[97] Tandus - http://www.tandus.com/sustainability/recycling.aspx

[98] McNeil, Steven J., Sunderland, Matthew R. and Zaitseva, Larissa I. (2007) *Closed-loop wool carpet recycling* Resources, Conservation and Recycling 51 (1) pp 220-224

[99] Textile recycling information sheet - Waste Online - http://www.wasteonline.org.uk/resources/InformationSheets/Textiles.htm

[100] Textile recycling information sheet - Waste Online - http://www.wasteonline.org.uk/resources/InformationSheets/Textiles.htm

useful lives. Compared to developing polyester materials from petroleum, this repeatable recycling system reduces energy consumption and carbon dioxide emissions by approximately 80% each.[101]

Teijin Fibers' also recycles polyester fibre into tyre components. The recycled material is used for the tyre carcass, which until now, required strict performance requirements that recycled plastic could not provide. The new material is to be used by Toyo Tire & Rubber.

4.9.6 Electronic wastes

4.9.6.1 Current technologies

In advanced economies electronic waste is disassembled in plants of various levels of automation. Increasing the level of automation decreases operating costs, increases efficiency and generally ensures a less hazardous working environment for operators.

Disassembly systems are currently used world wide and employ a variety of crushing and separation methods, including eddy currents and magnets, to break apart electrical waste into its basic components such aluminium, copper, silver, lead and gold. Plastics are separated using density separation. Recovered plastics can be used for the production of vineyard stakes, fence posts and plastic sleepers.[102,103,104] There are several facilities in Australia disassembling e-waste and many of the components are shipped overseas for further processing.

4.9.6.2 Emerging technologies

- **Chemical and Electrokinetic Treatment** – Chinese research has shown that copper metal and a lead concentrate can be recovered from printed circuit boards (PCBs) by (SCWO) combined with an electrokinetic (EK) process. The SCWO process decomposes organic compounds of PCBs and oxidises lead and copper; [105] and
- **Pyrolysis** - Spanish research has found that pyrolysis (see section 4.6.2) of electronic waste under nitrogen at high temperature decomposes electronic waste to obtain polymer free metals, gases as a potential energy source for the plant, and liquids as a potential energy or chemical source. A char by-product may also be used as a pigment, activated carbon, low quality carbon black or a component of asphalt fabrics. [106]

4.9.7 Treated Timber

4.9.7.1 Current technologies

Timber is often treated with combinations of chemicals such as copper-chrome-arsenate (CCA), to increase its durability and pest resistance in certain applications. These chemicals are toxic however,

[101] Teijin - http://www.teijin.co.jp

[102] Sims Recycling Solutions - http://au.simsrs.com/au%5Ferecycling/home/

[103] Kinver, Mark (2007) *Mechanics of e-waste recycling* BBC News 3 July - http://news.bbc.co.uk/1/hi/sci/tech/6254816.stm

[104] E-Cycle Recovery - http://www.ecyclerecovery.com.au/theprocess.htm

[105] Xiu, Fu-Rong and Zhang, Fu-Shen (2009) *Recovery of copper and lead from waste printed circuit boards by supercritical water oxidation combined with electrokinetic process* Journal of Hazardous Materials
165 (1-3) pp 1002-1007

[106] de Marco, I., Caballero, B.M., Chomón, M.J., Laresgoiti, M.F., Torres, A., Fernández, G. and Arnaiz, S. (2008) *Pyrolysis of electrical and electronic wastes* Journal of Analytical and Applied Pyrolysis 82 (2) pp 179-183

especially if released during processing or incineration after disposal. The recovery options for treated timber are therefore limited. One technology currently used at an industrial scale is the Chartherm™ process in France. This process uses low temperature pyrolysis to produce hydrocarbon gases and a mineral matrix containing the heavy mineral contaminants. The benefit of this system over incineration or combustion is that the temperatures involved are lower than the boiling temperatures of the major contaminants and they are not converted to gases.

4.9.7.2 Emerging technologies

There are several emerging technologies for the processing and sorting of treated wood wastes however, most are only in very preliminary stages of development. They include:

- **X-ray fluorescence (XRF) Sorting** – Materials can be identified by the emission of characteristic fluorescent X-rays released when bombarded with high-energy X-rays or gamma rays;[107]
- **Laser Sorting** – Laser technology used in the mineral industry is being adapted for sorting wood waste;[108]
- **Bioremediation** – Metal-tolerant bacteria may be used to release metals from treated wood fibre. A two-stage process of oxalic acid extraction followed by bioremediation has also been found to be more effective than bioremediation alone;[109]
- **Recycling** – This involves creating new wood composites with the requirement for rot- or pesticide-resistance; [110,111]
- **Chemical extraction** – The extraction of CCA compounds using a bioxalate solution has been tested in Japan and shows that after six hours of treatment, 90% of the chromium, copper and arsenic could be removed;[112]
- **Plasma Arc** - Plasma arc technology is described in more detail section 4.7. This technology can be applied to treated wood waste however, the main issue of concern for this and other thermal technologies is how to deal with contaminants (heavy metals and other substances);
- **Pyrolysis** - Pyrolysis of CCA timber on a semi-industrial scale in France has produced a charcoal product that can be directly re-used and reduces the heavy metals and other minerals in the feed by 99.9%. This French technology can apparently process wood waste regardless of the toxicity level without the need for sorting; [113,114]

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[107] Blassino, Monika; Solo-Gabriele, Helena and Townsend, Timothy (2002) *Pilot scale evaluation of sorting technologies for CCA treated wood waste* Waste Management & Research 20(3) 290-301 - http://wmr.sagepub.com/cgi/content/abstract/20/3/290

[108] CSIRO - Joely Taylor

[109] Clausen Carol A. (2004) *Improving the two-step remediation process for CCA-treated wood: Part II. Evaluating bacterial nutrient sources* Waste Management 24 (4) pp 407-411

[110] Lansbury Hall, Nina and Beder, Sharon Treated Timber - http://homepage.mac.com/herinst/CCAtimber/waste/reuse.html

[111] Patent Storm - http://www.patentstorm.us/patents/5320152-description.html

[112] Kakitani, Tomo; Hata, Toshimitsu; Kajimoto, Takeshi and Imamura, Yuji (2006) *A Novel Extractant for Removal of Hazardous Metals from Preservative-Treated Wood Waste* Journal of Environmental Quality 35,912-917 Published online 26 April

[113] Helsen, L., Van den Bulck, E., Mullens, S. and Mullens, J. (1999) *Low-temperature pyrolysis of CCA-treated wood: thermogravimetric analysis* Journal of Analytical and Applied Pyrolysis 52 (1) pp 65-86

[114] Thermya - http://www.thermya.com

- **Burning with other fuels** – This mainly involves forming briquettes with other materials for combustion. The main issue here is how to adequately deal with contaminants in flue gases;[115] and
- **Electrodialytic remediation** - Electrodialytic remediation uses a direct electric current to accelerate the diffusion of metals, combined with the use of ion exchange membranes to separate the electrolytes from wood chips. A two cubic-metre pilot plant has been trialled in Denmark.[116]

4.9.8 Hazardous Wastes

4.9.8.1 Emerging technologies

Some very preliminary new technologies for treating hazardous waste include:

- **Molten Metal Catalytic Extraction** - Molten metal catalytic extraction involves toxic materials being injected into a bath of molten metal where they are broken down into their elemental components. These then reform to produce useful products such as industrial gases, metal alloys, and ceramics. The only known pilot project, in the US, has closed down; [117]
- **Bioremediation** - Bioremediation is any process that uses microorganisms, fungi, green plants or their enzymes to return the environment altered by contaminants to its original condition. It may be used to attack specific soil contaminants, such as degradation of chlorinated hydrocarbons by bacteria. An example of a more general approach is the cleanup of oil spills by the addition of nitrate and/or sulphate fertilisers to facilitate the decomposition of crude oil by indigenous or exogenous bacteria. Mostly used with contaminated soil, research is being conducted into other types of contamination; [118,119]
- **Phytoremediation** - Phytoremediation involves the use of plants to break down toxic chemicals or to absorb and store them for release as gasses, which may be a less toxic form of the chemical, or for harvesting and safe disposal; [120,121,122]
- **Plasma Arc** – Plasma arc technology is described in more detail section 4.7. This technology has been applied for the treatment of hazardous wastes, and although only at a pilot level of development there seems to be significant research and commercial drive behind it. Promising pilot and commercial plants are in operation and a variety of technology improvements underway. One company, Startech, appears to have solved most dioxin and furan pollution problems in its exhaust gas treatment. Other companies involved include; Advanced Plasma Power, Plasco Energy Group, Hitachi Metals, Westinghouse Plasma and BCD Technologies; [123,124,125,126,127,128,129] and

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[115] RUF - http://www.briquetting.com/

[116] Christensen, Iben V., Pedersen, Anne J., Ottosen, Lisbeth M. and Ribeiro, Alexandra B. (2006) *Electrodialytic remediation of CCA-treated waste wood in a 2 m³ pilot plant* Science of The Total Environment 364 (1-3) pp 45-54

[117] Sheridan John H. (1993) *Catalytic extraction processing* Industry Week December 20 http://www.industryweek.com/ReadArticle.aspx?ArticleID=267

[118] Diaz, Eduardo (Editor) (2008) Microbial Biodegradation: Genomics and Molecular Biology Caister Academic Press http://www.horizonpress.com/gateway/biodegradation.html

[119] Sydney Olympic Park Authority - http://www.sydneyolympicpark.com.au/education_and_learning/history/site_remediation/sticky_wicket

[120] Missouri Botanic Gardens - http://www.mobot.org/jwcross/phytoremediation/

[121] Plantstress - http://www.plantstress.com

[122] The Great Plains/Rocky Mountain Hazardous Substance Research Centre - http://www.engg.ksu.edu/HSRC/phytorem/

[123] Startech Environmental Corp - http://www.startech.net

- **Big Oversized Blender** – A 'megablender' known as 'Bob the Big Oversized Blender' will be built in Victoria to reprocess hazardous waste into a fuel that can be used in cement kilns. Up to 7,000 tonnes of hazardous waste will be processed each year in the machine that separates it into different material streams for recycling and reprocessing. [130] The unit consists of a series of augers which shred material before it enters the blender itself, which is a fast spinning propeller over a shear plate. Magnetic conveyors pull out metal for washing and recovery. None of the components are new technology but combining them in a single machine is unique.[131]

Figure 14 BOB the Big Oversized Blender[132]

4.9.9 Tyres

There are a number of technologies for processing and treating waste tyres. These predominantly involve shredding or mechanical grinding of whole or split tyres to prepare the rubber for recycling or reuse. Others are more complex and include devulcansation, microwave technology and some other physico-chemical processes. Tyres are also currently used a fuel for cement furnaces.

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[124] Koerner Brendan I. (2008) *Can We Turn Garbage Into Energy? The pros and cons of plasma incineration.* Slate January 2 - http://www.slate.com/id/2181083/

[125] PlascoEnergy - http://www.zerowasteottawa.com/

[126] Pyrogenesis - http://www.pyrogenesis.com/index.asp

[127] Advanced Plasma Power - http://www.advancedplasmapower.com/

[128] Green Power Systems - http://www.greenpowersystems.com/

[129] Plascon - http://www.plascon.com.au/

[130] *'Can we fix steel? Yes we can!'* (2009) WME Monday, 11 May - http://www.environmentalmanagementnews.net/StoryView.asp?StoryID=1002976

[131] Lamb, Garth (2009) *Bob the blender fires up waste recovery* Inside Waste Weekly 12 May

[132] Inside Waste Weekly May 12, 2009 - http://www.insidewaste.com.au/StoryView.asp?StoryID=1003001

4.9.9.1 Current technologies

4.9.9.1.1 Mechanical processing

Whole or split tyres can be reused for engineering applications such as barriers and walls, soil reinforcement and erosion control. However, shredding, grinding and crushing after freezing produce a range of crumb sizes with a variety of applications, including athletic track surfaces, play ground surfaces, brake linings, landscaping mulch, carpet underlay, absorbents for wastes, shoe soles, adhesives, asphalt filler, bollards, barriers, kerbs and other drainage applications among others.[133,134,135]

Concerns have been raised however, about the potential release of arsenic, lead and mercury in shredded tyre products. The US EPA is investigating potential the health risks of using shredded tyres in playground surfacing among other applications. The US Centre for Disease Control has issued an advisory for potential lead contamination from artificial turf where shredded tyres are used as an additive.[136]

Australian firm Ecoflex Australia recycles used tyres into construction material for paving, retaining walls and erosion prevention. It has three main products; ‘E Pave’, ‘E Wall’ and ‘E Rosion’. ‘E Wall’ is used in the construction of soil retaining walls, ‘E Pave’ is a permeable road construction system and ‘E Rosion’ can be used to produce individually designed and certified structures to control water erosion. All three are currently being used in drainage channels, bridges, road and rail embankments and many other projects.[137]

4.9.9.1.2 Devulcanisation

Heat and or chemical treatment of tyres can produce devulcanised rubber, which has the potential for use in a variety of industries. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is currently working with a number of companies to complete a demonstration trial and commercialise a process whereby the molecular bonding properties of the rubber can be changed to produce a material similar to PVC with a 50% recycled rubber content.

Another current process is TyreRecycle, which involves coating the rubber crumb with latex to improve its adhesion to other materials.[138]

4.9.9.2 Emerging technologies

Various other technologies are emerging to deal with waste tyres including:

- **Microwave technology** - Advanced Molecular Agitation Technology has developed a prototype system that breaks the tyres into their original components; steel, carbon and oil which are all

[133] Anaxiom - http://www.anaxiom.co.uk/contact.html

[134] Tyre Crumb Australia - http://www.tyrecrumbaustralia.com/

[135] Motor Vehicle Dismantlers Association (UK) - http://www.mvda.org.uk/recycling.aspx

[136] *US EPA to check shredded tyres safety* (2000) WME Friday, 19 June - http://www.environmentalmanagementnews.net/StoryView.asp?StoryID=1003337

[137] *CleanTech company profile: Ecoflex Australia* (2009) WME 12 March - http://www.environmentalmanagementnews.net/StoryView.asp?StoryID=980444

[138] *A National Approach to Waste Tyres* Commonwealth Department of Environment, 2001 Department of the Environment, Water, Heritage and the Arts - http://www.environment.gov.au/settlements/publications/waste/tyres/national-approach/tyres10.html

recoverable. The amounts of emissions produced are minimal. The first commercial scale prototype has a capacity of 2,000 tonnes of tyres a year; [139]

- **Continuous reductive distillation -** this is a type of pyrolysis which involves continuous heating; [140]
- **High pressure water** – This technology developed by Aquablast in the UK uses high pressure water jets to remove tyre rubber from the reinforcing steel in earthmoving tyres. All the tyre components can be recycled including the water used in the jets. A pilot plant attracted funding from the Waste and Resources Action Programme (WRAP) and a full-scale facility for dismantling large industrial tyres is to be built soon; [141]
- **Gas phase halogenation** – This US technology oxidises the rubber tyre surface to make crumb suitable for a limited number of alternative applications; [142]
- **Steam gasification** – Tests of steam gasification on dry, 2 mm particles of waste tyres in a rotary kiln reactor produced both a char, which could be used as a feed for further processes, and a hydrogen-rich syngas with possible fuel cell applications. It could also be used as a starting material for Fisher-Tropsch syntheses, a reaction in which syngas is converted into liquid hydrocarbons; and
- **Pyrolysis** – Tyres subject to pyrolysis in test conditions produce a solid residue which when was combined with ground dry sludge produced activated carbon adsorbents which could be used in the treatment of wastewater.

4.9.10 Fluorescent light bulbs

4.9.10.1 Current technologies

Current commercially available technology for recycling fluorescent light bulbs includes:

- A batch crusher, separator, and particle and vapour filtration system available from Resource Technology Inc;
- Thermal retort of phosphor powders and ferrous light filaments;
- Distillation of mercury using thermal retort product; and
- Aluminium recovery from the end caps of the light bulbs.

The batch crushing process consists of a crusher, separator, particle and vapour filtration systems, material handling systems and a program logic control system. A US plant using this technology can process up to 4000 lamps per hour. The system crushes and separates fluorescent lamps into glass, aluminium, and phosphor powder (containing mercury), which is thermally treated to recover elemental mercury for commercial reuse. Mercury vapours are absorbed in activated carbon filters.[143,144]

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[139] *End of life vehicle and tyre recycling information sheet* Waste Online - http://www.wasteonline.org.uk/resources/InformationSheets/Vehicle.htm

[140] Lets Recycle.Com - http://www.letsrecycle.com/

[141] *Large industrial tyres to be recycled with water jets* (2007) Lets recycle.Com Wednesday 04 July - http://www.letsrecycle.com/do/ecco.py/view_item?listid=37&listcatid=217&listitemid=8933

[142] *A National Approach to Waste Tyres* Commonwealth Department of Environment, 2001 Department of the Environment, Water, Heritage and the Arts - http://www.environment.gov.au/settlements/publications/waste/tyres/national-approach/tyres10.html

[143] Resource Technology Inc - http://www.lampequipment.com/lss1.asp

[144] AERC Recycling Solutions - http://www.aercrecycling.com/information/fluor_process.php

4.9.10.2 Emerging technologies

Emerging technologies for the treatment of waste fluorescent light bulbs include:

- **Dense medium centrifugation** – This technology aims to separate low-density phosphors from high-density phosphors by processing them in a centrifuge and varying speed and retention time. Laboratory tests are being conducted in Japan; [145] and
- **Thermal desorption** – In Taiwanese tests of this technology, heat is used to convert toxic chemicals into gasses which can be captured.

4.9.11 Dry Cell Batteries

4.9.11.1 Current technologies

Current technologies for the treatment of waste dry cell batteries include pulverising them and using them as a feedstock in low grade steel furnaces or shredding them to separate their components. In a Canadian process Li-ion batteries are super-cooled, then sheared and shredded and the component materials separated. Metals from the batteries are collected and sold. The lithium components are separated and converted to lithium carbonate for resale. Hazardous electrolytes are neutralized to form stable compounds and residual plastic casings and miscellaneous components are recovered for appropriate recycling or scrapping. If the batteries contain cobalt this is also recovered for reuse. Manganese and zinc remaining in the process effluent are collected, filtered, and sold.[146]

A Chinese process recycles Zn-Mn batteries to produce Zn-Mn ferrite materials using magnetic separation and hydrometallurgy.[147]

4.9.11.2 Emerging technologies

An emerging technology for the treatment of waste dry cell batteries is hydrometallurgy.[148] This involves the leaching and dissolving of materials in acids or alkalis and then extracting them by electrolysis or precipitation. It is used to separate nickel from Ni-MH batteries.

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[145] Hirajima, T., Sasaki, K., Bissombolo, A., Hirai, H., Hamada, M. and Tsunekawa, M. (2005) *Feasibility of an efficient recovery of rare earth-activated phosphors from waste fluorescent lamps through dense-medium centrifugation* Separation and Purification Technology 44 (3) pp 197-204

[146] Toxco - http://www.toxco.com/processes.html

[147] Nan, Junmin; Han, Dongmei and Zuo, Xiaoxi (2005) *Recovery of metal values from spent lithium-ion batteries with chemical deposition and solvent extraction* Journal of Power Sources 152, 1 December, pp 278-284

[148] Rabah, M.A., Farghaly, F.E. and Abd-El Motaleb, M.A. (2008) *Recovery of nickel, cobalt and some salts from spent Ni-MH batteries* Waste Management 28 (7) pp 1159-1167

4.9.12 Wet Cell (Automotive) Batteries[149,150,151,152]

4.9.12.1 Current technologies

Current technologies for the treatment of waste automotive batteries include:

- **Crushing and separation** - Battery components are separated by crushing and screening to produce electrolyte, paste and solids. The solids components can then be separated into PVC ebonite, grids metal and polypropylene;
- **Electrolyte collection** - Electrolyte that escapes during battery handling can be filtered and sold as a pickling agent for various industrial processes;
- **Refining and smelting** - The non-ferrous metallic components of lead-acid batteries are processed in rotary furnaces to produce a raw lead product. This is smelted and cast to produce ingots of refined lead and lead alloys. A secondary lead smelter will be built in Newcastle by battery recycler HydroMet. The new plant will have the capacity to process 36,000 tonnes of used lead acid batteries, about one third of the batteries on the Australian market; and
- **Paste desulphurisation** – The paste that is separated from the crushing and screening of lead-acid batteries can be desulphurised to produce a desulphurised paste product. The filtration solution can be passed though a crystalliser to form sodium sulphate crystals that can be sold to detergent manufacturers.

4.9.12.2 Emerging technologies

Leaching is an emerging technology for the treatment of waste automotive batteries and is similar to hydrometallurgy, where metals are dissolved out of the batteries for recovery.

4.9.13 Construction and Demolition Waste

4.9.13.1 Current technologies

C&D waste is often composed of a mix of materials that if separated can be reused. These include bricks and tiles, concrete, timber, cardboard, ceramic tiles, glass and other materials. Current recovery methods concentrate on keeping these materials separate at the source and the processing of homogenous materials such as concrete which is crushed to specific size gradients. Typical common current uses for recycled concrete are as a drainage medium and road base. The presence of steel reinforcing in some types of concrete in the recycled aggregate restricts its options for use.

4.9.13.2 Emerging technologies

New technologies for the use of recycled concrete include:

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[149] The Engitec Cx Process For The Complete Recycling Of Lead-Acid Batteries - http://www.engitec.com/PDF/MORECXSYSTEM.pdf

[150] Kreusch, M.A., Ponte, M.J.J.S., Ponte, H.A. Kaminari, N.M.S., Marino, C.E.B. and Mymrin, V. (2007) *Technological improvements in automotive battery recycling* Resources, Conservation and Recycling
52 (2) pp 368-380

[151] *The Integrated Cx System From Scrap Acid Batteries To Soft Lead And Lead Alloys* Engitec Technologies - http://www.chloride-technical.com/General%20brochures/Scrap%20reprocessing.pdf

[152] *Battery Recycling Technology* Gravita Exim http://www.gravitaexim.com/Battery-Recycling/Battery-Recycling-Technology.html

- **Thermal Treatment** – To increase the proportion of building waste reused and increase the quality, a new concept called 'Closed Cycle Construction' is being piloted in the Netherlands. The original constituents of building waste (clay bricks, gravel, sand, cement stone) are recovered in thermal processes. The mixed C&D waste streams are separated and decontaminated using dry separation techniques. The quality of the stony fraction is improved so much, that this fraction can be reused as an aggregate in concrete. The new concept uses less energy, has lower carbon dioxide emission, produces less waste and saves on land use (for excavation and disposal sites). The thermal process steps are fuelled with the combustible fraction of the C&D waste itself. Economically the new process is more or less comparable with the current way of processing C&D waste.[153,154]
- **In-Place Recycling** – Several 'In Place' recycling demonstration techniques are being used in the US. Highway projects in Florida, Louisiana, and Nevada are recycling bituminous materials and granular bases by pulverizing, mixing with cement and water, and compacting into new soil-cement bases. Airport projects in Georgia and Oklahoma crush old concrete for use in cement-treated bases for concrete pavement. Aggregates are conserved and haul costs reduced.[155]

4.9.14 Transport and Collection

4.9.14.1 Current technologies

Until the 1970s kerbside garbage collections were carried out by hand by operators on foot running with conventional rear-loader compactor trucks. When kerbside recycling collections were introduced in the 1980s a similar system of manual collection was also used. Operators separated the contents of open crates putting materials into individual compartments in the collection vehicles. At this time mechanical collection of garbage in wheelie bins by side-lifting vehicles operated by only the driver became more common.

Although the vehicles were more expensive to acquire, they saved on staff costs and reduced occupational health and safety risks. With the advent of materials recovery facilities that separate recyclables at a central facility, recyclables were also collected 'comingled' in wheelie bins rather than in crates. The vehicles used were the same design as those used for garbage. Invariably they were diesel powered.

Since those early vehicles, there have only been small advances in vehicle design, most notable in the area of recycling collection. Vehicle manufacturers have designed lifting arm and hopper mechanisms that reduce the vigour with which recyclables are collected and distance that they have to fall from the bin into the collection vehicle. These advances have been nullified somewhat by the ability of drivers and fleet operators to override these mechanisms.

4.9.14.2 Emerging technologies

The most recent changes in collection vehicle design have revolved around the fuel they use. In the quest for zero-emissions, electric and hybrid-powered vehicles are coming onto the market. Traction

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[153] Mulder, Evert; de Jong, Tako P.R. and Feenstra, Lourens (2007) *Closed Cycle Construction: An integrated process for the separation and reuse of C&D waste* Waste Management 27 (10) pp 1408-1415

[154] *To closed material cycles for concrete and masonry construction* - http://www.kringbouw.nl/kringbouw/data/publiek/nieuws/bestand_Docublad%20Kringbouw%20engels.pdf

[155] Kuhlman, Robert H. (1989) *Soil-Cement from Recycled Pavement Bases and Surfaces* Concrete International 11 (5) - http://www.concreteinternational.com/pages/featured_article.asp?FromSearch=True&keywords=recycling&srchtype=ALL&ID=3455

batteries provide continuous power over longer periods and are used for transport and industrial applications. Despite improvements in traction battery design, electric vehicles still cost more to buy, take longer to refuel and have a limited operating range.

A number of manufacturers such as Isuzu, Mitsubishi-Fuso, Hino and Mercedes-Benz have a diesel-electric hybrid power option in their ranges. Options to power electro-hydraulic bin lifters include a hydraulic power pack, charged by a small petrol auxiliary engine converted to LPG fuel, that could be used while the truck was driving between bin collection stops, then shutting down, when stationary.[156]

Volvo has developed a hybrid 6 x 2 rear steer truck chassis, fitted with a Geesink Norba 'plug-in' hybrid compaction refuse collection equipment. This means that there is a hybrid power system for the chassis and another for the compactor and bin lifters. The compactor and lifter hydraulic power system had an independent battery pack that is primarily charged overnight and topped up by the truck engine. This then powers the hydraulics. Even when the truck is stopped there is enough power to make up to 1000 bin lifts and enough compaction cycles to last an eight hour shift without any additional charging from the engine.

The hybrid chassis power is more useful in city streets where in slow speed stop/start situations the internal combustion engine is automatically shut down, and the drive comes from the electric motor powered by the battery pack. If required, pressing the accelerator will automatically start the internal combustion engine and engage drive. The diesel engine and an electric motor can alternate in use or be used in tandem. The electric motor is designed to be used when the vehicle is going slow or accelerating and is said to cut fuel consumption by 15-20%. An extra battery with a plug-in recharging facility to power the ancillaries also cuts an extra 10-15% off the fuel consumption.

The vehicle makes virtually no noise while in operation, emit no exhaust while under electric power and have low carbon emissions. The plug-in compactor system can be fitted to existing conventional diesel truck chassis.[157]

4.10 Other Waste Innovations

4.10.1 Regulation and Guidelines

Governments and regulators have taken a number of different measures to control waste disposal and encourage recovery. These have included direct regulation but also other measures.

4.10.1.1 Waste to Energy

The increasing popularity of waste to energy (WtE) technology in Europe has seen necessary regulatory shifts to accommodate the opportunities that it can deliver. By 2006 there were about 370 WtE plants in Europe treating 59 million tonnes of municipal solid waste per year. One of the complicating factors of WtE is that it falls into both waste and energy policy areas. Investment in this technology requires extensive planning and regulatory and policy certainty. Several new pieces of European legislation address these issues.

[156] *Electric Vehicle Developments* (2009) Waste Management World 16 July - http://www.waste-management-world.com/display_article/366326/123/ONART/Display/none/1/Electric-Vehicle-Developments/?dcmp=WMW_NEWS

[157] Bates, Malcolm (no date) *Driving the future* Waste Management World - http://www.waste-management-world.com/display_article/364854/123/CRTIS/none/none/1/Driving-the-future/?dcmp=WMW_NEWS

The Waste Framework Directive (WFD) specifies the exact criteria that WtE plant operators must fulfil for their plant to be classified as an 'energy recovery' operation, putting them higher up the waste hierarchy than waste disposal. This also gives an incentive for plants which do not yet achieve the thresholds of the WFD to improve energy efficiency.

The Industrial Emissions Directive looks forward to the amalgamation of several other directives relating to incineration and pollution control, to standardise methods for calculating emissions levels. It does not set emissions limits, which will be left to authorities in member states.

An 'Energy Package' of three proposals is now before the European Commission. These go towards achieving the EU's targets of 20% energy from renewable sources, plus 20% reduction of CO_2 emissions, by 2020. The package includes a directive on the promotion of the use of energy from renewable sources, a directive to improve and extend the greenhouse gas emission allowance trading system and a decision on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments.

As always there is disagreement between the members, for example some members would like waste facilities included in the EU Emissions Trading System. There is also concern about the proposal to change the definition of biomass, which if approved would define biomass as 'separately collected', material. This would mean that residual material that remains after source separation and recycling would not be included. This has implications for the production of energy from the biodegradable part of municipal waste which is recognised as renewable energy under another directive.[158]

4.10.1.2 E-waste

The quantity and potential toxicity of electronic waste has prompted regulatory intervention in a number of cases. Most well known is the WEEE Directive in Europe, although there is mixed opinion on how successful it has been.

Without no Federal legislation or direction in the US, some individual states have developed their own e-waste legislation. At April 2007 Arkansas, California, Maine, Massachusetts, Minnesota, New Hampshire and Rhode Island had all banned e-waste to landfill and California, Maine, Maryland and Washington had comprehensive e-waste recycling legislation.[159] California's *Electronic Waste Recycling Act* is modelled on the European WEEE (Waste Electric and Electronic Equipment) and RoHS (Restriction of Hazardous Substances) Directives[160] and includes advanced recycling fees, up-front payments made by consumers that cover the cost of recycling the computer they have just bought. In addition, many states have commenced e-waste collection and recycling systems for the residential and business sectors.[161]

In May 2009, Indiana passed major electronics recycling law which includes a 'producer take-back' scheme. All manufacturers of TVs, monitors and laptops must collect and recycle 60% of the volume of

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[158] Stengler, Ella (2009) *WTE and the law - Keeping track of WTE legislation* Waste Management World - http://www.waste-management-world.com/display_article/348562/123/ARCHI/none/none/1/WTE-and-the-law---Keeping-track-of-WTE-legislation/

[159] Davis, G. and Herat, S. (2008) *Electronic waste: The local government perspective in Queensland, Australia* Resources, Conservation and Recycling 52, pp 1031–1039

[160] Billinghurst, Betsy M. (2005) E-*Waste: A Comparative Analysis of Current and Contemplated Management Efforts by the European Union and the United States* Colorado Journal of International Law and Policy 16 pp 399

[161] Kahhat, Ramzy; Kim, Junbeum; Xu, Ming; Allenby, Braden; Williams, Eric and Zhang, Peng (2008) *Exploring e-waste management systems in the United States* Resources, Conservation and Recycling 52 pp 955–964

products they sold the previous year in Indiana. After two years manufacturers that have not achieved these targets will pay additional recycling fees.[162]

In Turkey laws have been enacted to comply with EU Directive 2006/66/EC that regulates the labelling and marking of all battery and accumulator products and reduces harmful substances in their production, transport and disposal. The law only covers commercial and industrial uses, not household uses.

The US state of Rhode Island has established a manufacturer-financed collection, recycling and reuse system for electronic waste that covers new computers, televisions and monitors. Manufacturers that do not comply with the new law are banned from selling in the state.[163]

4.10.1.3 Waste Definitions and Standards

Changing the legal definition of waste can change responsibilities for certain wastes and how they are handled. In October 2008 the US EPA did this by changing the definitions of hazardous waste in the regulation of hazardous secondary materials. The regulation excludes materials from the federal hazardous waste system if they are used or sent for legitimate recovery. The aim of this measure was to encourage recycling. Metals and solvent recycling will be most affected.[164]

Industry has also moving towards standardising waste. The European Recovered Paper Association (ERPA), the European Federation of Waste Management and Environmental Services (FEAD) and the Confederation of European Paper Industries (CEPI) have implemented the Recovered Paper Identification System. Recovered paper suppliers can register for a unique code to be added to their recovered paper bales to enable the suppliers of paper purchased, received, stored and consumed in paper mills to be identified. This will makes sure that the right raw materials are used to produce high quality products. Previously bilateral agreements had been in place that varied from company to company and country to country. This system will be used across Europe and the world so that the supplier and grade of every bale of recovered paper is clearly identified and recorded.[165,166]

4.10.1.4 AWT Risk Assessment Guidelines

The UK Environment Agency has funded the development of tighter risk assessment procedures for composting and organic waste treatment sites as a result of concern over the impact of waste processing issues such as odour and bio-aerosols. The new guidelines will change the way UK waste operators carry out their risk assessments. Only new sites are likely to be affected.[167]

4.10.1.5 Simplifying Regulation

The Scottish Environment Protection Agency has simplified its waste law into three sets of regulations:

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162 *Indiana adopts WEEE recycling* (2009) Waste Management World 19 May - http://www.waste-management-world.com/display_article/362665/123/ARTCL/none/RECYG/1/Indiana-adopts-WEEE-recycling/

163 *RI Seeks to Limit Electronic Waste* (2008) Recycling Magazine Number 7 - http://www.recyclingmagazin.de/epaper/rm0026/default.asp?ID=5

164 *US EPA redefines waste to encourage recycling* (2008) Waste Management World 8 October - http://www.waste-management-world.com/display_article/341941/123/ONART/Display/none/1/US-EPA-redefines-waste-to-encourage-recycling/

165 *CEPI launch Recovered Paper Identification System* (2008) Waste Management World 10 November - http://www.waste-management-world.com/display_article/344869/123/ONART/Display/none/1/CEPI-launch-Recovered-Paper-Identification-System/

166 Recovered Paper Identification System - www.recoveredpaper-id.eu

167 *Tighter control on risk assessment* (2008) Waste Management World 28 November - http://www.waste-management-world.com/display_article/346478/123/ONART/Display/none/1/Tighter-control-on-risk-assessment/

- the Producer Responsibility (Packaging Waste) Regulations;
- the Waste Electrical and Electronic Equipment Regulations (WEEE); and
- the Trans Frontier Shipment Regulations (TFS).

The regulations reduce the amount of reporting required and avoid duplication.[168]

4.10.1.6 Waste Facility Guidelines

The UK Department of Environment Food and Regional Affairs (DEFRA) and the Commission for Architecture and the Built Environment (CABE), have released design guidelines for organisations interested in developing or building waste facilities. The guidelines cover all types of waste facilities from small community and municipal compost units to large-scale heat and power generators and provide advice on key design principles, best practice and consulting the public.[169]

4.10.1.7 Bans and Prohibitions

In order to stimulate recycling and promote safer handling and disposal, Metro Vancouver[170] has banned cardboard, paper, gypsum, car batteries, paints and solvents, flammable liquids and gasoline, pesticides, tyres, oil and oil filters, green waste, beverage containers, pharmaceuticals and electronic waste from landfill.[171]

China's State Council has prohibited shops, supermarkets and sales outlets across the country from handing out free plastic bags and has banned the production, sale, and use of ultra-thin plastic bags under 0.025 millimetres thick. Penalties include closing businesses down, fines and confiscation of goods and profits.[172]

Shop keepers and other businesses in the town of Bundanoon in NSW, have agreed to ban bottled water from being sold in local shops. Local councils across Australia may also ban sales of bottled water in order to reduce the amount of plastic bottles generated and disposed of. There are no plans to ban the sale of other drinks and products sold in plastic bottles.

4.10.1.8 Buy Back Schemes

To encourage Canadians to stop using old polluting vehicles, the Canadian Government has set up a US$ 92 million fund to reward those who voluntarily scrap their vehicles.[173]

Computer manufacturer Dell has launched a program in the US that encourages people to return old computers to any Goodwill charity store. Items in decent shape are resold in store. Devices in need of

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168 *SEPA improves waste regulations* (2009) Waste Management World 19 February - http://www.waste-management-world.com/display_article/353800/123/ONART/Display/none/1/SEPA-improves-waste-regulations/

169 *Guidance on WTE and biomass facilities released in the UK* (2008) Waste Mangement World 5 November - http://www.waste-management-world.com/display_article/344522/123/ONART/Display/none/1/Guidance-on-WTE-and-biomass-facilities-released-in-the-UK/

170 A group of 22 municipalities in the Vancouver region that provides services, utilities and planning - http://www.metrovancouver.org

171 *Metro Vancouver cracks down on recycling and hazardous waste* (2008) Recycling Magazine Number 1 - http://www.recyclingmagazin.de/epaper/rm0020/default.asp?ID=4

172 *Plastic in China - Will Market Tools Change Old Habits?* (2008) Recycling Magazine Number 5 - http://www.recyclingmagazin.de/epaper/rm0024/default.asp?ID=16

173 *The Canadian Government Launches Vehicle Scrapping Program* (2008) Recycling Magazine Number 17 - http://www.recyclingmagazin.de

repair are either refurbished or broken down to salvage as scrap and recycled by Dell partners. Dell also operates an online exchange tool that allow consumers to calculate the trade-in value of used electronics regardless of the brand. When traded in Dell sends gift cards to that value.[174]

4.10.2 Government Grants

Apart from direct or indirect regular, governments can also influence the direction of waste policy by distribution of funding.

Michigan State University received state and foundation grants of more than $3 million create affordable waste to energy systems for small and medium-sized farms by developing technology that will convert animal waste into heat, electricity and other commodities.[175]

With most plastic collected in Scotland currently being sent to Asia for processing, the Scottish Government has made available £5 million in grant funding to ensure the development of new plastics recycling facilities. Funding from a grant can cover up to 30% of the total investment required for a plant and is operated through the Scottish arm of the Waste & Resources Action Programme (WRAP).[176]

WRAP in Scotland has also launched capital grant program to increase the recovery of the non-inert fractions (timber, plastics, packaging and soils) of construction and demolition waste in Scotland. The aim is to help recycling companies develop capacity for these materials.[177]

The European Union also makes grant finding available. One of its initiatives is the LIFE program, which funds demonstration projects that develop and test innovative solutions to environmental problems. The aim is that it will fit between research and development and large scale applications. Project areas to have received funding included; waste collection, recycling, reuse and recovery, hazardous waste, municipal waste, packaging and plastic, agricultural waste, electronics and end-of-life vehicles.[178]

4.10.3 Partnerships and Joint Ventures

Companies and organisations that are otherwise involved in different fields are partnering to explore opportunities in the waste industry.

As examples, in the US, Valero Energy Corp is investing in Terrabon, a waste to energy company that is testing technology that will produce liquid fuel from waste and biomass. Valero's funds will be used to

[174] *Dell online tool for consumers with e-waste* (2009) WME 12 February - http://www.environmentalmanagementnews.net/storyview.asp?storyid=1002470&sectionsource=s0

[175] *Michigan State University to develop WTE projects* (2008) Waste Management World 10 November - http://www.waste-management-world.com/display_article/344863/123/ONART/Display/none/1/Michigan-State-University-to-develop-WTE-projects/

[176] *Scotland releases £5 million in funds to aid plastics recycling* (2009) Waste Management World 12 March - http://www.waste-management-world.com/display_article/355991/123/ONART/Display/none/1/Scotland-releases-pound;5-million-in-funds-to-aid-plastics-recycling/

[177] *Wrap Capital Grant Program Recycles Construction Waste* (2008) Recycling Magazine No 22 - http://www.recyclingmagazin.de/epaper/rm0041/default.asp?ID=5

[178] *LIFE: supporting and evolving waste policy* (2008) Recycling Magazine Number 03 - http://www.recyclingmagazin.de/epaper/rm0022/default.asp?ID=6

accelerate the commercial roll-out of Terrabon's alcohol from waste technology. This ties in with Valero's purchase of seven VeraSun Energy plants to make it the US's largest ethanol owner.[179]

In another case, the World's largest waste company, Waste Management Inc, has partnered with InEnTec to develop and operate a plasma gasification plant using InEnTec's Plasma Enhanced Melter technology. The plant will process waste from commercial and industrial sources to produce renewable energy.[180]

Three major manufacturers of electronic goods, Sharp, Panasonic and Toshiba, have established a company called MRM in the US to manage electronic waste recycling and collection programs. The service is available to other electronics manufacturers as well as state and local governments.[181]

4.10.4 Waste Transfer Station Design

4.10.4.1 Principles of Transfer Station Design

Waste transfer stations were traditionally designed to bulk up and compress wastes in the most efficient way possible, so that they could be cost effectively transported to a landfill site in larger vehicles. This enabled the waste collection vehicles, which are designed for stop/start operation, but not long haul, to continue their collection runs after disposing of their loads. Therefore little thought was given in terms of space or logistics for resource recovery.

This has been changing as recycling has been developing and most new transfer station designs, especially in rural areas, have designated bins and areas for resource recovery activities for. Pricing policies enable residential and some small commercial customers to dispose of separated materials at reduced or zero cost. The price differences between segregated wastes and mixed waste disposal encourage customers to separate their wastes before arriving at the facility. The variety of solutions adopted by regional councils in NSW and elsewhere are outlined in references such as the Handbook for Design and Operation of Rural and Regional Transfer Stations published by the Department of Environment and Conservation (NSW)[182]

Many transfer stations are located on or within the boundaries of former landfills. If the constructed over an old landfill site, the design must also consider ground stability and differential settlement. Innovative design and construction considerations have been built into facilities located on former landfill sites to allow for ground movement, requirements for raising buildings and structures off ground-level and landfill gas vents.[182]

There is no standard for waste transfer station buildings. Design trends however are heading towards simplifying and standardising facilities. As an example, open and open-sided buildings are often preferred because they save costs on materials such as roller doors and there are fewer structures for vehicles to hit, reverse into or otherwise damage.

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[179] *Oil refiner invests in WTE* (2009) Waste Management World 19 May - http://www.waste-management-world.com/display_article/362612/123/ONART/Display/none/1/Oil-refiner-invests-in-WTE/

[180] *WM and InEnTec announce joint venture* (2009) Waste Management World 24 June - http://www.waste-management-world.com/display_article/365159/123/ONART/Display/none/1/WM-and-InEnTec-announce-joint-venture/

[181] *Electronic brands form new Recycling Company* (2008) Recycling Magazine Number 2 - http://www.recyclingmagazin.de

[182] Handbook for Design and Operation of Rural and Regional Transfer Stations Department of Environment and Conservation (NSW, 2006)

Modern transfer stations not only also include drop off facilities for a range of recyclable and recoverable materials but often a suite of waste-related features such as areas for customers to drop off hazardous materials such as e-waste and chemicals and potentially reusable materials such as timber, bricks, second hand toys, bric-a-brac, books and homewares, education and awareness centres and materials recovery facilities. In some cases, a contract is let for a second hand business to operate at the site with scavenging rights for the operator included in the contract.

Depending on the size of the transfer station, customers can deposit directly into bins or pits, or into a separate open area that is swept by a loader or other plant.

The most important part of a transfer station is the circulation pattern. This allows collection vehicles to move quickly and safely through and out of the facility.

Other important design elements include:

- Having one or more queuing lanes before the weighbridge to accommodate traffic;
- A bypass lane next to the queuing lane for transfer truck and emergency vehicle access;
- A layout that accommodates different users. Some need to be able to reverse to the tipping area while others can drive straight in;
- Separate areas for public and commercial or small and large vehicles;
- Building orientation so that openings do not face public streets or into dominant wind directions;
- An area to reorient roll-on-roll-off bins before or after tipping;
- Additional space for other drop-off services away from the main building circulation routes;[183]
- Parking and unloading areas should be level to prevent runaway vehicles;
- The prevailing natural topography of the site should be used wherever possible to take advantage of existing wind barriers and visual screens;
- Drop-off points for recyclables and reusable items should be located before the mixed waste drop-off point;
- Where separation of recyclables and recoverables is required, more space given to recycling and recovery areas than for general waste disposal encourages recycling;
- Providing adequate space in the facility so that customers waiting to enter do not interrupt traffic flows on public roads, nearby residents or businesses or general operation of the facility;
- Intersections between entry roads and public roads should designed for safe use;
- Traffic flow in the facility should be one way;
- Gatehouse and weighbriodge operators should be able to;
    - See approaching traffic in both directions (vehicles accessing and leaving the site);
    - See wastes loads from the seated position;
    - Prevent vehicles from entering before data is recorded and fees paid;

[183] Bukojemsky Stefan (2003) *TRANSFER: Transfer Station Design Tips* Waste Age 1 January - http://wasteage.com/mag/waste_transfer_station_design/

- Talk to customers without having to leave the gatehouse building;
- Design features that can achieve this include;
  - Closed circuit television;
  - Gatehouse windows adequately positioned;
  - Alarms to indicate when vehicles are in position;
  - Boom gates to control access to the site;
  - Adequate signage;
- At least one and preferably two weighbridges should be installed with suitable weighing and recording software;
- Weighbridges should be;
  - the length and capacity for the longest and heaviest vehicle that uses the site;
  - sited far enough inside the site to allow for queuing onsite and a straight approach;
- Weighbridges and appropriate software allow;
  - Electronic recording of exact type and quantity of materials disposed of;
  - Consistent application of fees by load weight;
  - Ability to set and change fees for different waste types;
  - Greater understanding of type and volume of materials deposited; and
  - Increased possibility to identify opportunities for improved resource recovery.
- Hand-held data recording devices can also used as an alternative to a weighbridge at small sites to record waste quantities, types and fees and issue customers with receipts.[184]

4.10.4.2 Vertical Transfer Stations

In the 1980s, Netherlands-based NCH Hydraulic Systems developed a vertically operating waste transfer station. The system works by waste being deposited in the top of a vertical container. The weight of the materials deposited provides compaction. The main advantage of the system is that it saves space.

A number of vertical transfer stations are operating in the Netherlands, Australia, the Caribbean, Turkey, Chile, China and Malaysia, with capacities ranging from 350 to 7,000 tonnes per day. The Jingan District Waste Transfer Station in the centre of Shanghai is one of these and handles about 400 tonnes of waste per day. The world's largest vertical transfer station is in Santiago de Chile. This transfer station handles 6,000 to 7,000 tonnes per day and up to 10,000 tonnes in peak-periods.[185]

4.10.5 Other Innovations

4.10.5.1 Web-based waste and recycling data collection tool

Return is a new web-based waste and recycling data collection tool that has been designed to assist local governments to manage their waste data. It allows waste managers to measure collection and

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[184] GHD (2006) Handbook for Design and Operation of Rural and Regional Transfer Stations Department of Environment and Conservation (NSW)

[185] NCH Hydraulisc - http://www.nchhydraulic.nl/index.php?id=12

recycling details through a single web interface. The tool records waste data from all household, commercial and industrial sources and contracts. The software offers benefits such as capturing invoice details and weighbridge return data and relating it to vehicle routes, recycling schemes as well as comparing recycling and landfill data. These reports allow users to understand how routes perform and record the impact of recycling schemes on recycling performance.[186]

4.10.5.2 Reusable Containers

In the UK, supermarkets are trialling reusable packaging programs where shoppers can buy some products in reusable pouches that can be refilled up to 10 times at no extra cost. Reduced costs, greenhouse emissions and waste and increased customer loyalty are seen as the main benefits. Similar trials are expected in the home improvement sector where a trial is being conducted that encourages tradespeople to return empty paint containers in-store for cleaning and refill.[187]

[186] *Return: A new innovation in waste data knowledge* (2009) Waste Management World 10 (5) - http://www.waste-management-world.com/display_article/364849/123/CRTIS/none/none/1/Return:-A-new-innovation-in-waste-data-knowledge/

[187] *Shoppers can choose to reuse* (2009) WME 13 July - http://www.environmentalmanagementnews.net/StoryView.asp?StoryID=1003532

5. Applicability of Technologies to Local Contexts

When assessing the applicability of technologies to the local context, consideration must be given not only to the particular local situation but also the associated collection and disposal systems. Solutions should be thought of in terms of integrating collection, processing and disposal systems. To that end, a simplistic model for integrated municipal systems is suggested below.

Table 21 Suggested models for integrated municipal systems

Situation	Characteristics	Collection	Processing	Disposal
Inner City	Medium to high density housing, small land size, narrow streets and lanes, little storage space for bins, small or no gardens, low per household population, close to established markets and processing, viable quantities.	Two bin kerbside collection system, MSW and recyclables	MBT with anaerobic digestion for MWS, MRF for recyclables	Residual low grade compost for land rehabilitation or daily cover
Suburban	Low to medium density housing, large land size with gardens, wide streets, large suburbs, higher per household population, close to established markets and processing facilities, viable quantities.	Three bin kerbside collection system, mixed food and garden organics, recyclables and residual	Organics to aerobic processing facility, recyclables to MRF, residual to waste to energy facility	Residual to landfill
		Three bin kerbside collection system, garden organics, recyclables and residual including food	Green waste to aerobic composting, recyclables to MRF, residual to anaerobic facility	Residual to landfill
Regional Cities	Low density housing, large land size with gardens, wide streets, high distance to established market for recyclables, low distance to regional processing facilities, viable quantities, close to agricultural market.	Three bin kerbside collection system, mixed food and garden organics, recyclables and residual	Organics bin to regional aerobic processing, recyclables to MRF, residual to waste to energy facility	Residual to landfill. Valuable separated recyclables to market, others monofilled
		Three bin kerbside collection system, garden organics, recyclables and residual including food	Organics to regional aerobic composting, recyclables to MRF, residual to anaerobic facility	Residual to landfill. Valuable separated recyclables to market, others monofilled
Rural Settlements	Very low density housing, large land size with gardens, wide streets, high distance to established market, medium distance to regional processing facilities, quantities not viable.	Bank-of-bins system at central location for residual. Drop off at transfer stations for recyclables.	Home compost food and garden waste. Recyclables to MRF.	Residual bin to landfill. Valuable separated recyclables to market, others monofilled

6. Key emerging innovations, trends and opportunities

6.1 Drivers

Increases in the cost of landfilling and community pressure to avoid landfilling and increase recovery are the driving forces behind innovation in waste management and technology is the means by which this is being brought about.

Previous emphasis has been on the source separation of materials, and the necessary associated education campaigns, in order to keep materials pure for the most efficient processing. This reasonably passive approach could be tolerated when landfill disposal costs were low. Diversion was high for some easily separated materials of high value but the deficiencies of this approach became obvious when landfill costs increased and attention turned to lower value and logistically problematic materials such as food.

Now the clear trend in municipal and commercial waste collection is to collect materials mixed or with limited source separation. These limited mixed streams are processed at facilities that often use a combination of technologies such as initial mechanical separation followed by biological treatment of the organic fraction. This has long been the case overseas where landfill costs are high and there are additional regulatory drivers.

6.2 New Technologies and Combinations

There is likely to be a growing acceptance of thermal technologies in Australia as the level of sophistication increases and there are more examples of proven performance in advanced economies overseas. Thermal technologies have advanced considerably since early mass burn incinerators however, it is the mass burn idea that still inhabits the community consciousness whenever the issue of waste to energy is raised. It is likely that future AWT facilities built in Australia will incorporate some form of thermal technology, possibly utilising refuse derived fuels produced in the plant from the residual materials.

There has also been encouraging changes in the way that overseas technology is adapted and used in Australia. While reasonably mature ‘off-the-shelf’ technologies are still most common, there has been some success in the establishment of facilities that combine different technologies, not all from the waste sector, in new ways. Global Renewables’ UR-3R facility in Sydney used a unique combination of a European digester with mining technology to separate and process mixed waste and AnaeCo has used a new locally developed hybrid aerobic/anaerobic system in its Perth facility.

Wherever the cost of landfilling is high, higher cost technological solutions become economically viable. The shift away from landfilling to technological processing has been most pronounced in the municipal sector of these markets where there are significant quantities of homogenous material available from a small number of sources.

6.3 Commercial Waste

The diversion challenge is greater in the commercial sector which has similar large quantities but which are heterogenous and generated from thousands of sources. In addition, and far more than the municipal sector, the C&I sector is driven by economics.

In Australia, a destination-based approach to the C&I sector using separation technology is the most likely viable means of recovering significant proportions of this stream. Without government intervention, this will only happen where landfill costs are high enough to make investment in technology worthwhile.

Currently only Sydney approaches this situation (landfill costs have now exceeded $176/tonne) and it is most likely that there will be a significant a number of C&I waste processing facilities coming on line in Sydney over the next 5-10 years. Most of these facilities will use or adapt proven technology from overseas to sort dry materials, with wet materials such as food collected separately and processed in biological treatment plants. Like current municipal AWT facilities, these new plants would use a combination of technologies to handle and process more materials to the greatest extent possible. It is also likely that different technologies would be implemented at different facilities.

6.4 Technology Financing

Finance for any particular AWT facility is normally provided by banks in the form of a long term loan. Tightening of lending policy as a result of the global financial crisis may affect the future ability of companies developing new AWT facilities to obtain finance for their projects. The only Australian markets in which new AWT facilities are being considered are Sydney, Melbourne and Perth. No new facilities requiring bank funding are currently being developed in Perth.

The Victorian State Government's plans for AWT are only in early planning stages and are likely to be Government backed in any case. In Sydney, two facilities are under development whose progress might have been affected. These are the SHOROC facility (to be built at Kimbriki) and the Woy Woy MMF being built for Gosford and Wyong Councils.

Whether particular AWT projects obtain financing largely depends upon the contract conditions and the performance requirements and the method of payment. In many contracts, there is a complicated formula which determine the monthly payments to the operator based on key performance indicators such as the amount of material processed, diversion from landfill, hours that the plant operated, number of environmental complaints. In some cases, it has taken many months for the project to reach financial close, because of the lack of understanding of the financiers about the lack of certainty associated with certain aspects of the operations, including the ability of the compost products to be sold, reliability/availability of the processing equipment, and the ability of the process to guarantee maximum physical or chemical concentrations in the compost product.

The financial crisis has has a direct effect on the recycling industry through the drop in commodity prices. This has only really had an effect on those with a majority of their business in the recycling environment, especially where income from the sale of commodities is a key element. However

6.5 Legislation and Regulation

Changes in legislation and regulation seem to have two main drivers. The first is the advent of new kinds of waste such as electronic waste. The large quantities, increasing rates of disposal and potential toxicity of these materials has forced many governments to implement a variety of mechanisms to encourage their recovery and reduce potential hazards. These measures have included landfill bans, deposit and buy back schemes, collection service provision and partnerships.

The other driver has been the advent of new waste processing technologies. Waste to energy for example, is both a method of waste disposal and a way of generating more sustainable power and heat.

In some cases the regulatory environment has had to be changed in order to allow and encourage WtE facilities to be built.

6.6 Hazardous Waste

Little attention has been paid in the past to household hazardous waste. Small quantities from millions of source households and businesses could be easily disposed of in the conventional waste stream. Over the past 30-40 years however, there has been a steady increase in awareness of the toxic nature of many familiar and household items and materials. This has coincided with an exponential increase in that time in the number of electronic items and household appliances with electronic components being used and requiring disposal. Many people are now aware that everyday items such as tyres, light globes, computers and treated timber have characteristics and toxic components that make safe recycling and disposal difficult.

There have been satisfactory disposal and recycling options for few of these materials and they mostly consisted of manual and simple mechanical separation of components. New research however, and the development of novel chemical, biological and other techniques, such as microwaving, is creating safer and more efficient ways to disassemble and extract the valuable materials and neutralise the dangerous elements of these materials.

6.7 Green Design

6.7.1 Manufactured Goods

Australia is a net importer of manufactured goods and manufacturing that does take place here is often the assembly of imported components, for example in the automotive industry. As a result there is limited opportunity to apply green design principles directly to manufactured goods in the way that the WEEE Directive did to electronic goods in Europe. Despite this, some countries are considerably more advanced in the area of green design and Australia benefits from this when we import and use their goods. One way to encourage green design would be to impose sale or import restrictions on those products that do not meet certain green design principles in same way that goods sold in Australia must meet certain safety standards.

6.7.2 Construction Industry

Waste from the construction and demolition industry forms a significant proportion of all waste generated in Australia. The reduction and recycling of this waste is one area that green design could go some way in achieving. In Australia we are seeing a greater emphasis on green building design and operation with increasing specification of Green Star standards and the development of the Australian NABERS program.

The Green Star rating system maintained by the Green Building Council of Australia and covers the environmental design and construction of buildings. Green Star has nine standard categories such as Indoor Environment Quality, Energy and Transport. Points are awarded for achieving credits in each category. A maximum of 120 points is available from which a formula calculates the overall score and what star rating is achieved out of a maximum of six stars. Waste is covered in the Materials category and points are awarded for building and materials reuse, shell and core fit out, use of concrete and steel, minimising PVC, use of sustainable timber, design for disassembly and recycling waste storage. A maximum of 22 points is available in the Materials category. Up to two waste points are also available in the Management category where the waste contractor implements a Waste Management Plan and up to 80% of all demolition and construction waste is reused or recycled.[188]

The National Australian Built Environment Rating System (NABERS) applies to existing office buildings, hotels and homes and does not cover the design or construction phase. It works by measuring operational impact and covers energy, water, waste and indoor environment. The waste element of NABERS measures the amount of materials generated, how much of it is diverted from landfill and provides a rating of up to five stars.[189]

To further encourage waste minimisation and recovery in both the design and construction and operational phases of building use, the weighting given to waste in these schemes could be increased.

[188] Green Building Council of Australia - http://www.gbca.org.au/

[189] National Australian Built Environment Rating System - http://www.nabers.com.au/

7. Market and non-market barriers

7.1 Market Barriers

By far the most obvious market barrier to innovation in waste management is the low cost of landfilling in many areas. In markets where landfilling costs are high, such as Sydney, a number of AWT facilities are operational and in the planning stages. It is expected that in the next ten years not only will all municipal waste generated in Sydney be processed through AWT facilities, that there will also be a number of facilities for the separation of the C&I stream and the processing of some of its components.

A key element in the high price of landfilling in Sydney has been the NSW Waste Levy. The NSW levy is currently over $50 per tonne and AWT is an increasingly common form of municipal waste processing. In Melbourne, where landfilling prices are currently quite low and the waste levy is only $15 per tonne, there are virtually no AWT plants at present. However, the Victorian Advanced Resource Recovery Initiative (VAARI), which commenced in early 2009, intends to investigate the most appropriate way to establish up to 8 AWT facilities across Greater Melbourne. It aims to contribute to a target of recovering 65% of municipal solid waste by 2014. The scheme includes consideration of the adequacy of existing waste collection systems to match the proposed AWT processing of collected wastes. _

Gate fees for Sydney's putrescible transfer stations are around $190-$200 per tonne. This makes the treatment of waste, the estimated cost of which is $100-$140 per tonne, much more cost effective than landfilling. Even in Sydney, where landfill charges are the highest in the country, the cost of waste disposal for businesses is still relatively low compared with other more significant operating costs, such as labour and rent.

Planning for sufficient AWT facilities to be commissioned and operating in the Greater Sydney Metropolitan Area is not sufficiently advanced for the NSW Waste Strategy targets for municipal waste to be achieved before their 2014 target dates. There are also insufficient economic drivers to force commercial wastes to be diverted to AWT facilities, so it is unlikely that the commercial waste targets will be met either.

Most of the AWT plants built in Australia so far have been funded by private consortia and waste companies either responding to tenders from local government or asking local government to enter 10-20 year contracts. These are needed to provide the surety with which to fund the construction and operation of the facilities. Local government contracts with AWT providers range from 10 to 20 years and are for financing, construction and operation of the AWT facility. The council(s) agrees to direct all municipal waste that they or their contractors collect to the plant for the contract period. They often also pay an availability fee to cover the financing costs of the plant and an agreed rate per tonne for waste received. In some cases, councils have also provided the land and environmental approvals for the successful tenderers.

Different funding models of alternative waste technology plants are being explored. Private organisations can enter into BOO (build, own, operate) projects in which they build the plant, own it and operate it accepting waste from customer councils. Private organisations and governments can also form partnerships in BOOT (build, own, operate, transfer) projects in which they build the facility, own it and operate it for an agreed period or until agreed standards or benchmarks are reached and then ownership is transferred to the client council.

7.2 Non-Market Barriers

GHD has identified four main non-market barriers to the uptake of innovation and new waste processing technologies in local government; the requirement for more co-operation between councils, a distrust of AWT, a fear of thermal technologies and a fear of committing to inappropriate or outdated technology.

The high cost of AWT processing means that AWT facilities operate more efficiently and with lower costs per tonne if certain quantities of waste are processed through them. Individual councils cannot often provide these quantities so AWT facilities usually must accept waste from more than one council. Sometimes facility operators proceed with the project on the basis of one or more 'foundation' councils, then sign others up as time goes on. In other cases, groups of councils co-operate to engage or contract a service provider to build and operate an AWT facility with the councils delivering the required quantities of waste. An example of this was the Macarthur Region in south west Sydney, with its MACROC tender.

While councils often co-operate on a range of issues and regional council groups are common and usually work well, signing a joint processing contract worth at least $100M over 15 years requires a considerable commitment from councils to work together, and involves them surrendering a significant degree of control over a key service that they are used to providing independently. In the MACROC example, the councils involved were all independent customers of WSN, that operated the landfill at Jacks Gully, and they were already reliant on a service provider for waste disposal, so a joint contract was not a significant cultural change.

There is also a significant distrust of alternative waste technology, often with good reason. While most AWT plants function quite well on a technical level, low gate fees from competitive bidding on the original contract, combined with unexpected expenses for refining what is often a relatively new and innovative process have resulted in several facilities failing to provide the returns on investment that were originally envisaged. Global Renewables sold its UR-3R facility in 2008 and the Bedminster plants in Cairns and Port Stephens were sold to SITA. The Atlas plant in Perth has also closed down. The Southern Metropolitan Region of Councils took over the plant that was designed and built by Bedminster, after a number of technical issues could not be satisfactorily resolved.

The Wollongong SWERF project is often cited as AWT's most spectacular failure The $25 million SWERF (Solid Waste to Energy Recycling Facility) was opened in January 2001 and planned to use gasification and pyrolysis to process 90% of Wollongong's waste and supply electricity to 24,000 houses. Commissioned to serve Wollongong City Council and built next to the Whytes Gully Landfill by Brightstar Environmental, a division of Energy Developments Limited (EDL), it was one of the first facilities to attempt to use this technology. Only test tonnages were ever processed through the plant however, as stack emissions could not consistently meet NSW EPA standards, with the normal variations in waste characteristics. After considerable investment (pumoured to be an additional $100 million) to resolve various technical performance issues, the facility closed in 2004.

The failure of the SWERF and the limited past experiences of mass burn incineration in Australia with the Waverley Woollahra Incinerator have also contributed to a significant reluctance by Councils to embrace complex technologies that are not 'proven'. Adverse reactions from community and green groups to thermal technologies has limited the range of approaches used for processing of municipal wastes. .

Even if councils are willing to implement AWT, there is a view it might be best to wait for a better, cheaper technology that is 'just around the corner'. Continual publicity about new waste technologies in the environmental media creates an impression that any plant that is built today could well be obsolete by the time it is commissioned, 3-4 years after tenders were first issued. As well, there is a need for either the Council to borrow a substantial amount of money to fund the capital infrastructure, or enter a 10-20 year contract with a service provider to amortise the capital costs of the new processing technology.

Councils are generally risk adverse and tend towards safe options but they also want to be seen as leaders and innovators. Waste management is a very visible arena in which they can display this leadership. Councils often take the opportunity that new waste contracts present to have slightly different and more up to date collection systems than their neighbours, often for financial reasons but also for their own sake.

This type of attitude has sometimes resulted in significant friction between councils and contractors and increased costs for both. Brisbane City Council discovered that SITA's innovative single-pass trucks, which collected both garbage and recyclables in the same vehicle, confused residents who thought that their recyclables were being landfilled. Wyong Council introduced a single bin divided for garbage and recyclables and spent the entire contract period in discussions with its contractor over whose fault it was that the recycling was heavily contaminated. Very few councils now implement divided bins and a number have chosen to remove the existing dividers from their recycling bins.

7.3 Role for Product Stewardship

Product stewardship (PS) and extended producer responsibility (EPR) are concepts that require manufacturers of certain products and by extension their importers, distributors and retailers, to take responsibility for the recovery of these products after use. The products targeted by these schemes often have characteristics, such as toxicity, that make them inappropriate to dispose of in the conventional waste system and the recovery programs are often also outside the normal waste collection system.

Typically EPS schemes involve establishing incentives for the recovery of identified items which are redeemed or fulfilled when the items are surrendered after use. An example is the deposit system on drink containers, which is a common product stewardship system in many parts of the world including South Australia. In these cases consumers pay an additional small amount, for example 10 cents, over the normal cost of a drink in a container at a retail outlet. In effect they put a deposit on the container which is returned when the empty container is taken to a designated collection point.

Other EPR schemes also involve up front payments although the deposits are not returned. Televisions and electronic waste in some parts of the world are subject to additional $20 payment at the point of purchase which is used to fund the recovery and reprocessing of the item at the end of its life. A system like this already operates in Australia for the tyre industry, and could be applied to televisions and computers.

In some cases the main incentive for product stewardship is avoiding punishment. The National Packaging Covenant (NPC) in Australia is such a system. Companies that sign the Covenant must produce an action plan that outlines the actions they will take to reduce the amount of packaging they will produce. Those that do not sign or do not fulfil their action plan commitments are subject to a National Environment Protection Measure (NEPM) which imposes comparatively harsh terms and conditions, such as take back provisions.

EPR schemes are useful mechanisms for recovering particular items especially when these items are whole, easily identifiable and the producers are easily identifiable. This is an issue in the computer industry when a large proportion of machines on the market and requiring recovery are so called unbranded 'white box' machines. These machines have been manufactured from individually imported components and are not attributable to a particular brand owner.

Having said that, pilot programs for the recovery of computers have been quite successful. They often take place at, or are associated with, conventional waste disposal sites or utilise waste industry stakeholders such as councils and waste companies. Veolia and Simsmetal jointly run such a schemefor commercial customers. Recycling of the E-Waste equipment is performed at Sims E-Recycling, a joint venture set up between Veolia[190] and the Sims Group. Electronic waste collected undergoes a manual dismantling process. The individual materials such as printed circuit boards, cabling, glass and plastics etc., are recovered and then processed so that they can be used as raw materials to produce new products.

Future EPR schemes could be either outside the normal waste collection chain, like the South Australian deposit system, or part of it, like the pilot e-waste collection schemes. Which works best will depend on the particular item being recovered and what systems are already in place for waste recovery. Municipal and commercial transfer stations, AWT facilities and other waste disposal facilities are obvious and easy collection points for items subject to EPR schemes. Their use for such programs would negate the need, and cost, for separate purpose-built receiving centres and have the ability to capture those items deposited separately or as part of the waste stream.

[190] http://www.veoliaes.com.au/commercial-services/waste-collection-and-recycling/electronic-waste-recycling.asp

8. Findings of the Study

8.1 Introduction

The study directly addresses a number of elements mentioned in the Draft National Waste Policy Framework. A strategic framework of waste management is presented in this report that includes guideline principles, their application to waste management, the waste hierarchy, limitations and needs, integration of solutions, strategy and markets.

Much of this report deals with technological innovation. That is not to say that there has not been anything new outside technological advances, but it is clear from the research done for this project that much faith and many resources are being invested in technological solutions to waste management problems.

On the non-technological side, many “innovations” are variations of existing systems or programs. Cash back programs for e-waste are a variation of deposit systems in use for drink containers for more than 40 years. Genuine non-technological innovation is in fact related to technological innovation and takes the form, in some cases, of new legislative and regulatory regimes to both encourage and control the construction and operation of waste processing facilities or resource recovery schemes.

8.2 Technologies

A range of systems for processing mixed waste have been examined in this study. These vary from composting processes (which are net consumers of energy) to anaerobic digestion processes, which are net exporters of energy. Many of these are mature technologies with plants operating both in Australia and overseas. The applicability of certain technologies depends very much on a range of issues such as waste stream characteristics, distance to markets, the financial situation of local government and waste quantities.

When a mixed waste composting process is geared towards producing a saleable compost, it becomes more complicated and expensive to operate, and the amount of residual material increases, as contaminants are removed from the incoming waste stream or screened from the raw compost to meet higher standards. Mixed waste treatment processes therefore carry a greater risk as far as acceptance of the resulting compost than composting processes that are based on treating separated food and garden wastes.

Anaerobic digestion processes are more technically complex than composting processes, and therefore have a higher capital cost, but they produce a commodity (green energy) that is in high demand. Generally there is less residual material for landfill disposal than comparable composting processes.

Many emerging technologies such as pyrolysis, plasma arc, hydrolysis and irradiation for the processing of mixed waste are in still in the early development or in pilot plant stages overseas. Some of these technologies are still considered to be commercially risky at a large scale and their widespread adoption in Australia is therefore likely to be delayed until they are proven overseas by a number of years of continuous operation.

Emerging technologies for the processing of toxic or difficult materials such as e-waste, treated timber and tyres among others, include pyrolysis, chemical extraction, electrodialytic remediation and hydrometallurgy. Many of these technologies and their applications to various materials are still in their early stages of development. There are only relatively small quantities of these materials in Australia and few economies of scale compared to Europe, Asia or the Americas, which have much larger volumes to be processed.

However, smaller scale plants could be established in some capital cities if extreme measures, such as banning the landfilling of particular wastes were adopted. The main barrier to introduction of some of these technologies in Australia is that more convenient alternatives, such as landfilling, or exporting the wastes have existed for a long time. Mechanisms such as advanced disposal fees (deposits paid at the point of sale or import) would assist in attracting sufficient quantities of these items to reprocessing facilities..

8.3 Adaptability to Local Conditions

It is recognized that some technologies used in other countries may not be suitable for use in Australia. The economic, regulatory and technical environments are much different in Europe and the US than they are in Australia. In Germany, the TASi[191] regulations have very strict criteria on the biological stability of landfilled materials (the tightest in Europe) and they also prohibit the landfilling of high calorific materials. This results in considerable efforts made to prevent high calorific wastes and untreated biological wastes from being disposed of to landfill.

In the UK, the Landfill Allowance Trading Scheme (LATS) results in local authorities incurring high financial penalties if they exceed their landfilling quantity limits. This, and a grant system to regional councils has pushed the development of a number of new and proposed alternative waste technology plants in the UK. In Germany, concerns about air emissions from thermal plants have driven much of the past development of mechanical biological treatment technologies, but there is an active waste to energy sector based on refuse derived fuels, rather than mass burn incineration.

Increases in the cost of landfilling and community pressure to avoid landfilling and increase resource recovery are the driving forces behind innovation in waste management in some parts of Australia and overseas, and new technology is the main means by which this is being achieved. When assessing the applicability of technologies to the local context, consideration must be given not only to the particular local situation for marketing the outputs, but also the affordability and suitability of associated collection and disposal systems.

In regional areas, there is a clear trend towards collecting and processing source separated materials using simple technologies, while in the larger population areas, collection of mixed wastes with limited source separation, and processing them at more complex facilities that use a combination of technologies is a more common approach.

8.4 Waste to Energy

It is likely that in the future, some Alternative Waste Technology (AWT) facilities built in Australia will incorporate thermal technologies. Current AWT facilities are successful in removing recyclables such as glass, plastics and metals from the garbage stream, but much of the paper and cardboard is generally too soiled or contaminated to be recycled and is instead converted into low grade compost. This often has limited or zero marketability.

[191] Technical Guidelines on Municipal Waste

The recent fall in demand for plastics from China resulting from the global financial crisis has made recovery of mixed plastics in AWT facilities much less commercially viable than in the past. New approaches are therefore needed to deal with the recovered plastics from AWT facilities. Over the past few years, the high prices received from exporting these materials have meant that there has been little incentive for local value-adding, by additional sorting into different grades of plastics for example, or converting the mixed plastics into liquid fuels or to other products.

If the prices for recovered plastics remain low in the medium to long term, this may force the development of new products and processes in Australia for these materials, to absorb the increasing amount of plastics recovered from kerbside recycling, commercial recycling, from the various AWT facilities in operation and planned/being constructed. However if commercial organisations invest in such facilities, and the commodity prices rise, the feedstock that they rely on may then be diverted overseas if there are no contracts in place to prevent this. There is a need for financial incentives that encourage local value-adding, and ensure that waste plastic feedstock streams remain available in the face of fluctuating commodity prices.

Production of refuse derived fuel (RDF) from soiled cardboard and paper, plus recovered plastics not suited to higher order uses, textiles and wood, is quite successful in Germany. These processes could be integrated into many of the existing AWT plants. RDF is used overseas in cement kilns, power stations and industrial plants, such as paper mills, requiring significant amounts of steam and hot water. RDF production would be financially viable when existing facilities can be modified and licenced to use the RDF for heat or power production, or new purpose built facilities are able to be established for this purpose.

8.5 Commercial Wastes

The heterogeneous nature of the commercial and industrial (C&I) waste stream and the sheer number and diversity of waste generators and collectors presents challenges to the adoption of technology. In addition, waste disposal in the C&I sector is driven largely by economics. Separation plants in the form of ‘dirty MRFs’ (materials recovery facilities) are the most likely means of recovering significant proportions of this stream. However, there are not likely to be any significant increases in resource recovery from the C&I sector unless there are regulations or enforceable waste targets put into place nationally.

New AWT facilities coming on line in the near future to service municipal wastes should be able to cope with a proportion of their inputs being C&I wastes from offices and some factories (non-industrial wastes from canteens and personnel areas). Indeed, this may be an innovative way of establishing new AWT facilities, to design them with the flexibility to process up to 20-30% commercial wastes.

With long term municipal waste receival contracts underpinning the original establishment of the plants, topping up with suitable commercial wastes could be seen as an opportunity to better utilise the existing plant and equipment, with benefits shared between municipal waste customers (local councils) and the facility operators. The composition of wastes originating from office buildings and commercial premises (being mainly paper and plastics) makes production of RDF, after removal of recyclables and biological materials, a potentially viable approach for these C&I waste streams..

8.6 Green Design

New research into the development of novel chemical, biological and other techniques for processing and recovery of hazardous materials is gradually creating safer and more efficient ways to disassemble and extract the valuable components and neutralise the dangerous elements found in these materials. As a net importer of manufactured goods, there is limited opportunity for Australia to apply green design principles directly to manufactured goods. However it may be possible for the Federal Government to impose some sale or import restrictions on those products that do not meet certain green design principles.

Waste from the construction and demolition industry still forms a significant proportion of all waste generated in Australia. Green design principles could be more widely applied in this sector by increasing the weighting given to waste management in green design measurement schemes. This, and accompanying material specifications to cover their application to various situations, would increase the re-processing and recovery of specific C&D wastes.

8.7 Role of Waste Transfer Stations

Waste transfer stations were traditionally designed to bulk up and compress wastes in the most efficient way possible, so that they could be cost effectively transported to a landfill site in larger vehicles. This enabled the waste collection vehicles, which are designed for stop/start operation, but not long haul, to continue their collection runs after disposing of their loads. Therefore little thought was given in terms of space or logistics for resource recovery.

This has been changing as recycling has been developing and most new transfer station designs, especially in rural areas, have designated bins and areas for resource recovery activities for. Pricing policies enable residential and some small commercial customers to dispose of separated materials at reduced or zero cost. The price differences between segregated wastes and mixed waste disposal encourage customers to separate their wastes before arriving at the facility. The variety of solutions adopted by regional councils in NSW and elsewhere are outlined in references such as the Handbook for Design and Operation of Rural and Regional Transfer Stations published by the Department of Environment and Conservation (NSW)[182]

8.8 Regulations and Policies

Some changes in the regulatory environment have been introduced overseas to accommodate new advances in technology applied to waste management situations. Waste facilities have been prohibited in some local government areas, but AWT facilities and other resource recovery processing facilities have lower environmental impacts than landfills. As a result they can be located in industrial areas, closer to residential and other community areas than new landfill sites. There have been some innovations in the planning area to overcome these restrictions, which arose when landfills were poorly run and many waste recycling facilities were not subject to environmental impact assessments and licencing controls. In NSW, an Infrastructure State Environmental Planning Policy (SEPP) introduced in 2007 can now be used to assist resource recovery facilities being established in industrial areas, close to where they are actually needed.

Some forms of waste technology innovation involving waste to energy, straddle several policy areas; waste, energy, environment and carbon reduction. Existing regulations and legislation, none of which addresses it in a holistic way, prompting a number of new approaches. The European Union has developed several regulatory instruments to deal with waste to energy facilities in particular.

8.9 Barriers to Innovation

By far the most obvious market barrier to innovation in waste management is the low cost of landfilling in some states and territories. In areas where landfilling costs are high (such as Sydney), it is noticeable that more AWT facilities are operational and in the planning stages than in locations where landfilling costs are low (such as Brisbane). Overall it is clear that there are no one-size-fits all solutions for increasing the use of technology and level of innovation in waste management in Australia.

There seem to be four main non-market barriers to the uptake of innovation and new waste processing technologies; the requirement for more co-operation between councils, a distrust of new and unproven technologies, a fear of incineration and reservations about making a long term committment to inappropriate or outdated technology. Generally, local government is responsible for waste management, and as a result, the task of implementing new waste technologies has fallen to this sector, whose staff often have limited commercial and technological expertise. Many of the councils themselves are struggling financially and considerable amounts of money are involved in establishing and operating AWT facilities.

In addition, the amount of waste required to make each facility financially viable means that groups of smaller councils potentially need to enter into joint contracts with service providers. This is a major undertaking, as all partner councils need to be satisfied that their interests, as well as the overall interests of the collective councils are being met. A joint waste processing contract was achieved with the MACROC Councils in Sydney, and with the Coffs Coast Councils in northern NSW, but the Hunter Waste project did not proceed partly because of difficulties in resolving issues between the various councils involved. Because of some technical and commercial issues with existing plants in Australia, there is also a degree of distrust of some new technologies. In addition there is often a reluctance among councils to commit to a long term contract when they think that the technology may become outdated before the contract period ends.

8.10 Overcoming the Barriers

Possible ways of overcoming barriers to innovation include developing means to enable councils to more easily assess new technologies, such as the NSW DECC's AWT Assessment Tool. However, these tools, whilst assisting in decision-making, do not overcome the major issues of perceived or real financial risks for councils that commit to new technologies. In the UK, a system of 'ring fenced' technology grants[192] was provided to local government by DEFRA, to reduce the capital costs associated with building new technology plants, and thereby reduce the costs per tonne of the waste throughputs. This resulted in a massive program of building a wide range of AWT type plants in all areas of the UK. A similar system of Federal Government grants to Local Government could be considered in Australia, to bring councils in all states and territories to a more equitable level of technological innovation in waste management.

Innovation in waste management is not restricted to new end-of-pipe technologies to treat wastes and divert them from landfill. Tapping into the voluntary resources of the community to assist in streaming and sorting wastes before they reach any form of mechanical processing offers huge potential to recover valuable resources.

[192] Grants to which conditions are attached

Deposit schemes for items like televisions and computers could be a cost effective way of gathering these materials in sufficient quantities to make the setting up of electronic waste reprocessing plants in the major cities a commercial reality. National product stewardship and extended producer responsibility schemes aimed at particular wastes would assist in the implementation of more advanced material processing technologies in Australia.

Due to the distances involved in transporting materials from generation points to the likely location of high technology plants (large regional centres or cities), providing financial incentives in the form of cash or credit vouchers to private individuals or businesses who deliver materials such as computers, computer monitors and other electronic wastes such as televisions would make recovery of these materials more efficient than trying to establishing broad scale collection systems.

Future product stewardship schemes could operate outside the normal waste collection chain or as part of it. Municipal and commercial transfer stations, AWT facilities and other waste disposal facilities are obvious and easy collection points for items subject to Extended Producer Responsibility (EPR) schemes, negating the need for separate purpose-built receiving centres.

Partnerships and joint ventures in industry are also forming to exploit opportunities. Sharp, Panasonic and Toshiba have established a joint venture to manage electronic waste recycling and collection programs. Veolia and Simsmetal jointly run an electronic waste recovery scheme for commercial customers in Australia. Recycling of the E-Waste equipment is performed at Sims E-Recycling, a joint venture set up between Veolia[193] and the Sims Group. Electronic waste collected undergoes a manual dismantling process. The individual materials such as printed circuit boards, cabling, glass and plastics etc., are recovered and then processed so that they can be used as raw materials to produce new products.

8.11 Conclusions

In conclusion, much of the progress to date in waste innovation seems to have been in the area of development of new technologies to treat wastes. However, there is evidence of many innovative waste management approaches focusing on waste prevention, waste minimisation, source separated collection and specific technologies for treating particular waste streams. Source separation is much more effective in conserving resources than relying solely on highly complex, expensive end-of-pipe technologies for managing increasing quantities of highly heterogeneous mixed waste streams.

Whilst there is still a need for research into improving recovery and reprocessing technologies, the main challenge in Australia is to improve the access to such technologies across the country. This could be done by providing incentives to efficiently collect and transport materials to strategic locations for reprocessing, develop local and export markets for recovered materials and value added products, and encourage the community and businesses to actively participate in these schemes.

Further innovation is needed in terms of economic and regulatory drivers to overcome current disincentives to establishing advanced technologies close to the population centres that are producing the wastes. Equally important in terms of resource conservation are enforceable waste targets and green product design/local standards that enhance the recyclability of discarded items.

In addition, there is a need for more programs that encourage sustainable behaviour, to reduce excessive consumption and wastefulness. This would slow down the rate at which waste is generated,

[193] http://www.veoliaes.com.au/commercial-services/waste-collection-and-recycling/electronic-waste-recycling.asp

and reduce the reliance on innovations in technology as the solution to all waste problems. Innovative thinking beyond the scope of normal waste awareness campaigns, is needed to encourage and reinforce behavioural change at a business and personal level.

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