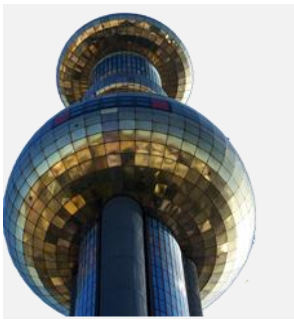
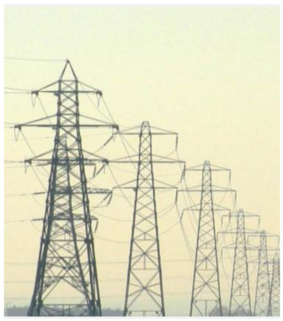
RICARDO-AEA

Waste to Energy Background Paper

Zero Waste SA





Report for Zero Waste SA
Ricardo-AEA/R/ED58135
Issue Number 5 – Final Report
Date 02/07/2013

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South Australian Solid Waste Levy:

This report was developed when the South Australian Solid Waste Levy was $42 per tonne for metropolitan and $21 per tonne for regional areas in 2012-13. From 1 July 2013, the Solid Waste Levy has increased to $47 per tonne for metropolitan and $23.50 per tonne for regional areas but these increases have not been included in this report.

Customer:

Zero Waste SA

Customer reference:

Waste to Energy Background Paper

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02 July 2013

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Ref: ED58135- Issue Number 5 – Final Report

Executive summary

South Australia is undoubtedly a leader in waste management and resource recovery, not only in Australia but also in global terms. This has already been demonstrated by delivering the highest landfill diversion rate in Australia, and the continuing success of their Producer Responsibility and Take Back Programmes, with the state reaping the rewards of the leadership and direction shown through the delivery of South Australia's Waste Strategy (2005-2010).

South Australia's current Waste Strategy, for the period 2011-2015, aims to build on this success, and sets further challenging targets for landfill diversion of Municipal Solid Waste (MSW), Commercial and Industrial (C&I) waste and Construction and Demolition (C&D) waste streams.

The strategy recognises a role for energy recovery where it is consistent with the waste management hierarchy. Many other countries across the world also recognise the need to include W2E as part of an integrated waste management system which aims to achieve zero waste to landfill. Many of these countries have developed active programmes, policies and funding structures to set out a clear direction for the development of W2E and to encourage its development and delivery. In particular, W2E is often the only alternative to landfill for wastes which have no further recovery or recycling value, and as such plays a critical role in sustainable waste management solutions across Europe.

The development of a W2E policy for South Australia will not only enable the successful development and delivery of a portfolio of energy and power generation projects, but will also complement the State Waste Strategy and National Waste policy, which outlines high level strategies to enhance biodegradable resource recovery and diversion from landfill to reduce GHG emissions. The national carbon tax is one such measure looking to drive materials away from landfill into more productive treatment, recovery and recycling based solutions. South Australia recognise the need for a policy on W2E to help direct local decision-making, stimulate investment and offer leadership for the development of new projects, and are looking at the development of similar policies in NSW, Victoria and overseas to help inform their thinking.

In addition to increased landfill diversion, South Australia may also benefit from the community opportunities and social value that W2E can provide, such as lower energy prices and job creation.

In order to underpin a suitable W2E policy for the State, ZWSA have commissioned this background paper to examine developments in W2E technologies both in Australia and globally, and to fully understand the strategies, policies and plans that impact on their development, design and delivery.

Whilst still limited in South Australia, this paper demonstrates how the use of both thermal and biological treatment to recover energy from waste is not only well established globally, but is commonly applied to a wide range of wastes, including non-recyclable fractions of MSW, C&D and C&I waste streams. This paper showcases an abundance of proven technologies which could be applied in South Australia for the recovery of energy from a wide range of target waste feedstocks, and concludes that they could all play a part in a developing W2E sector in South Australia if the right policies, strategies, programmes and support mechanisms are put in place.

Technology choice aside, there are many drivers and barriers which will impact on the development of W2E infrastructure. The cost and gate fees associated with local landfill sites will always dictate the financial viability of W2E projects, but instruments such as landfill bans, levies and taxes have been successful in incentivising the development of alternatives to landfill, in particular W2E sites particularly in Europe. Climate Change and greenhouse gas emissions targets can also be an effective additional driver, but only if backed up by mandatory regulation or financial incentives. Energy security is becoming an increasingly important driver globally, but W2E has to compete with other renewable energy technologies for support and funding, and in Australia the abundance of relatively cheap coal may hinder the development of any W2E solutions without a portfolio of other incentives, policies and programmes.

South Australia has already proven how policy intervention and legislation can help drive resource recovery, through the Waste Disposal Levy and the Environment Protection (Waste to Resources) Policy 2010 (W2R EPP). As such, the State is looking at whether W2E solutions could be encouraged in a similar fashion. This paper outlines the need for further interventions, incentives and support that will be essential to prepare the market to respond to any policy requirement for more energy recovery, and to develop the appropriate W2E infrastructure that can help South Australia meet its long term sustainability, waste management and energy goals.

South Australia can take advantage of the experiences in other countries, particularly those in Europe, to ensure that any new W2E facilities are designed and developed within a new policy framework which delivers safe, modern and efficient energy recovery from waste solutions for years to come.

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Agrivert Cassington Anaerobic Digestion facility, Oxfordshire, UK, www.biogas.org.uk

1 Introduction

1.1 Objectives

Over the last five years, South Australia has become a leader in waste management reform and resource recovery in Australia. The state currently has the highest landfill diversion rate of all states in Australia, and in 2010-11 diverted 79.9% of waste from landfill (SA Recycling Activity Report, 2010-11). Much of this progress has been a result of the leadership and direction provided by South Australia's Waste Strategy 2005-2010.

South Australia's Waste Strategy 2011-2015 aims to build on this progress, and sets further targets for landfill diversion of Municipal Solid Waste (MSW), Commercial and Industrial (C&I) waste and Construction and Demolition (C&D) waste.

The strategy is the Government's tool in reforming waste management by guiding state and local government activities, and involves business, industry and the wider community. The waste strategy is underpinned by primary objective and guiding principles of *Zero Waste SA Act 2004*, including the principles of the waste management hierarchy, ecologically sustainable development, best practice and standards, along with policy development through open dialogue and consultation.

The two objectives of the Waste Strategy 2011-2015 are:

+ To maximise the useful life of materials through reuse and recycling; and
+ To avoid and reduce waste.

In order to achieve this, the strategy recognises the need to support new and alternative technologies that will either enhance recycling or reuse performance or will help to replace landfill as a disposal option.

Zero Waste SA (ZWSA) previously examined alternative waste technologies in a position paper in 2006. ZWSA would now like to benefit from further developments and experiences of these technologies globally, with the aim of gaining a better understanding of the opportunities available and priorities for recovering energy from residual waste streams.

Through the development of a Waste to Energy (W2E) policy, the Government of South Australia will be able to evaluate and respond to W2E proposals in a consistent and effective way, utilising information and lessons learned in international W2E projects.

A W2E Background Paper will be used to inform the development of future government policy on W2E issues. The overarching aims of the W2E background paper are to:

+ Identify and assess current waste to energy technologies;
+ Identify and review waste to energy strategies, policies and plans;
+ Identify and present case studies of working waste to energy technologies; and
+ Develop high level waste to energy strategies, policies or mechanisms, which may be adopted by South Australia to facilitate best practice waste management.

1.2 Approach and Structure

Chapters 2 to 7 contain a detailed review of current waste to energy technologies, including applications, feedstocks, outputs and by-products, maturity, strengths and weaknesses. Technologies include Conventional Combustion, Advanced Thermal Treatment and Biological technologies.

Chapter 9 details the investment profile associated with each W2E technology, including capital and operating costs, income from incentives and other revenues and costs.

Chapter 10 summarises the environmental and social impacts of W2E technologies.

Chapter 11 identifies existing W2E plants in Australia.

Chapter 12 reviews how W2E fits in to South Australia's broader renewable energy and waste management strategies, and examines international policy and strategies.

Chapter 13 identifies key drivers and barriers in W2E, including technical, economical and regulatory. Local drivers and barriers are evaluated, including input from key stakeholders. International examples of how drivers have been used successfully and barriers addressed are also identified.

Chapter 14 outlines a high level strategic approach for South Australia, identifying potential support mechanisms and types of intervention that could be deployed in the local setting.

The key objective of taking this approach is to set local impacts against an international context and learning, with the aim of using both contexts to shape and develop a fit-for-purpose high level W2E strategy for South Australia.

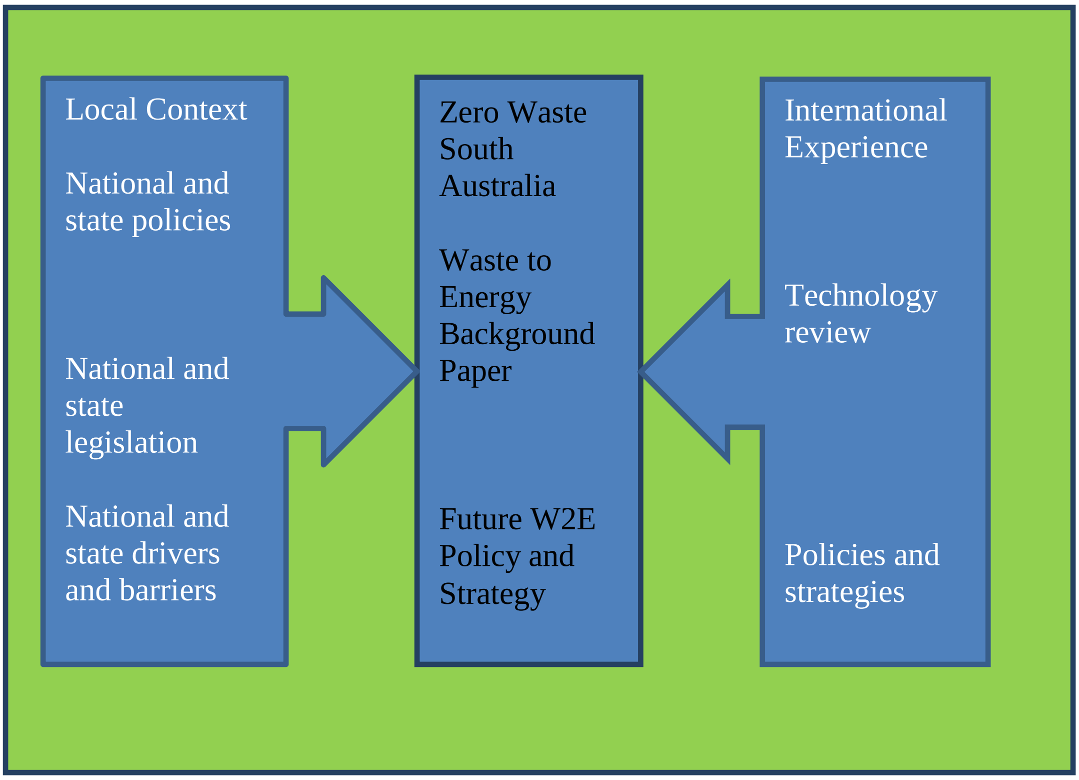

Figure 1-1: Summary of approach

2 Assessment of Waste to Energy Technologies

The following sections aim to give an overview of the main technology options that are available to recover energy from waste. Key waste streams with which the South Australia Waste Strategy are concerned are Municipal Solid Waste (MSW), Commercial and Industrial (C&I) Waste and Construction and Demolition (C&D) Waste.

The technology review aims to determine the following key points of interest:

+ Type of conversion technology;
+ Method of energy recovery;
+ Typical application and feedstock characteristics;
+ Technology scale and capacity;
+ Capital and operational costs;
+ Process inputs and outputs;
+ Markets for outputs; and
+ Environmental and social impacts.

Implications for W2E in South Australia

- The use of thermal treatment to recover energy from waste is well established globally, and is commonly applied to a wide range of combustible wastes including MSW, Refuse Derived Fuel, waste wood, tyres, plastics and agricultural residues and other forms of biomass;
- Conventional combustion on a moving grate is the most common thermal treatment technology, with over 500 plants in operation worldwide;
- Conventional combustion technologies can be applied at varying scales, and are flexible in the types of feedstock they can accommodate;
- Residues produced from conventional combustion include Incinerator Bottom Ash and Air Pollution Control Residues;
- Advanced Thermal Treatment (ATT) technologies are generally less developed than more conventional systems for the recovery of energy from waste, although progress is being made on overcoming financial and technical barriers;
- ATT are more sensitive to waste feedstock, and will require tighter specification on feedstock characteristics;
- The outputs from ATT include syngas (from which energy can be recovered), chars, tars, and oils. There is flexibility in how these materials can be further synthesised into chemical products such as ethanol and ammonia;
- The biological treatment of organic waste by Anaerobic Digestion (AD) is a well-established technology, particularly in Europe where it is applied to source separated food waste from households, commerce and industry;
- The AD process produces both a solid and a liquid residue, for which markets or disposal outlets will need to be secured;
- There is an abundance of proven technologies which could be applied in South Australia for the recovery of energy from a wide range of waste feedstocks.

3 Thermal Treatment Inputs

There are many different forms of feedstock available and suitable for thermal technologies. These range from single source waste streams, which may have a high calorific value, such as wood, through to unprocessed residual wastes collected at kerbside, or processed wastes produced at a Mechanical Biological Treatment plant (MBT).

In many instances pre-treatment technologies can be used to produce a reliable feedstock, which can be tailored to customer requirements, these include refuse derived fuel (RDF) and solid recovered fuel (SRF), and therefore would be more suitable for use in a wider range of technologies, such as gasification and pyrolysis.

3.1.1 Municipal Solid Waste

Municipal Solid Waste (MSW) usually refers to household waste, but often includes some commercial and industrial waste from small enterprises. The commercial and industrial content of MSW is similar in nature to household waste. The composition of MSW can be highly variable across different locations and can be influenced by socio-economic factors. MSW has been used as an input to conventional incineration technology-based for facilities for over a century. Early incineration facilities only addressed waste disposal and energy recovery was not considered. However, in some countries, and particular Europe, recent changes to government policy and legislation have ensured that energy is recovered. The recovery of material for recycling result in a residual, the calorific value of which is approximately one third of black coal (i.e. between 8 and 12 GJ/tonne). Even with high recycling targets and zero waste strategies, it is generally accepted that there will be a residual fraction from which energy could be recovered.

3.1.2 Refuse Derived Fuels (RDF) and Solid Recovered Fuels (SRF)

The pre-treatment of residual waste prior to combustion to produce a specific fuel fraction is increasing globally and in particular across Europe. European environmental and energy policies include measures to enhance the recovery of residual waste as a sustainable energy recovery option. The European Union has put in place standards for waste derived fuels so as to support the free trade of such fuels on the internal market.

The current prevalent term used for a fuel produced from combustible waste is refuse derived fuel (RDF). The types of technologies used to prepare/segregate a fuel fraction from MSW include many of the MBT processes described later in this report.

Whilst the terms SRF and RDF are often used interchangeably, it is generally accepted that SRF usually refers to a fuel that is manufactured to meet more stringent quality criteria. Whereas RDF is seen as a by-product from the processing of waste, SRF has quality and composition specifications.

In Europe, SRF is defined as a solid fuel prepared from non-hazardous waste to be utilised for energy recovery in incineration or co-incineration plants, and meeting the classification and specification requirements set out in EN15359. This standard provides for a system of specification and classification of SRF. It also provides for a set of compliance rules that points out how SRF can be characterised in a reliable way. In general, SRF has a higher calorific value and lower moisture content than RDF, which makes it a more attractive fuel. The successful application of gasification technology to SRF has been demonstrated at the Lahti gasification plant in Finland, where stringent fuel specifications are credited for the plants operation. See further details in Case Study 1.

Prior to the development of standards, SRF was produced in an uncontrolled manner with each sector or individual company having its own fuel specification.

The introduction of technical standards for SRF has reassured the market as to the quality of the product (calorific value, physical and chemical properties, moisture content, chlorine content, heavy metal content, etc.).

There is no such standard or definition for RDF in Europe, which is used as a term to describe similar waste derived fuels but which do not meet the quality requirement of an SRF. Despite this, there is a strong European market demand for RDF, and the increase in exports from the UK has been widely reported. This is due to overcapacity in European W2E plants that need to be fed in order to maintain their operational efficiencies.

The Environment Protection Authority in South Australia (SA EPA) has developed a standard for the production and use of RDF.[1] The SA EPA standard sets out the information and processes that are required to support the beneficial recovery of energy from waste by combustion of RDF in an industrial process. The standard requires all proposals for the production and use of RDF to be approved by the EPA, to ensure that genuine energy recovery is being realised, and not just waste disposal. If the standard is met, then the RDF will be considered a fuel and no longer be considered a waste.

SRF/RDF can take various forms including a loose or flock material, which has been size-reduced or further compacted to produce a fuel pellet, the final form being dependent on the type of energy recovery.

Consequently, there are many methods for producing SRF/RDF and these will generally include the following processes:

+ Sorting or mechanical separation;
+ Size reduction (shredding, milling);
+ Separation and screening;
+ Blending (dependent on end specification);
+ Drying; and
+ Further shredding or pelletisation (depending on end specification).

SRF/RDF can be used in specific applications such as cement kilns, Combined Heat and Power (CHP) plants and some forms of power plants (e.g. coal-fired). Such uses results in higher efficient use of the calorific value of waste and a significant CO_2-e reduction by substituting fossil fuels.

The applications for which SRF/RDF could be used as a fossil fuel replacement include:

+ Combustion in dedicated energy from waste facilities, including combustion, gasification or pyrolysis;
+ Partial displacement of existing fossil fuels in existing coal fired power stations, or smaller wood/biomass power stations;
+ Partial substitution of existing solid fossil fuels at industrial users, for example in power stations, steel works and paper and pulp processing facilities;
+ Use in CHP plants, with heat being used by process heat users in close proximity to the plant; or
+ Use as a fuel in district heating schemes.

[1] http://www.epa.sa.gov.au/xstd_files/Waste/Guideline/standard_rdf.pdf

SITA Resource Co, South Australia

Australia's first Process Engineered Fuel manufacturing plant was commissioned in 2006 at Wingfield South Australia following a commercial agreement in 2004 between Adelaide Brighton Cement Limited and Resource Co to develop a Processed Engineered Fuel (PEF) as a partial replacement (20-30%) for fossil fuels in the Adelaide Brighton cement kiln. The fuel is produced from commercial and light industrial waste streams that have been diverted from landfill. The PEF is comprised specifically of a mix of timber, plastics, cardboard and paper. The SITA-ResourceCo facility at Wingfield was built in 2007 and is a joint venture with SITA and ResourceCo, with the capacity to convert up to 350,000 tonnes of raw material per annum into 100,000 to 150,000 tonnes of PEF.

The facility costs over $20 million, and the plant sorts, sizes and extracts combustible material from commercial waste streams in order to manufacture PEF. The PEF has a high calorific value and can be used as a fuel substitute for coal and gas in high-combustion facilities including cement kilns.

SITA-ResourceCo is now in the process of establishing additional PEF manufacturing facilities throughout Australia, based on the same technology platform as used by the existing Wingfield premise in South Australia. The next facility is likely to be co-located at SITA Australia's Hampton Park Resource Recovery Facility in Victoria, which was established in 2010.

3.1.3 Waste Wood and Other Waste Biomass Fuels

Waste wood is produced by a number of sectors, including timber production, furniture and chipboard manufacture, other C&I operations, construction and demolition (C&D) sites, and the municipal waste stream. Virgin untreated wood is commonly used as a fuel in biomass plants, whereas lower grade and treated waste woods can be combusted in W2E facilities[2]. Case Study 2 outlines several examples of the use of waste wood to generate power, including the increasing trend to co-fire wood chip at large coal burning power stations.

Agricultural residues are generally categorised as wet or dry. Wet residues are animal slurries and manures, which typically have a solid content of <15% and are generally treated via anaerobic digestion (AD, see below). Dry residues include straw, husks and processing waste, including poultry litter. These materials are suitable for energy recovery in combustion or Advanced Thermal Treatment (ATT) facilities.

Agricultural residues are generally large in volume and bulky to transport. As such, transportation costs usually prohibit movement of these residues at significant distances. High density straw bales are an exception but it remains a low value commodity, and any facility intending to make use of these residues would ideally be constructed near to a significant supply of resource and so would be preferably at a local or regional scale.

Forestry residues are produced as a by-product from the felling of timber supplied to sawmills and the timber processing industry, and which may be suitable as a fuel. These residues include branches, brash, stumps, and bark. It is likely that this material would need processing before it would be usable as a fuel. This is because raw biomass such as forestry residues has a low energy density, owing to its high moisture content and non-uniform physical form. Processing will generally involve chipping or shredding, and drying to reduce the moisture content.

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[2] In Europe biomass plants and W2E plants are considered different, due to the fact that a biomass plant will not need to comply with the Waste Incineration Directive. Virgin untreated wood is not considered a 'waste'.

South Australia has a widespread area of forest and all timber production is from plantations (as opposed to ‘old growth’ forests).

The South East (known as the Green Triangle Region) has an extensive wood processing industry that is the largest regionally-based manufacturing industry in the State[3] and the largest wood-fibre producing region in Australia[4]. Significant facilities also exist in Adelaide, Mount Lofty Ranges, Mid North and on Kangaroo Island.

The range of products is diverse including sawlogs, particleboard, fibreboard, laminated veneer lumber and woodchips. These are supply resources for constructing buildings, furniture, paper, fence posts and for biofuels. Demand for by-products (namely sawdust) generated from the manufacture of these products varies regionally.

Trends over the past three years have seen three significant particleboard manufacturers close Australian operations. This has resulted in a reduced demand for by-products from the forestry and wood-product manufacturing (i.e. saw mills) sector due to the smaller scale of operations. In Queensland, where two particleboard manufacturers have ceased trading, sawdust and other by-products are now commonly open-burnt as there is no commercial market, particularly with increasing transport costs.

Suncoast Gold Macadamias

Suncoast Gold Macadamias, based at Gympie, processes around 7,000 tonnes of macadamias per annum and currently employs around 140 people. Their core business is the shelling, drying and packaging (essentially value adding) of macadamia nuts. Suncoast Gold Macadamias sells around 25% of their product to the domestic market and exports the remainder to Japan, the US and Germany with smaller consignments to other countries (DERM, 2010).

The business produces very little waste except for shell, which comprises around 70% of the weight of the nut. Prior to the commission of the existing co-generation facility, most of the shell was sold for a variety of applications including the landscape industry as a component of mulch, a plastic producer who added powdered shell as a filler to some plastic products, and a small amount was retained to fuel an on-site hot water boiler which provided some drying capacity.

Suncoast Gold Macadamias started a dialogue to upgrade the hot water boiler to a larger facility to provide green power to the site with Ergon Energy around seven years ago. Shortly after which Ergon sold some of its smaller interest to AGL, resulting in AGL also becoming a project partner. The plant is grid connected to the local 11kV lines via a 2MVA transformer and the power is sold to Ergon Energy under a long-term agreement. In 2005, a larger scale energy generation facility was designed specifically for macadamia nut shells, which would facilitate the use of all of the waste macadamia nut shells, produced on-site (around 10,000 tonnes of shell). This project was seen as viable long-term also as the company was doubling in size every 8-10 years with the growth in macadamia supply and demand.

The installed facility is a 6MW boiler, which produced around 9t/hr of steam that is used in the nut process (to dry the nuts) as well as for electricity generation; equating to around 1400kW steam turbine with an output of 1.4GW per annum, which is consumed on-site. This saves around 9,700t of GHG emissions whilst providing enough heat to dry approximately 7,000t of macadamias per annum.

[3] PIRSA. (n.d). Primary Industries and Regions of South Australia. ’Forestry in South Australia: Growing Sustainable Regions. Government of South Australia
[4] GTRPC. (n,d). Green Triangle Regional Plantation Committee, Forests for the Future Strategy Plan: Towards the 2020 Vision, date unspecified.

The plant did have a number of commissioning problems, which took a significant amount of resource out of the company. Although Ergon supplied the equipment, Sunshine Coast Macadamias supplied the raw materials and also the daily on-going maintenance. The plant requires manual input and monitoring seven days per week.

Unfortunately, the supply of macadamia shell also reduced over the first few years after installation. This was caused by a reduction in the production of macadamias, which resulted in an inadequate supply of shell to power the boiler all year round. The macadamia nut is seasonal (typically April to December) thus it is essential that excess shell be stored for use out of season.

The plant is currently exporting around 50% of the electricity generated. However, this was expected to be around 75% in the planning stages.

3.1.4 Plastics

Plastic waste has a high calorific value compared with other materials due to its crude oil origins. Typical household plastic mixtures have a calorific value of 31.8 GJ/tonne (petroleum has a calorific value of 42.3 GJ/tonne). Generally, the incineration of plastic waste results in a volume reduction of 90 to 99% reduces reliance on landfilling but increases greenhouse gas emissions. Additionally, energy may be recovered.

Advanced Thermal Treatment technologies are also suitable for energy recovery from plastics. Ideally, the gasification process for plastic waste should produce a high calorific value gas, a completely combusted char, and a metal fraction which can be separated from the ash. The cement industry in the UK has been utilising alternative fuels from plastic waste for over two decades. The energy costs of cement kilns can be up to 25% of turnover and the financial benefits of using waste fuels is clear. Cement kiln operators and cement producers have set their own standards utilizing plastic waste as a feedstock.

A large body of research exists around “tertiary” recycling processes for waste plastic (either thermal or catalytic) since they may produce chemicals or fuels. Long carbon chains of polymers are cracked thermally and result in a mixture of gases and liquid hydrocarbons. Products can be used for different purposes. For example, polymer can be made from the decomposed product, or they can be used in other chemical processes such as in oil refining, where they can be made into raw chemical materials together with the mineral oil fractions.

The preferred plastics for chemical recycling are polyethylene, polypropylenes and polystyrene as their properties are similar to petrochemical feedstocks. The pre-treatment and source of plastic wastes can considerably modify the end product properties. Sometimes impurities have attached on the surface of plastic wastes, which deteriorate the favourable properties of gasoline, oils, etc. Therefore, researchers quite often have focused on the pyrolysis of granulated, pure plastics, which are not wastes as such. A study undertaken in 2011 by the American Chemistry Council identified twelve plastic to fuel facilities operating in the US and eleven facilities operating outside the US. The majority of these manufacturers have pilot-scale facilities (typically one fifth the size of a commercial facility). Recently, Cynar Plc., a company which manufactures ‘End of Life Plastic to Diesel’ (ELPD) plants have recently begun constructing a full scale plant in the UK. Cynar has an agreement with SITA/Suez to build a total of ten plants (see Case Study 3).

3.1.5 Waste tyres

Waste tyres have a high heating value, and are used as a fuel in a wide range of applications. The use of tyres as fuel is well established in the US, where applications include in cement kilns, paper mills and electrical power plants.

Tyre-derived fuels typically have lower greenhouse gas emissions than comparable fossil fuels.

Cement kilns can generally accept whole tyres, whereas most other applications will require tyres to be shredded or chipped. Processing tyres into a useable form will first involve shredding, using one or a series of shredders depending on tyre size. After shredding, any steel will be removed using magnetic separators.

Cement kilns in Europe are actively increasing the use of tyres as fuel due to a number of benefits such as achieving compliance with emissions limits, process efficiency and being a cheaper alternative to conventional fossil fuels. It has also been demonstrated that using tyres along with coal decreases emissions of nitrogen oxides.

The high temperature (up to 1400°C) and long residence time of fuel in the kiln mean that complete combustion of the tyres can be achieved. Any ash from the combustion of the tyres is incorporated in to the cement product and therefore there is no residual waste. The high temperatures also mean that there are no odours or smoke produced which may be associated with the burning of tyres.

The consistent energy value and low moisture content of tyres also makes them attractive for use as a fuel within the paper and pulp industry.

Numerous standards have been developed for the use of tyres as a fuel. For example, the American Society for Testing and Materials has developed a 'Standard Practice for Use of Scrap Tire-Derived Fuel' for shredded tyre derived fuel.

The SA EPA allows tyres to be used as a fuel substitute in high temperature furnaces as cement kilns, power stations and smelters, but this would be subject to approval. Processes choosing to use tyres as a substitute fuel would still need to meet the statutory air quality emissions limits.

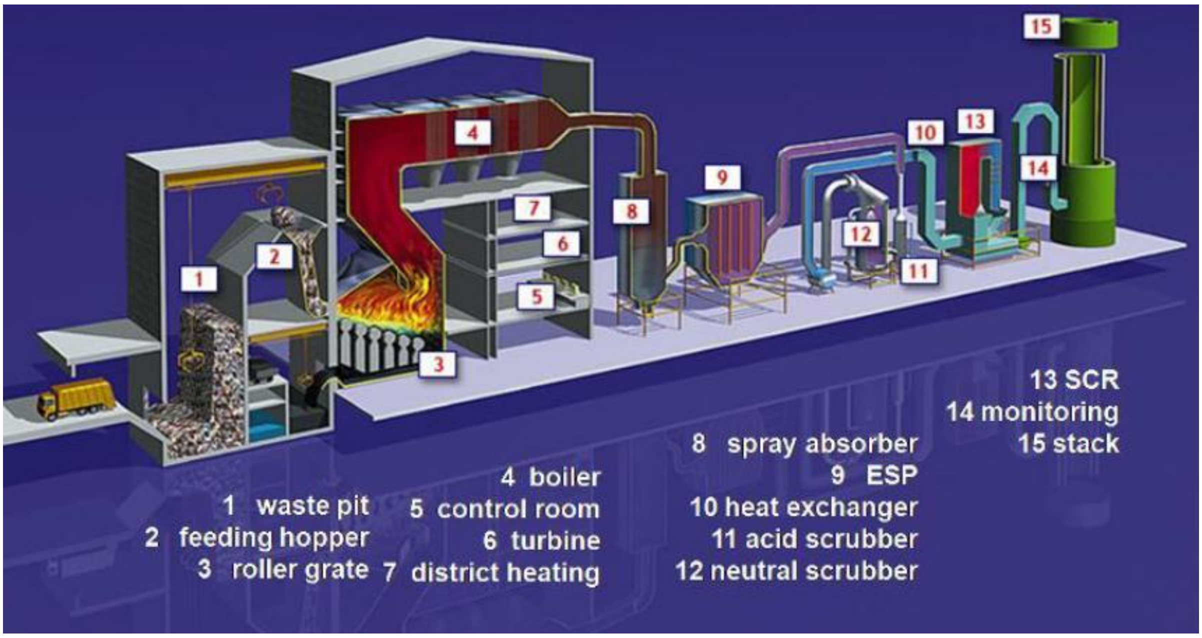
4 Conventional Combustion

4.1 Technology Types

The combustion technology group encompasses those processes where the waste feedstock undergoes complete oxidation in a furnace, releasing heat into the gaseous and solid combustion products. Energy recovery is achieved by using the hot combustion gases to heat water to produce steam, which is then expanded through a steam turbine to generate electricity.

A process flow diagram for a typical combustion W2E plant is given in Figure 4-1.

Figure 4-1: Flow diagram of a MSW grate incinerator equipped with a roller grate, Offenbach, Germany. (Source: IEA Task 36 – Overview of Technologies Used for Energy Recovery.)



This technology type is well established, with a large number of technology providers offering a wide variety of different furnace configurations.

Principle furnace types include:

+ Moving grate;
+ Fluidised bed; and
+ Rotary kiln.

Table 4—1: Thermal Treatment Technology 1: Moving grate combustion

Technology	Combustion in a moving grate furnace
Concept	Moving grate technologies are widely used, and in particular for the combustion of Municipal Solid Waste (MSW). Waste is fed on to a grate, which uses either reciprocating, rocking, travelling or rolling movement to conveyed the waste through the combustion chamber, and which also transfers the unburned material or ash, out of the chamber. Waste is burned in an excess of air. Primary air is fed through the grate, with secondary air introduced above the grate to create turbulence. Moving grate incinerators are suitable for processing non-homogenous and low calorific value waste streams.
Commercialisation	Moving grate technology is the oldest form of incineration technology and is still the prevailing W2E technology worldwide. There are over 500 plants in operation across the world.
Size (per line)	3 – 40 tonnes per hour
Size (per installation)	Wide ranging. Small scale plants from 50,000 tonnes per annum with larger installations up to 1.2 – 1.4 million tonnes per annum
Energy recovery	Steam turbine Power efficiency – up to 30% Combined Heat and Power – can reach >70%
Inputs/Feedstocks	MSW, C&I, RDF, Wood, Hazardous waste, clinical waste Moving grate combustion plants are generally flexible with regards to feedstock requirements.
Feedstock pre-treatment	Pre-treatment is not normally required for combustion in moving grate furnaces, hence the term 'mass burn'. Pre-treatment may simply include the removal of bulky items, and mixing within a waste bunker to homogenise the composition of the waste.
By-products	Incinerator Bottom Ash (IBA) and Air Pollution Control Residues (APCr)
Indicative costs/tonne	$450-$700

Riverside Resource Recovery CHP facility, London, UK

One of the most recent W2E facilities to be commissioned in Europe is the Riverside Resource Recovery facility in the London Borough of Bexley. Developed by Cory Environmental, the plant was commissioned in October 2011, and has an average annual capacity of 585,000 tonnes. The majority of waste input is from contracts to process household waste from four London boroughs, and accounts for 60% of the input. The remaining capacity is sourced from other London boroughs and commercial waste contracts.

The plant uses conventional moving grate combustion technology, and consists of three lines, each processing approximately 30 tonnes of waste per hour. A thermal conversion efficiency of 27% makes this one of the most efficient plants in Europe.

The plant has been designed to provide heat to homes in the area, but the density of heat consumers has been found to be too low at present for district heating to be viable. The intention is to establish a heat distribution network in the future.

The majority of waste is delivered by boat, where waste is transported in sealed containers on a fleet of barges, each with a capacity of 300 tonnes. This is estimated to eliminate 100,000 vehicles movements from London’s congested roads each year.

Cory Riverside Resource Recovery Facility, London

Table 4—2: Thermal Treatment Technology 2: Fluidised bed combustion

Technology	Combustion in a fluidised bed
Concept	In this technology, waste is suspended and burned in a hot bed of material typically consisting of sand, ash or other inert materials. The fixed bed of fine solids is transformed into a liquid-like state through contact with an upward flowing gas. The hot bed material acts to dry and ignite the waste. It is effective on fuels with relatively low heating values. Historically, fluidised bed technology has been applied to the combustion of a wide variety of fuels, including biomass, MSW, and Commercial and Industrial (C&I) waste. Configurations include both bubbling and circulating beds.
Commercialisation	Utilised for incineration of MSW since the 1970's. Used extensively in Japan for smaller throughputs.
Size (per line)	3 – 15 tonnes per hour
Size (per installation)	<10,000 – 700,000 tonnes per annum
Energy recovery	Steam turbine Power efficiency – up to 25% Combined Heat and Power – can reach >70%
Inputs/Feedstocks	MSW, C&I. Waste particle size <200mm.
Feedstock Pre-treatment	Fluidised bed furnaces will generally require material to be of a particular particle size in order to achieve complete combustion and so will require some pre-treatment. This may involve sorting and removal of bulky items and metals. Particle size will be reduced by crushing and/or shredding. It is for this reason that fluidised bed furnaces tend to be use feedstock that has undergone substantial pre-processing, such as refuse derived fuels (RDF) or solid recovered fuels (SRF).
By-products	Incinerator Bottom Ash (IBA) and Air Pollution Control Residues (APCr)

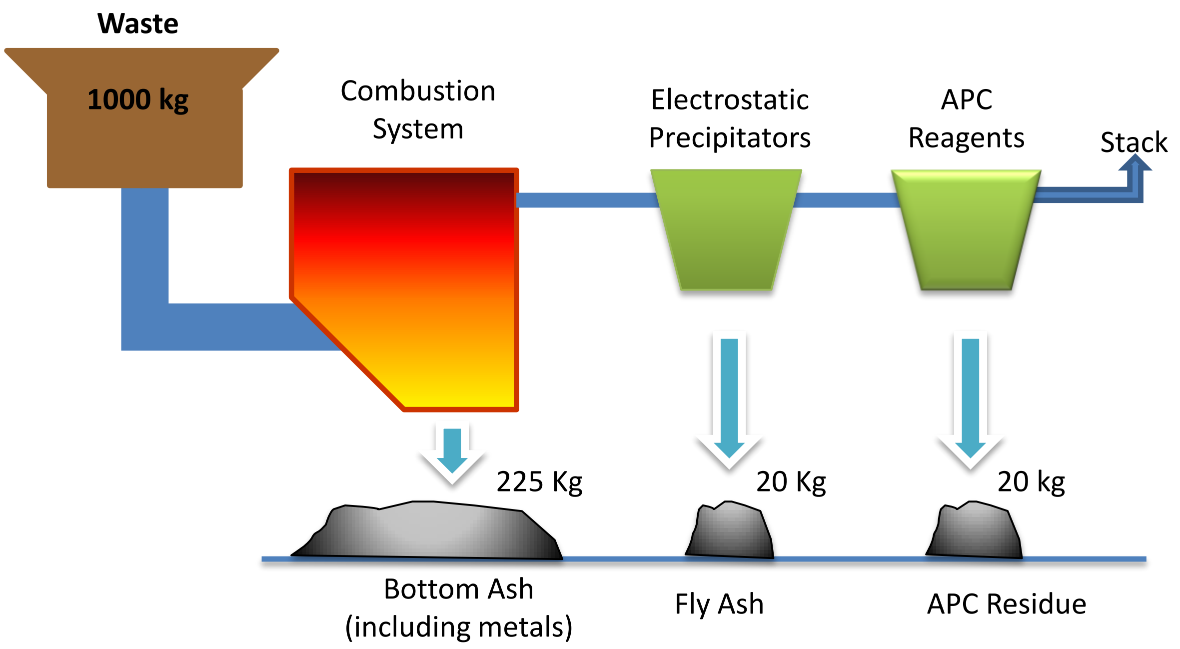
Table 4—3: Thermal Treatment Technology 3: Rotary kiln

Technology	Combustion in a rotary kiln
Concept	A rotary kiln incinerator consists of rotating combustion chamber, set on a slight incline to the horizontal. The waste is introduced to the kiln at the higher end, with the resulting ash discharged through a grate at the lower end. Temperatures in the kiln can reach 1,800°C depending on the application, and the versatility of this technology means that it is often used in the treatment of hazardous and difficult waste streams such as medical waste, sludges and contaminated soils.
Commercialisation	Whilst they are less common than moving grate incinerators, rotary kiln incinerators are widely used across the world, often for the treatment of hazardous waste, sewage sludge and waste water sludge incineration.
Size (per line)	0.5 – 30 tonnes per hour, although much higher for rotary cement kilns.
Size (per installation)	Wide ranging. Generally smaller than moving grate combustion plants, with small scale plants from 5,000 – 10,000 tonnes and larger plants up to 150,000 tonnes per annum.
Energy recovery	Steam turbine Power efficiency – up to 25% Combined Heat and Power – can reach >70%
Inputs/Feedstocks	Mainly used for treatment of industrial and hazardous wastes. Flexible technology that can process solids, liquids and sludges.
Feedstock Pre-treatment	Pre-treatment of waste is not generally necessary for rotary kiln furnaces although bulky items may need to be shredded.
By-products	Incinerator Bottom Ash (IBA) and Air Pollution Control Residues (APCr)

4.2 Conventional Combustion Outputs

Figure 4-2 identifies the sources of incineration residues. Incinerator Bottom Ash is material discharged from the combustion grate and collected in hoppers below the furnace.

Figure 4-2: MSW incinerator residues (source: IEA Bioenergy)



4.2.1.1 Incinerator Bottom Ash (IBA)

Any incineration process will produce IBA. After IBA is discharged from the combustion grate in a mass burn incineration facility, it is quenched in water before ferrous metal is separated by magnets and potentially non-ferrous metals by eddy current separators for recycling.

IBA typically represents 20-25% of input waste by weight and contains varying quantities of non-combustible materials such as glass, ceramics, brick, concrete and metals in addition to clinker and ash, depending on the waste being burnt.

IBA composition is important to consider for its treatment and utilisation. IBA is fairly stable and inert in comparison to the waste input but will contain heavy metals such as lead and zinc. It is primarily composed of a mix of ceramics, slags, and glassy material along with some metals.

IBA can be used in number of applications, including as a fill material in construction, and as a secondary aggregate material.

IBA can be used in the following ways:

+ Unbound – bulk fill (e.g. embankments, structural fill, backfill with capping); sub-base (roads, car parks, paved areas); pipe-bedding
+ Hydraulically bound material (HBM): base, sub-base or capping layer, blended with a hydraulic binder (e.g. cement, steelmaking slags, lime)
+ Bitumen bound: foamed bitumen asphalt, binder course;
+ Cement bound: foamed concrete, low strength concrete.

The reprocessing of IBA into secondary aggregate involves the following steps:

- Crushing;
- Maturation or weathering; and
- Screening or separation.
  - Removal of ferrous metals;
  - Removal of non-ferrous metals; and
  - Separation of oversized particles.

When IBA has been processed, it is generally referred to as IBAA – Incinerator Bottom Ash Aggregate. In the UK, the Highways Agency accepts IBAA as an aggregate for bound and unbound layers in road construction.

The Environment Agency in England and Wales also supports the use of IBAA, and is in the process of gathering evidence in relation to the standards that the material meets, available markets, and more importantly any potential impacts on human health and the environment.

IBA possesses similar properties to natural aggregates and recycling and reusing it offers significant environmental benefits:

- Reduced quarrying of primary aggregates;
- Additional tonnages of ferrous and non-ferrous metals can be recovered from IBA for recycling;
- Avoids landfill;
- Lower energy production needed compared to the production of primary aggregates.

In Europe and the US, it is common for larger incineration plants to be co-located with IBA re-processing plants. Metals and aggregates recovered from the IBA can count towards recycling and landfill diversion in some cases.

For IBA to be used in a construction fill application in SA, the user would need to demonstrate that the use of the Waste Derived Fill (WDF) meets the SA EPA 'Standard for the production and use of waste derived fill'. The key criteria of this standard are:

- the need to demonstrate that the use of WDF is for a beneficial purpose rather than a means of convenient disposal and the associated avoidance of regulation and costs;
- the need to ensure that harm to the environment or human health is prevented or the risks minimised to levels acceptable to the EPA (as well as to the satisfaction of other relevant planning and health authorities); and
- a requirement for WDF to meet a defined specification that is suitable for the proposed use.

The Standard outlines three sources of waste materials that could potentially be suitable for use a waste derived fill. These are waste soils, processed Construction and Demolition waste, and homogenous mineral-based industrial residues. Whilst IBA from a W2E facility may be considered a homogenous mineral-based industrial residue, there is no mention of IBA in the standard. Accordingly, the potential for the use of IBA across the W2E sector is a matter that the EPA would need to determine if and when a proposal was brought before it.

4.2.1.2 Air Pollution Control Residues (APCr)

Waste incineration processes may also produce fly ash, which is the particulate matter removed from the flue gas stream prior to the air pollution control (APC) system. Fly ash can also include boiler ash, which is particulate matter removed from the heat recovery systems. The APC system produces APCr, which can comprise scrubber residue and/or bag house filter dust. APCr is a hazardous waste that can only be disposed in specialised landfill sites or storage facilities. APCr is typically a very fine-grained powder, ranging in colour from light to dark grey. The type of incinerator and flue gas cleaning system defines the physical and chemical nature of APCr and its chemical composition also depends on the waste incinerated.

A typical APC system consists of flue gas recirculation (FGR) and selective non-catalytic reduction (SNCR) or selective catalytic reduction (SCR) by injection of aqueous ammonia or dry urea. Acid flue gases are neutralised by semi-dry scrubbing in a solution of lime and water. An activated carbon injection system installed on each stream aims to minimise the flue gas emissions of dioxins, mercury and other heavy metals. After flowing through the gas scrubber, the gases will pass through bag filters to remove particulates, including lime and activated carbon particles, known as APCr. Two types of APC systems are used widely:

- Dry and semi-dry residue systems. Slaked lime is injected into the flue gas, either in dry form or as slurry. This neutralises the acidic components in the flue gas and is typically done before removing the fly ash from the flue gas. Fly ash, reaction products and unreacted lime is typically removed in fabric filters. Activated carbon may be injected for dioxin removal and removed together with the fly ash.
- Wet residue systems. Fly ash is typically removed before neutralising acidic components. After this, the flue gas is scrubbed in one, two, or a multistage arrangement of scrubbers. The scrubber solutions are then treated to produce sludge and gypsum. Wet systems typically generate more than one residue.

APCr composition is important to consider for its treatment and utilisation. APCr contains toxic elements such as lead, nickel, and mercury as well as elements that are both carcinogenic and toxic such as cadmium, hexavalent chromium and arsenic. In addition, it contains high a concentration of lime with other organic contaminants, which poses a treatment and disposal problem due to high alkalinity. When compared with IBA, APCr contains a significant amount of calcium oxide, chlorides and heavy metals.

Due to its hazardous nature, the reuse or recycling of APCr has always been challenging, and therefore historically is has been disposed without treatment. Disposal needs to be in hazardous landfills, or APCr can be deposited in underground salt mines as in some cases in the UK and Europe.

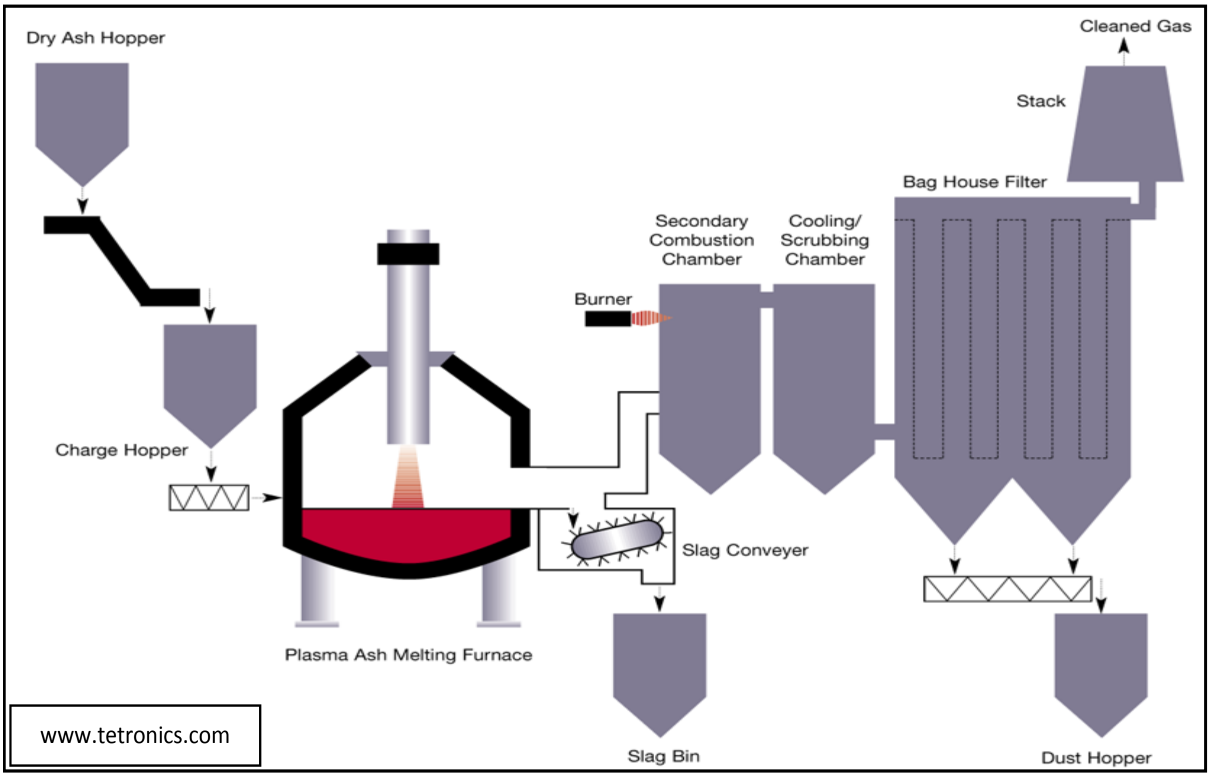
However, there have been some more recent developments in treatment options for APCr. These treatment options include:

- Washing:
    - Ash washing with magnesium sulphate (MgSO4);
    - Acid leaching with nitric acid (HNO3); and
    - Bioleaching using asphergillus niger (fungus)
- Stabilisation and solidification:
    - Cement and concrete production;
- Thermal treatment:
    - Vitrification;
    - Sintering.

An example of using thermal treatment of APCr is the plasma vitrification process developed by Tetronics in the UK. Tetronics' patented Direct Current (DC) Plasma Arc plant technology is used to vitrify hazardous inorganic materials such as APCr into a dense, stable aggregate known as Plasmarok. Plasmarok is produced inside the plasma converter where temperatures up to 1500°C reduce the inorganic feedstock to a molten vitreous material, see Figure 4-3. This material can then be cooled and granulated to produce a sub 10mm product, or allowed to cool slowly into high strength products such as blocks. These can be used as a sub-base material in high load bearing structures.

The Environment Agency in England has awarded 'end of waste'[5] status to Plasmarok, meaning that it can be marketed as a product and is no longer a waste. However, this process is still currently only undertaken in a test facility, with a capacity of only 2-3,000 tonnes per annum.

Figure 4-3: Tetronics Plasma Vitrification system (www.tetronics.com)



4.2.1.3 Use of IBAA and Fly Ash/APCr in Australia

There is currently no specific legislation in South Australia for the use of bottom ash. Cement Concretes & Aggregates Australia examined the use of recycled aggregates in construction in a 2008 report.[6] This outlined investigations into using cement-treated MSW IBAA into concrete, and also identified the use of IBAA in construction. The report notes that there are limited IBA proprietary products available in Australia.

A barrier to the use of IBAA in Australia may be the fact that residues from the incineration of household waste are deemed as hazardous waste under the Hazardous Waste (Regulations of Exports and Imports) Act 1989.

In comparison, Coal Combustion Products (CCPs) are widely used in concrete manufacture, as structural fill, in road construction, in the manufacture of masonry products and for mine back-fill.

Currently within Australia, fly ash is classified as regulated or hazardous wastes whilst bottom ashes are typically classed as inert, non-hazardous wastes. For example, the National Environmental Protection Measure: Movement of Controlled Wastes between States and Territories specifically lists fly ash as a controlled substance and therefore its transport is monitored and must be reported.

[5] http://www.environment-agency.gov.uk/business/sectors/124299.aspx
[6] http://www.concrete.net.au/publications/pdf/RecycledAggregates.pdf

Fly ash is currently the most widely utilised CCP in Australia, with a long-term and stable market where it is commonly used as a 20% – 40% cement replacement in concrete. This sector is highly regulated by a number of Australian Standards. An example of the use of fly ash from coal burning is at Adelaide Brighton Cement. Flyash is added to cement products in order to improve properties such as durability and workability and to reduce shrinkage.

The use of ashes from W2E in Australia will be dependent on their individual properties and consistency. They may also have to compete with the use of CCPs, and in particular from black coal. However, combustion of brown coal in South Australia typically results in an ash with a much higher level of contaminants, as the coal is of lower quality and has a lower gross calorific value. This could potentially be an advantage when marketing by-product from future thermal energy recovery facilities in SA. Ultimately, the use of by-products from future thermal energy recovery facilities in SA will need to meet the requirements of the Environment Protection Act and may require approval from the SA EPA.

4.3 SWOT Analysis of Thermal Treatments

Table 4—4: SWOT Analysis of conventional combustion

Technology	Strengths	Weaknesses	Opportunities	Threats
Combustion	+ Established, mature and reliable technology. + Significant experience and operational data on wide range of waste feedstocks. + Can process multiple fuels, and is tolerant of fluctuations in fuel quality and composition. + Fuel is generally not dependent on pre-treatment, with the exception of fluidised bed technology. + Several designs available: moving grate, bubbling fluidised bed, circulating fluidised bed, and fixed bed designs. + Can reduce the volume of the waste by up to 95%.	+ Combustion processes require sophisticated gas cleaning monitoring and control system that may require significant capital expenditure. + Process produces small volumes of fly ash and APCr that must be handled as hazardous waste. + Power generation from combustion is only possible by means of raising steam to drive a steam turbine delivering low electrical efficiency. Gross electrical efficiencies of such processes tend to be in the order of 15-30%. + Potential net increase in greenhouse gas emissions. + Low value by-product associated with the use IBAA.	+ Diversion of biodegradable materials from landfill and associated reduction in greenhouse gas generation potential. + Opportunities for electricity and heat generation. + Incinerator bottom ash can be diverted from landfill due to potential uses as an aggregate substitute.	+ Combustion suffers from poor public image, thereby presenting difficulties in gaining public and political support for the development of such processes. + Other forms of W2E technology can receive enhanced support through mechanisms such as the Renewable Energy Certificates, placing combustion at a competitive disadvantage

5 Advanced Thermal Technologies

5.1 Technology Types

Gasification and pyrolysis processes are collectively referred to as Advanced Thermal Treatment (ATT) processes or Advance Conversion Technologies (ACT).

Gasification refers to the process where a feedstock is heated in the limited presence of an oxidising agent (e.g. oxygen) whereas pyrolysis refers to the application of heat to a feedstock in a reducing (i.e. oxygen-free) atmosphere.

Both processes cause the feedstock material to chemically degrade to form a synthesis gas (“syngas”) composed of carbon dioxide, hydrogen, carbon monoxide, methane and steam. Furthermore, pyrolysis processes can generate a combination of condensable vapours that, upon cooling, form a mixture of oils, tars and waxes known as pyrolysis oil.

Pyrolysis/gasification can be achieved using either purpose-designed chemical reactors or modified versions of furnaces used for combustion.

Figure 5-1: Flow diagram of a Nippon Steel MSW gasification and combustion plant. (Source: IEA Task 36 – Overview of Technologies Used for Energy Recovery.)

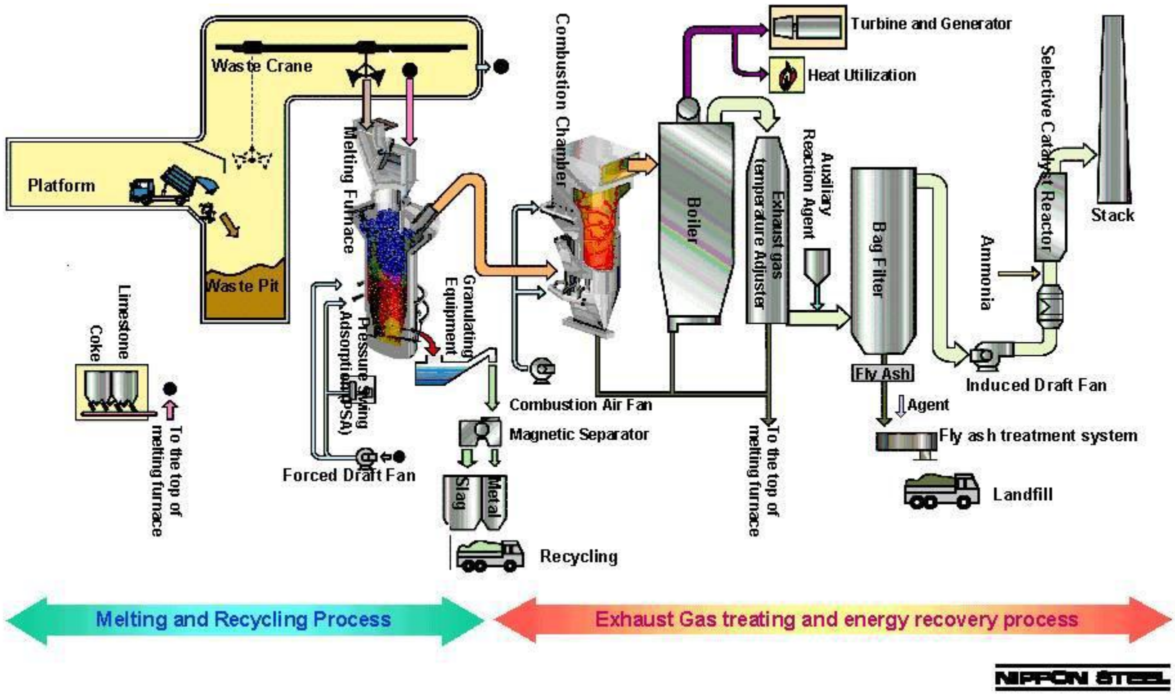


Table 5—1: Thermal Treatment Technology 4: Gasification

Technology	Gasification
Concept	Gasification is the process of converting solid or liquid feedstock into a partially oxidised gas, known as 'syngas' – a combination of carbon monoxide, hydrogen and methane. Typical temperatures required for gasification range between 500-1800°C. Syngas can be used in a number of ways, including combustion in an engine, boiler or for conversion into a transport fuel.
Commercialisation	Gasification has historically been used for the processing of oil, coke and petroleum products but in more recent times attempts have been made to apply the technology to MSW and other waste derived fuels. Down-draught is the most widespread, but despite a wide range of technologies, the process itself if broadly similar. The market for gasification processes is embryonic within the UK. However, there is significant experience with gasification in other parts of Europe and Japan. Gasification facilities in Australia are predominantly using biomass, as opposed to mixed waste, as a fuel feedstock. In several European countries, the process is used to provide syngas as a chemical intermediate or to generate power. In Japan, several thermo chemical processes using MSW have been operational for several years. Companies such as Europlasma, Plasco Energy Group, Energos and Advanced Plasma Power are all involved in the development and operation of gasification technologies.
Size (per line)	<1 – 11 tonnes per hour
Size (per installation)	<10,000 – 250,000 tonnes per annum Fluidised bed gasifiers are typically used at a larger scale and can accommodate wider variation in fuel quality, making them suitable for processing waste and biomass.
Energy recovery	Steam turbine, gas engine or gas turbine Power efficiency – up to 23% Combined Heat and Power – can reach up to 81% using steam turbine.
Inputs / Feedstocks	The range of feedstock properties is much narrower than for conventional combustion due to the chemistry and thermo-dynamics of gasification being more sensitive to variations in composition, ash content, moisture content, particle size and density.
Feedstock Pre-treatment	As gasification operates by treating biodegradable materials present in a waste stream, non-combustibles such as metals and glass must be removed. For some types of gasification system, the particle size will be a critical parameter and therefore waste will need to be shredded to the required particle size. Moisture content may need to be reduced for some systems. The amount of pre-treatment required means that gasification is suited for integration with a waste treatment technology such as MBT.
Outputs	Syngas can be utilised to generate electricity via boilers, gas turbines or engines.
By-products	In gasification, inorganic materials are converted to either bottom ash (low temperature gasification) or a vitreous slag (high temperature gasification).

Ebara Corporation, Japan
Ebara Corporation is an organisation based in Japan with more than 25 years' experience in delivering waste management, energy recovery and resource recycling technology using fluidised bed furnace designs. Ebara has at least 14 Twin Rec reference plants known to be operational and they were responsible for the development of the innovative twin internally-circulating fluidised bed furnace design that lowers the feedstock pre-treatment requirements.

Ebara typically uses close-coupled gasification / combustion, coupled to open steam cycles with high-pressure super-heated steam at 400˚C. These systems are designed to operate at high furnace temperatures capable of melting the ash (in particular fly ash) generated and producing a clean but low gross calorific value syngas that is then combusted, although they vary their designs according to the anticipated feedstock.

Table 5—2: Thermal Treatment Technology 5: Plasma gasification

Technology	Plasma gasification
Concept	Plasma gasification is the term that applies to a range of technologies that involve the use of a plasma torch or arc. Plasma is an electrically conductive gas, such as nitrogen or argon, which is heated by an electrical current to very high temperatures. The reaction takes place within a chamber connected to a plasma torch, which is refractory lined to withstand the high temperatures produced by the plasma torch. The plasma torch can be applied directly to the feedstock, or to the syngas produced by a proceeding gasification process. Plasma gasification operates at temperatures as high as 7,000°C, resulting in rapid chemical reactions to break down the feedstock into gases. Inorganic materials are melted into a liquid slag, which is cooled into a solid. The higher temperatures ensure that the syngas produced by a plasma process is cleaner than conventional combustion, as the higher temperatures allow for the breakdown of tars. Whilst the syngas can be used for energy utilisation, the plasma process itself has a high electric consumption.
Commercialisation	Whilst there are some commercially operating plants, such as the Tetronics facility in the UK, this technology is not yet considered proven and some plants are still only at pilot scale. Plasco Energy Group is currently operating a 100 tonne per day commercial demonstration facility in Ottawa, Canada, and a 5 tonne per day research and development facility in Castellgali, Spain.
Size (per line)	0.5 – 10 tonnes per hour
Size (per installation)	Unknown, due to limited operating plants
Energy recovery	Syngas Steam turbine, gas engine or gas turbine Power efficiency – up to 23% Combined Heat and Power – can reach up to 81% using steam turbine
Inputs/Feedstocks	MSW, C&I, hazardous wastes, ashes
Feedstock Pre-treatment	The commentary on feedstock preparation above, for Gasification, applies equally for Plasma Gasification.
Outputs	Syngas can be utilised to generate electricity via boilers, gas turbines or engines.
By-products	Aggregate product or slag

Plasco Energy Group, Ottawa, Canada
Plasco's Plasma treatment plant is part of a joint 'Partnership for a Zero-Waste Ottawa' project between Plasco Energy Group and the City of Ottawa. Approval for the facility was granted in 2006. Plasco Energy Group has agreed to finance all costs associated with the evaluation facility, whilst the City Council provide the site, the waste and pay a $40/tonne tipping fee.

The MSW undergoes a sorting process to recover recyclables, and is then shredded prior to entering the conversion chamber, where it is converted into a crude syngas. The syngas is refined to remove sulphur and acid gases, resulting in a clean, high energy gas. The syngas is then used to fuel internal combustion engines to produce electricity. Solid residues are removed from the conversion chamber and melted in a separate chamber by a plasma torch. This stabilises the solids into an inert vitrified residue, and converts any remaining volatile compounds into syngas. Any remaining solids are melted and cooled into pellets.

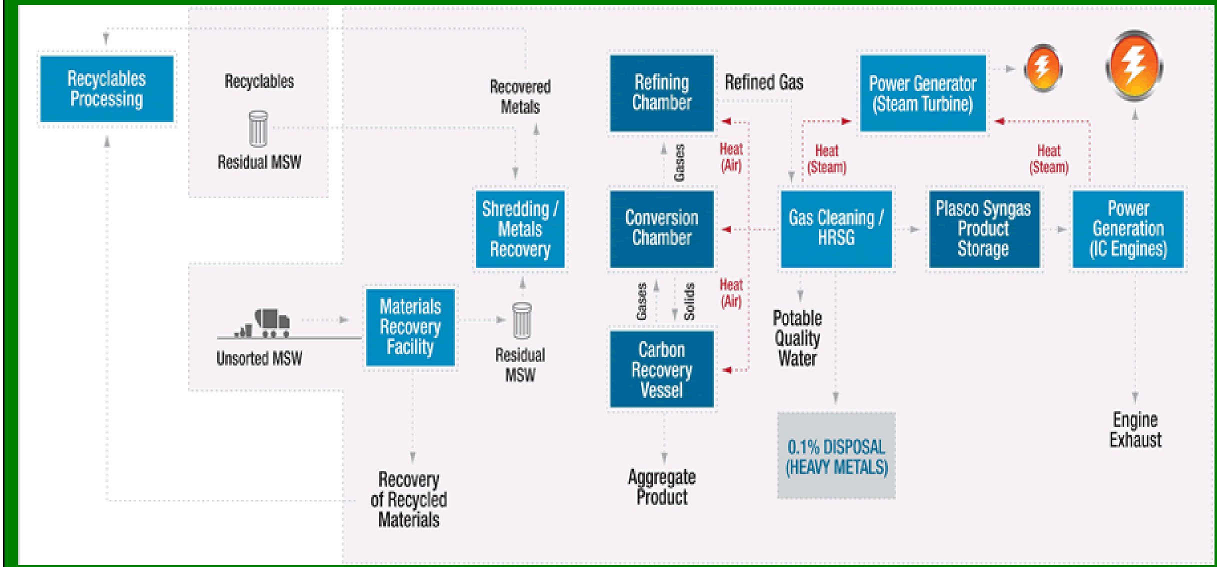


Table 5—3: Thermal Treatment Technology 6: Pyrolysis

Technology	Pyrolysis
Concept	Pyrolysis is similar to gasification except that the feedstock is thermally degraded in the complete absence of oxygen. Conventional pyrolysis takes place in temperatures ranging between 400-900°C. Slow pyrolysis is characterised by low heating rates and long residence times, whereas fast pyrolysis is characterised by very high heating rates and short residence times. There are different configurations of pyrolysis equipment, including fluidised bed, moving bed and rotating cone. The design of the pyrolysis process will impact on the characteristics of the process outputs. For example, slow pyrolysis will produce charcoal, oil and gas, whereas fast pyrolysis is designed to maximise the production of pyrolysis oils.
Commercialisation	Pyrolysis is also a mature technology in terms of its application to coal, peat and liquid fossil fuels, however there is limited examples in its application to waste derived fuels. There is some experience of slow pyrolysis of MSW, but these still tend to be in development stages, and there are several examples of project failures (for example, the MSW and clinical waste-based pyrolysis process operated by Compact Power in the UK is no longer operational). Successful examples of pyrolysis tend to be those plants using homogenous waste streams such as tyres and wood chip. There are several examples of pyrolysis plants in Australia that utilise black liquor from the paper industry.
Size (per hour)	0.2 – 30 tonnes per hour
Size (per installation)	Unknown, due to limited operating plants
Energy recovery	Steam turbine, gas engine or gas turbine Power efficiency – up to 23% Combined Heat and Power – can reach up to 81% using steam turbine
Inputs / Feedstocks	As with gasification, pyrolysis is sensitive to variations in feedstock characteristics and waste may need an element of processing to ensure it is a suitable feedstock.
Feedstock Pre-treatment	Pyrolysis systems may require extensive pre-treatment of the waste stream, depending on the feedstock type and system design. This may involve removing non-combustible materials, shredding or grinding, and drying. Pyrolysis systems are also more widely used on homogenous feedstocks as opposed to mixed wastes.
Outputs	Syngas can be utilised to generate electricity via boilers, gas turbines or engines.
By-products	Products of pyrolysis of waste are: + gases, predominantly primarily carbon monoxide, hydrogen, methane, CO_2 and short chain hydrocarbons; + pyrolysis oil comprising low volatile hydrocarbons up to tars; and + solid residues, which are a mixture of coke and inert ashes.

Pacific Pyrolysis, Somersby, Sydney

Pacific Pyrolysis have developed a slow pyrolysis pilot facility, named PyroChar 300, at the Somersby Advanced Engineering Facility north of Sydney. The demonstration facility has a capacity of 300 kg/hr of biomass materials, and powers a 200kW electrical generator. The by-product from the pyrolysis process is used to produce ‘Agrichar’, a soil enhancer.

The data acquired from operating the demonstration unit is facilitating the development of larger commercial units, which will be capable of processing up to 4 tonnes per hour. These units will be modular and can be designed to provide syngas to an engine, or to interface with a thermal process such as a steam boiler.

5.2 Advanced Thermal Treatment Outputs

5.2.1 Syngas

All Advanced Thermal Treatment processes will produce a syngas, which is used for energy recovery, and a solid residue, such as a slag, ash or char. Pyrolysis processes can also be designed to produce a liquid by-product in the form of an oil or tar.

Syngas can be used in a number of different ways. The most common method of energy recovery from syngas is to combust it directly in a boiler to raise steam, and into electricity via a steam turbine. Syngas can also be used in a gas engine, but will need considerable cleaning and cooling. Syngas also has the potential to be used as a vehicle fuel, but only after significant upgrading.

Depending on the waste feedstock, syngas will be composed of hydrogen, carbon monoxide, carbon dioxide, methane and nitrogen. Other contaminants will include particulates, tars, alkalis and sulphur. Syngas cleaning technologies are still under development, but a typical gas cleaning process may comprise of:

+ Particulate removal – using cyclonic separators, barrier filters or electrostatic filters;
+ Tar elimination – using water or oil scrubbing, or thermal or catalytic cracking;
+ Sulphur removal – by wet scrubbing or chemical gas treatment; and
+ Nitrogen elimination – by wet scrubbing.

The level to which syngas must be cleaned or upgraded will depend on the end use of the syngas.

An alternative to using syngas to produce energy is for it to be used as a chemical feedstock. For example, syngas can be used in the Fischer-Tropsch process to produce diesel, or be converted into methane or methanol in a catalytic conversion process.

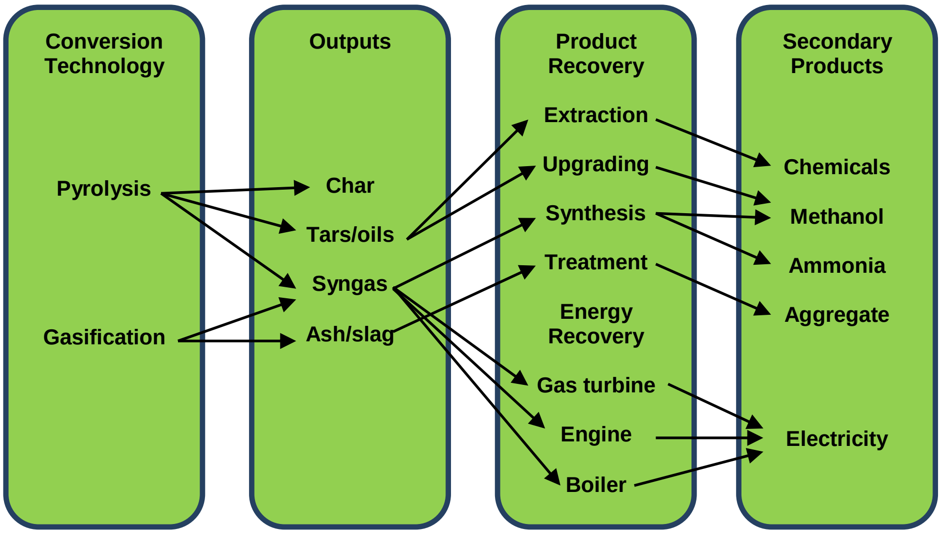
5.2.2 Solid Residues

Ash and slag residues from gasification can potentially be used as an aggregate, or in the manufacture of bricks and blocks. In the case of high temperature gasification, inorganic ash materials are quenched and crystallised into a slag. Generally these slags do not leach and can be considered inert. It can be crushed in to a fine powder for ease of handling, and used in applications such as the manufacture of roof tiles, or as sandblasting grit.

Char from pyrolysis process can be used as a coal replacement, or be further processed by gasification. Biochars that have fertiliser properties have also been developed. Biochar is a carbon rich material produced from the pyrolysis of organic materials in a low oxygen environment. Adding biochar to soil can improve soil condition, and can also have the added benefit of sequestering carbon within the soil. The International Biochar Initiative[7] is an organisation that has been formed to develop standards and classification systems for the production of biochar, and advocate its production from agricultural and forestry residues.

[7] http://www.biochar-international.org/

Figure 5-2: Summary of Advanced Thermal Treatment outputs and applications



5.3 Safety issues relating to Advanced Thermal Treatment processes

W2E facilities are increasing in complexity, as technology is developed to maximise the recovery of valuable resources and energy and to minimise potential environmental impacts. As with all process industries, there are potential safety hazards which need to be risk assessed and appropriately controlled on a case by case basis.

Safety issues relate both to feedstock and residue handling as well as the energy recovery process itself. Whilst the process and energy industry already have well defined procedures and processes to manage and control safety risks, the introduction of alternative waste treatment technologies such as gasification and pyrolysis may mean that safety risks are not so fully understood.

Safety risks associated with waste feedstocks may include the risk of fire, explosion or formation of toxic gases. Large stockpiles of wastes such as wood can generate heat and ignite. Self-heating can also result in the formation of carbon monoxide, an even greater risk if waste is stored in confined spaces.

Whilst conventional combustion is generally undertaken at atmospheric pressure, gasification can take place under lower or higher pressures. Syngas produced by the gasification process is highly flammable, and if the internal pressure is too low, the ingress of air could result in an explosion within the gasifier. Conversely, high pressure could result in gas leaks and a potential for ignition external to the gasifier. Gas leaks also present a hazard in the form of toxic gases containing carbon monoxide. Similarly, over-pressure in pyrolysis systems can result in gas leaks.

These potential safety risks are managed by optimum process control, and by designing systems with appropriate venting and flare systems.

5.4 SWOT Analysis of Advanced Thermal Treatments

Table 5—4: SWOT Analysis of ATT technologies

Technology	Strengths	Weaknesses	Opportunities	Threats
Gasification	+ The technology is currently available. + Gasification allows efficient power generating technologies (i.e. reciprocating engines and gas turbines) to be used. + The process has low dioxin, furan & VOC emissions as reactions occur under a homogenous low oxygen atmosphere at high temperature. + Low NOx & SOx emissions due to process occurring in a low oxygen environment. + Process has better volume reduction performance than combustion or pyrolysis due to the higher operating temperatures and the longer residence times. + Hazardous heavy metals vitrified in leach resistance slag. + The technology is available in a semi-modular format.	+ Process carries safety risks that would be new to the waste management industry. + Significant technical residual risk in gas cleaning for power production. + Some limitations on the type and mix of input feedstock to ensure the syngas has a high calorific value of syngas and that flue gas emissions limits are not exceeded. This limits feedstock flexibility and availability. + Limited experience in operating gasifiers with MSW feedstock. + Conversion Process requires the input of energy (equivalent to 20-25% of input energy) to sustain gasification process.	+ Diversion of biodegradable materials from landfill and associated reduction in greenhouse gas generation potential. + Opportunities for electricity and heat generation. + Syngas produced has the potential to be used as a versatile fuel. + Ash (if produced) has potential uses as an aggregate substitute.	+ Previous experience of gasification has predominantly been on industrial locations (i.e. petrochemicals refineries) where the impacts have been minimised. + Community resistance to gasification due to the perception that it is another form of incineration. + Attainment of syngas with a sufficiently high syngas may place constraints on feedstock. Wastes with a low CV may not be suitable.

Technology	Strengths	Weaknesses	Opportunities	Threats
Pyrolysis	+ The process has low dioxin, furan & VOC emissions as reactions occurring in an oxygen-free environment at high temperature + Low NOx & SOx emissions due to process occurring in an oxygen-free environment.	+ Process carries safety risks that may be new to the waste management industry. + Still at R&D stages, very limited commercial operating experience demonstrated using MSW and other mixed waste streams + Cleaning gas for power production introduces technical risks and uncertainty. + Limited experience in operating gasifiers with MSW feedstock. + Process requires the input of energy to sustain pyrolysis process (equivalent to 20-25% of input energy). Whilst gasification systems can be designed to release some of the energy in the feedstock to sustain the gasification process, Pyrolysis generally needs energy from an external source to sustain the process.	+ Syngas and pyrolysis oils produced have the potential to be used as versatile fuels. + Potential to recover the material value of the organic fraction, i.e. as methanol + Process can be designed to produce a range of outputs for different applications.	+ Pyrolysis processes have historically used other feedstocks and have tended to be located on industrial sites where impacts can be managed. + Community resistance to pyrolysis due to the perception that it is another form of incineration. + Experience of waste pyrolysis remains limited at this time. Bulk of research knowledge to date has been regarding the pyrolysis of fuels such as coal.

Table 5—5: Summary of technical specifications and feedstock compatibility of thermal treatments of waste

Technology	Technical Requirements and Specifications						Feedstock Compatibility						
	Capacity (per module)	Tonnes per hour	Particle Size	Calorific Value (GJ/tonne)	Moisture Content	Prime Mover Compatibility	Wood Waste	Other biomass	RDF/SRF	Agricultural residues (e.g. straw)	Plastic	Mixed C&I waste	Hazardous Waste
Combustion													
Moving grate	5-110	0.1-40	all	6-15	10-50	Boiler	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bubbling Fluidised bed	10-170	>3	<50mm	6-20	10-50	Boiler	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Circulating Fluidised bed	50-170	>10	<25mm	6-20	10-50	Boiler	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rotary kiln	5-110	0.1-30	all	6-15	10-50	Boiler	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gasification													
Fixed bed (downdraft)	Max 50 - modular	<10	<130 mm, Critical parameter for operational performance	12-20	15-20	Boiler. Engine only with extensive gas preparation	Yes	Yes	Yes	Depending on feedstock properties	No	Depending on feedstock properties	No
Fixed bed (updraft)	Max 50 - modular	<10	23 - 63mm Less sensitive to size	6-20	10-50	Boiler. Engine only with extensive gas preparation	Yes	Yes	Yes	Depending on feedstock properties	No	Depending on feedstock properties	No
Fluidised bed	>20 - Modular	>10	<32mm	6-20	10-50	Boiler. Engine only with extensive gas preparation	Yes	Yes	Yes	Depending on feedstock properties	No	Yes	No
Plasma Arc Gasification	Max 50 - modular	0.5-100	23 - 63mm Less sensitive to size	6-20	10-50	Boiler. Engine only with extensive gas clean up	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pyrolysis													
Fixed bed	Max 50 - modular	0.1-10	<200mm	6-20	<10%	Boiler	Yes	Depending on feedstock properties	Depending on feedstock properties	Depending on feedstock properties	Yes	Depending on feedstock properties	Yes
Moving bed	Max 50 - modular	>10	<200mm	Limited operational data	<10%	Boiler	Yes	Yes	Yes	Yes	No	Depending on feedstock properties	No
Fluidised bed	Limited operational data	2-20	2-3mm	Limited operational data	<10%	Boiler. Engine only with extensive gas preparation	Yes	Depending on feedstock properties	No	Depending on feedstock properties	Yes	Depending on feedstock properties	Yes
Flash pyrolysis	Limited operational data	3	<3mm	Limited operational data	<10%	Boiler. Engine only with extensive gas preparation	Yes	Depending on feedstock properties	No	Depending on feedstock properties	No	Depending on feedstock properties	No

6 Biological Technologies Inputs

6.1.1 Organic Fraction of Municipal Solid Waste (MSW)

In many European countries, and increasingly in the UK, kerbside collections of food waste from households have already become the norm, with over one third of local authorities now offering a segregated collection (or one commingled with green waste). The organic fraction of MSW (e.g. recovered from an MBT process) has a typical yield of 50-100 m^3 of biogas per tonne of waste whereas source segregated biodegradable municipal waste (BMW) can yield 70-170 m^3 of biogas per tonne of waste. Source segregated food waste from households is an ideal feedstock for AD plants, as it is a high energy waste, and has a high moisture content.

6.1.2 Organic Fraction of Commercial and Industrial Waste

Food waste from this sector is produced from a wide range of sources, including processing waste from food manufacturers, unsold food from wholesale, distribution and retail outlets and leftover food from the food service industry. The Australian Government National Waste Report 2010, estimates that food waste accounts for up to one-fifth of the C&I waste stream.

As can be seen in Case Study 4, food and drink manufacturers who have sufficient on-site waste streams can choose to invest in on-site Anaerobic Digestion facilities, both as a means of a waste disposal solution and to benefit from the production of heat and electricity. Other C&I producers of food waste will be dependent on the availability of a local food waste collection service. The challenge to fully realising the potential of the organic fraction of C&I waste is separating it from the mixed residual waste stream. Food waste from retail and food services is often packaged, and will need to be de-packaged for input into an anaerobic digestion facility.

6.1.3 Manures

Interest in AD as a manure management option is expanding rapidly across Europe as concerns about methane emissions and other environmental impacts from livestock waste increase along with its potential to capture and utilise methane as a renewable energy source. This feedstock comprises of slurries and manures produced on farms. Feedstock with a dry solids (DS) content of up to 15% is generally treated in wet AD systems. Hence, most agricultural plants treating manure and slurries are based on this system.

Methane potential varies between livestock types. Pig and cattle slurry has the potential to yield between 15 and 25 m^3 per tonne of biogas (10% dry matter) while poultry manure can yield up to 100 m^3 per tonne of biogas (20% dry matter). Chicken manure is generally considered to be too rich and unbalanced a feedstock, due to its very high nitrogen content, but lends itself to co-digestion with other slurries and wastes. Traditional manures have been used as a fertiliser for grass and crops. However, environmental legislation, such as the EU Nitrates Directive, has placed constraints on the land application of manures. When compared with traditional land application of raw manure, AD digestate has a number of advantages including improved fertiliser value, ease of spreading, reduction in pathogen load and malodours and reduction in pollution potential.

6.1.4 Other Agricultural Wastes

South Australia has a strong agricultural and food industry. The area of farmland in South Australia is increasing (ABS 2012), including crops such as barley and wheat. The growing and processing associated with these commodities generates waste streams suitable for energy recovery under a range of technologies and they also qualify for RECs for energy produced can be exported to the grid.

The wine grape industry produces a number of waste streams, although these wastes are highly seasonal. Existing enterprises such as Tarac Industries have already recognised the commercial opportunities associated with this sector and produce high value products from winery waste (grape seeds and skins).

6.1.5 Co-digestion of Feedstocks

Mono feedstocks are rare and often manure and slurries are added to the mixture of dry feedstocks and vice versa, as the digestion of manures and slurries may be accelerated by the addition of carbon sources contained in energy crops and food waste. This is the main advantage of co-digestion – an increase in gas yield and improvement in the economic viability of the plant.

A UK study conducted by Southampton University in 2011[8] evaluated the feasibility of centralised pre-processing and pasteurisation of source-separated domestic food waste followed by transport to farms for anaerobic co-digestion with dairy cattle slurry. The results showed that the addition of food waste improved the energy yield per digester unit volume, with a corresponding increased potential for improving farm income by as much as 50%.

Tarac Technologies, South Australia

Tarac Technologies was established in 1930 and provides environmental solutions and valued products and services to the Australian Wine Industry by value adding to the disposal and treatment of solid and liquid winemaking residuals. Tarac has distilleries located in three of the major grape growing and wine producing regions of Australia, namely Nuriootpa and Berri in South Australia and Griffith in New South Wales, with the largest state of the art facility located at Nuriootpa, South Australia. Tarac currently accepts and treats over 120,000 tonnes of grape marc, more than 40 million litres of liquid waste and approximately 7,000 tonnes of solid waste annually, diverting these waste streams from landfill disposal.

Tarac also provides a number of other products and services to the wine industry. These include the manufacture and supply of Tartaric Acid, GrapEX natural grape seed (anti-oxidants) and skin tannins, AlcoTECH alcohol adjustment and grape juice concentration, manufactured using the waste products.

Tarac operates a Closed Loop system. All residues from product manufacture are then supplied for soil conditioning to the horticultural industry and the cattle feed industry.

Liquid residuals, including distillation wine, tank lees, centrifuge waste and stripwater, are treated at Tarac's joint venture waste water treatment plant in Nuriootpa, South Australia. The treated water is used to irrigate local vineyards and pasture, and to offset the consumption of mains water in Tarac's own processes. Tarac utilises the Biogas, captured at its wastewater treatment plant, as a fuel in its internal production processes. This assists in the replacement of fossil fuels and reduction of greenhouse gas emissions.

The success of farm-scale digestion in Europe has been based largely on the use of energy crops rather than the digestion of manure or slurry, although this does form part of the mix. There are some UK examples of plants that follow this model. Concerns have been raised in the UK that wide spread development of large plants fed principally on purpose grown crops could have negative impacts in terms of food production, biodiversity loss and water quality. The UK government recognises the important role that energy crops can play when used in co-digestion with waste derived feedstocks, but is keen to ensure that the framework of

[8] Banks, C.J, Salter, A.M, Heaven, S, Riley, K (2011) Energetic and environmental benefits of co-digestions of food waste and cattle slurry: A preliminary assessment, *Resources, Conservation and Recycling, (56), 71-79*

policies and incentives does not encourage an unsustainable growth in the use of energy crops for AD.

SA Water Co-digestion Operations

SA Water is currently seeking suitable high strength organic wastes for a full scale co-digestion trial at the Glenelg Sewage Treatment Plant. Co-digestion is the process of combining high strength organic materials (HSOM) that are by-products from industrial activities with the sewage sludge with to generate additional methane. The biogas, containing methane, produced in the digesters is used as a fuel source for Combined Heat and Power engines producing electricity for the WWTP operations, and any excess power to the WWTP needs is feed into the power grid.

This trial will extend to 30 June 2014 and if successful, offers a very cost effective disposal option. A range of materials are being considered as suitable substrates to be co-digested with wastewater, including:

- Dairy whey
- Waste milk
- Starch sludge
- Fruit/beverage waste
- Organic oils and fats
- High carbon organic sludge
- Food manufacturing sludge

SA Water initially assesses the suitability of material proposed for co-digestion, based on theoretical considerations, and if favourable will arrange for NATA endorsed testing for a series of critical parameters.

The benefits to SA Water of co-digestion include:

- reduce sewer loads
- generate methane for electricity generation
- the opportunity to maximise the efficiency of anaerobic digesters through co-digestion of industrial high strength waste streams with the sludge from municipal wastewater treatment plants
- re-direct problematic trade waste streams
- reduce the impact of trade waste disposal into operations
- potential for energy savings

Such benefits have already been realised during a trial of ‘salty whey’ a by-product from the manufacture of cheese which has been trialled as a substrate for co-digestion at the Glenelg Wastewater Treatment Plant. The additional electricity produced by co-digestion of the salty whey is equivalent to $8.30 of energy produced from each kilolitre of feed into the anaerobic digester. The annual financial benefit for the projected salty whey delivery is approximately $16,000.

6.1.6 Landfill Gas

Landfill gas is produced when biodegradable matter such as food and garden wastes decompose under anaerobic conditions as found within a landfill.

South Australia has a variety of gas reserves that can be utilised for electricity generation including landfill gas, natural gas, and coal seam gas and waste coal mine gas. Biogas which may be referred to as biomass gas includes gaseous emissions from landfills (landfill gas), sewage treatment and other organic anaerobic degradation processes. Landfill gas is regarded as a renewable energy source under the Australian Government's Renewable Energy Target as defined under S17(1) Renewable Energy (Electricity) Act (Cth) and consequently, landfill gas power generation facilities are able to qualify for Renewable Energy Credits (REC) for electricity generated.

Figure 6-1: Agrivert Cassington Anaerobic Digestion facility, Oxfordshire, UK

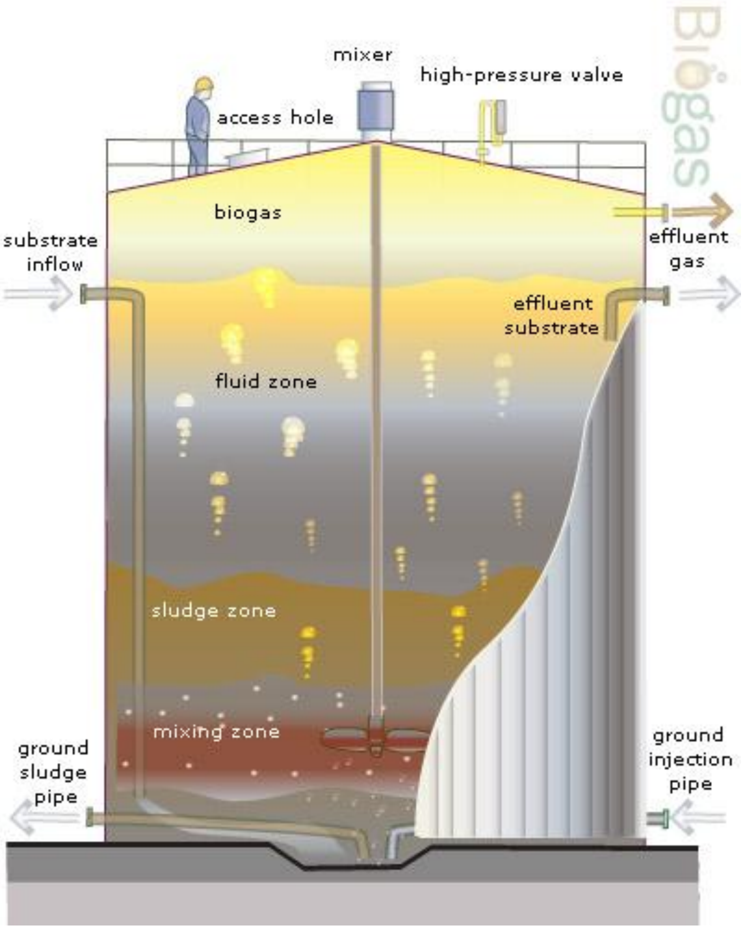
7 Biological Treatment

7.1 Anaerobic Digestion

The principal biological technology used to recover energy from organic waste is Anaerobic Digestion (AD). AD involves the conversion of biodegradable organic matter to energy by microbiological organisms in the absence of oxygen. The biogas produced in the process is a mixture of methane and carbon dioxide, and can be used as fuel source for heating and/or electricity production. The treatment of waste leaves behind residues, generally in the form of semi-solid or liquor called digestate that can be used as bio-fertiliser.

Whilst previously open windrow and in vessel composting systems were dominant in the treatment of food and garden wastes across Europe, AD has now become the preferred technology in many countries, due to the additional benefit of energy generation that AD can provide.

Figure 7-1: Anaerobic Digestion process. (Source: Renewable Energy Association, UK)



There are numerous AD facilities using waste feedstocks operating across Europe. For instance, there are over 20 centralised AD plants operating in Denmark, with a further 20 farm scale operations. Feedstocks are mainly pig and cattle manure, but also include waste food, fat sludge and brewery wastes.

Initial developments in Germany, in the mid-1990s, were focussed on the treatment of organic wastes, primarily driven by the requirement to meet landfill diversion targets. The rapid rise in the biogas generation took place in this manner, but later with dedicated and specifically designed AD plants.

Once the required landfill diversion targets had been met in Germany, the focus for biogas plants shifted from one of providing treatment capacity for organic wastes towards the generation of renewable energy using energy crops. Since 2000, the feed in tariffs associated with the German Renewable Energy Sources Act (EEG) have allowed the development of small to medium scale, farm-based AD plants, and thousands of such plants have been constructed across Germany.

Anaerobic digestion and biogas recovery is well suited to large food processing plants with high-strength wastewater, such as dairy processing plants or breweries. As such, AD has been widely adopted across Australia by the food and meat processing industries (industrial liquid and sludge waste streams) whilst its application to the organic fractions of MSW is limited to a few organisations such as the Macarthur Resource Recovery Park in NSW and the AnaeCo AD facility at Western Metropolitan Regional Council in Shenton Park, WA. .

Foster's AD Operations

Foster's Australia installed upflow anaerobic sludge blanket (UASB) units as part of their wastewater treatment process. Biogas is extracted from this process into a flexible container, which expands and contracts to maintain a constant pressure depending on the generation and use of the biogas. Biogas is burnt in the boilers and contributes approximately 20 per cent of the energy use on site saving approximately $750,000 per year. The biogas unit cost approximately $220,000 to install in 1995 and had a payback period of less than one year.

Table 7—1: Thermal Treatment Technology 7: Anaerobic Digestion

Technology	Anaerobic Digestion
Concept	Anaerobic digestion (AD) involves the conversion of biodegradable organic matter to energy by microbiological organisms in the absence of oxygen. There are three main stages in the digestion process: + Hydrolysis – conversion of insoluble molecules into fatty acids, amino acids and sugars; + Acidogenesis – conversion of products of hydrolysis into simple organic acids, carbon dioxide and hydrogen; and + Methanogenesis – production of methane. The biogas produced in the process is a mixture of methane and carbon dioxide, and can be used as fuel source for heating and/or electricity production. Varying degrees of cleaning need to be applied to the biogas, depending on its use. The treatment of waste leaves behind residues, generally in the form of semi-solid or liquor called digestate that can be used as bio-fertiliser.
Low Solids AD	A low solids digestion system is one that is operated at total solids content of less than 15% and is particularly suited to treating low solid feedstocks such as animal slurries and/or sewage sludge. The feed to the digester could comprise much higher solids content, but fed at a rate that dilutes it down to the operating condition of the digester. Low solids digesters are usually designed so that the contents are completely mixed and may be operated either in the Mesophilic (30 - 40°C) or Thermophilic (50 - 60°C) temperature ranges. Low solids systems are the most common form of AD process. They provide an effective and robust means of treating low solid content waste, or high solid waste that has been adjusted to below 15% total solid content. They are therefore the most versatile, and are able to exploit a variety of wastes, whose quantity and quality may vary seasonally or more frequently.
Dry or High Solids AD	A high solids digestion system is one that is operated at total solids content of between 15% and 40% and is particularly suited to treating high solid feedstocks such as municipal food waste. At the higher solids content, the fermenting wastes usually move in plug flow inside the digester. These systems are often operated at thermophilic temperatures, due to the lower water content that provides a favourable heat balance and because bacterial activity is greatly increased - together they lead to a more intense AD process, with higher organic loading rates. Mechanical mixing is generally required to mix the incoming wastes with the fermenting biomass; alternatively, it may be designed with a high recycle rate of the digester content to provide mixing along with the addition of fresh feed, in a controlled manner.

Technology	Anaerobic Digestion
Multi-stage AD System	A multi-stage AD system is one that uses two or more digesters in order to optimise conditions for the different populations of bacteria that carry out the different stages of the digestion process. Two-stage systems are most common, where conditions in the first digester are optimised for hydrolysis and acidification (and some degree of acetogenesis), and the second stage being optimised around methanogenesis (with some degree of acetogenesis also occurring).
Commercialisation	AD technologies are widely demonstrated, although those at small scale are considered rather expensive for wide scale applications and require effort to commercialise them for wide scale applications. In order to identify potential applications for South Australia, it is useful to breakdown AD plants into different scales and application types: + Large-scale merchant AD plants. These are typically based on food waste from municipal and C&I origins but also accommodate other wastes such as livestock slurries. Over 100 such plants exist in Europe and several are installed in the UK. The technology applied varies from Continuously Stirred Tank Reactors to high solids plug flow systems; + Medium-scale farm enterprise AD plants. These are typically based on co-digestion of various feedstocks but the main component tends to be livestock slurry with energy crops. Thousands of such plants are installed in Europe, notably in Germany. These are also implemented or being implemented in several locations in the UK. The market for these is increasing; and + Small-scale on-farm AD plants. These are defined as AD plants that deal with livestock slurry, agricultural residues and energy crops drawn from within the confines of the farm. While some 20 plants exist in the UK, this technology still requires development for wider acceptance and would perhaps offer greater scope for innovation.
Size (per installation)	AD can be carried out in small scale systems located at a farm scale and operated by farmers, or in large centralised systems, operated as commercial concerns. The latter deal with a variety of wastes ranging from food wastes from household and C&I premises to livestock slurries from farms within the locality.
Energy recovery	Energy recovery is achieved by combustion of biogas in engines, or upgrading and cleaning the gas for use a transport fuel.
Inputs / Feedstocks	The types, quality and mix of feedstock are a fundamental aspect of running an AD plant. The design of the digester will often be dictated by the types of feedstock available. Some types of feedstock produce a lot more biogas than others. For example, animal slurries yield relatively little biogas in comparison with silage or food waste.

Technology	Anaerobic Digestion
Feedstock Pre-treatment	The type of pre-treatment needed will depend on the feedstock. Food waste from C&I sources may need depackaging. Mechanical treatment may be needed in order to remove contaminant from feedstock, and to reduce particle size and/or mix and condition the feedstock. Chemical pre-treatment can be used to improve the digestibility of the waste stream and to increase biogas yield. A pasteurisation step may be used to increase pathogen destruction. Thermal or biological hydrolysis can be used to pre-treat the feedstock and reduce digester residence time.
Outputs	Biogas, heat, digestate

7.2 Outputs and Markets

The products of AD are referred to as biogas and digestate.

7.2.1 Biogas

The biogas can be utilised as a renewable energy source in the following ways:

+ In a boiler to produce heat only;
+ In a combined heat and power (CHP) unit to produce electricity and heat; or
+ To undergo further processing for use as a vehicle fuel, grid injection or for use in a fuel cell.

Biogas produced from AD plants generally has a composition of approximately 50% to 80% methane (CH_4) and 20% to 50% carbon dioxide (CO_2). There are often small amounts of other compounds such as Nitrogen (N_2), Oxygen (O_2) and Hydrogen Sulphide (H_2S).

Varying degrees of cleaning need to be applied to the biogas, depending on its use. For example, as a vehicle fuel or for a grid injection the gas will need to up-graded to different specifications. The energy content is directly proportional to the methane concentration in the biogas and by removing the carbon dioxide, the energy content of the gas is increased.

GreenGasGrids Project

The GreenGasGrids project was launched in June 2011 and is funded by Intelligent Energy for Europe (IEE), which aims to boost the market development of biogas feed-in and to contribute towards an increase in bio-methane production throughout the EU. The three-year project will address unresolved issues in the bio-methane field that are hindering the increase of biomethane production. The project's objective is to increase the production and use of biomethane for transport, heat and electricity by tackling the legislative issues, technical standards, trade barriers and increasing co-operation between stakeholders.

A working group led by the European Biogas Association is working to address these barriers by:

- Understand how the European Commission's sustainability criteria for biomass and biogas can be integrated in European biomethane markets;
- Developing a roadmap to create a European trade scheme;
- Produce a tool kit for each country to estimate potential biogas production;
- Improve transparency for biomethane markets; and
- Contribute to solving open issues of technical standards for biomethane.

Several countries have defined standards for grid injection of upgraded biogas or for utilization as vehicle fuel (e.g. Denmark). For example, requirements are applied for the upgrading of biogas with different standards applied for the injection of low and high quality gas into the grid[9]. In general, the decision to upgrade biogas to biomethane for transport fuel or opt for CHP is largely attributed to the economics of the project or in many cases is influenced by specific site restrictions.

The market for using biogas to generate electricity is well established, in particular across Europe, where it is incentivised in many countries as a renewable energy source.

The use of a biogas as a fuel is also growing, and in countries such as Sweden, Denmark and Germany, where many public authorities use biogas from the treatment of MSW as fuel in refuse collection vehicles and public transport.

[9] http://www.iea-biogas.net/_download/publi-task37/upgrading_rz_low_final.pdf

The use of biogas in Australia is predominantly to generate electricity, but there have also been developments in using biogas as a vehicle fuel, see Growcom case study below.

Use of heat from AD is dependent on the facility being located in close proximity to a suitable heat user.

Converting banana waste to a fuel

Australia grows more than 300,000 tonnes of bananas each year. As much as 60,000 tonnes of bananas end up as waste, due to damage during harvesting or transit. Most bananas are grown in northern Queensland, and in 2005, the Queensland Sustainable Energy Innovation Fund (QSEIF) awarded funding to the Australian Banana Growers Council to develop a project to convert banana waste in to energy using anaerobic digestion.

A 460,000 litre anaerobic digester was constructed at a banana packing plant in Tully, North Queensland. The pilot digester consisted of a hole in the ground, covered by high-density polyethylene sheets. The plant was designed to treat 2,500 tonnes of banana waste per year, with an estimated biogas yield of 85,000m^3. During the initial trial stage, 800m^3 of biogas were produced. The biogas produced was tested in two different applications. Firstly, biogas was combusted in an engine to produce electricity for use in the packing shed. This generated sufficient power to meet the base load, but was insufficient to meet peak loads. The biogas was high quality, with minimal contaminants and therefore suitable for direct use as a diesel substitute. The second application of the biogas was to convert it in to a transport fuel. The biogas was compressed, and used in a vehicle modified to run on a combination of diesel and compressed biogas. The biogas replaced approximately 30% of diesel.

The pilot project demonstrated the suitability of using banana waste to produce energy, as the feedstock produces a high quality, high yield biogas. Electricity generation was considered to have the most potential within the horticultural industry. Growcom, who represent Queensland fruit and vegetable producers, have received further funding to develop a commercial scale demonstration plant.

7.2.2 Digestate

There are three main forms of digestate materials produced during the AD process:

+ Whole digestate – this is the processed material unloaded as it is from the digester, and will consist of:
    - a mix of fibres which are unable to be digested, such as woody materials and other structural components of plants
    - liquid
+ Separated liquor – the whole digestate can be processed to separate the liquid from the solid digestate material, by using a centrifuge or separator.
+ Separated fibre – the solid fraction removed from the whole digestate.

The decision on whether to separate the solid and liquid fractions of whole digestate can be a technical, economic or legislative one. For example, in Wales, if the liquid fraction is separated and disposed to sewer, this would not count towards recycling and landfill diversion targets, therefore encouraging developers of AD plants to find markets for whole digestate.

Solid digestate provides a more manageable alternative to slurry. The availability of nutrients is improved, as the solid fraction of digestate is potentially rich in phosphorous reducing the need for man-made fertilisers and it reduces the impact of farm chemicals runoff into watercourses. However, the quality of the digestate and the feedstock supplied to the biogas plants (where digestate is intended for use as a fertiliser) require robust management. An effectively applied and regulated quality system is important to ensure the digestate meets certain specified requirements. Good examples of this can be found in countries like Austria, Canada (Ontario), Denmark, Germany, Netherlands, Sweden, Switzerland and the United Kingdom.

In the UK, a Quality Protocol and Publically Available Standard (PAS 110) have been developed to provide quality specifications for the collection, storage, transport and re-use of digestate. In order to be used as a bio-fertiliser on agricultural land, digestate produced from non-waste inputs (e.g. farm wastes[10]) or from source-segregated bio-waste, must be treated in accordance with the requirements of PAS110. The introduction of the Quality Protocol and PAS110 has been welcomed. However, the additional cost associated with obtaining and maintaining PAS110 certification are viewed by some as barrier to exploring alternative outlets for digestate.

There are no specific standards or guidelines for the use of digestate in any States in Australia, although most states have guidelines relating to compost, biosolids and for the application of agricultural and/or food processing wastes. These guidelines will set specific application rates and quality criteria, as determined by the administering authorities.

The 'South Australian Biosolids Guideline for the Safe Handling and Reuse of Biosolids' defines biosolids as *'sludges that have been treated to a standard suitable for beneficial reuse'* and that the sludges are the solid residues from municipal and septic wastewater treatment processes. It also states that other solid waste materials such as animal manures, or food processing or abattoir wastes are not classified as biosolids. Therefore these guidelines would not apply to digestate from a facility treating household food waste for example.

An Australian standard exists for Composts, Solid Conditioners and Mulches (AS54454: 2012). Digestate from anaerobic digestion may be classified under the definition of soil conditioner within the standard, as it is a broad and general definition (as a pasteurized organic product). However, digestate is not specifically mentioned within the standard, and it is unlikely that digestate would be able to meet all quality conditions (as many types of compost are also unable to).

South Australian soils in their natural state lack many essential plant nutrients including nitrogen and phosphorus. The depletion of soil carbon is also an issue for several key horticultural and agricultural areas in the state. Therefore, the application of composts, digestates, manures, biosolids and other soil improvers provides significant benefit. The rising costs associated with farming chemicals is also a factor driving demand for 'organically derived' soil conditioners and fertilisers.

The most common soil/earth in South Australia is clays and sands. Whist some of the clays have reasonable nutrient levels, their soil structure may be improved and thus increase the availability of the nutrients to plant growth.

However, as with chemical additions, nutrient leaching and runoff into ground and surface waters (particularly of nitrogen and phosphorous) is an issue.

Digestate often requires secure storage prior to application reflecting suitable conditions for application (based on time of year, crop type, soil type, weather, topography etc.). This can increase the costs associated with using digestate or any other organically derived soil improver.

[10] In the UK, if manures and slurries are used as fertiliser on agricultural land, then they are not technically deemed as a waste, and are exempt from waste management regulations. Other regulations such as ground water regulations will still apply.

The potential for nutrient leaching is higher on sandy soils with poor water retention capacity. A proportion of South Australia's soils including those around Adelaide are sandy. Additionally, nutrients will also be lost due to poor soil structure caused by the depletion of organics in the soil. However, in all cases this issue may be minimised by avoiding the application of digestate (or any fertilisers) in periods with low plant uptake or high rainfall.

SA Water biosolids management

Biosolids is the term given to the stabilised organic residue produced as a by-product from the wastewater treatment industry. The biosolids consist of water and organic matter from the treatment of mainly household wastewater.

SA Water is responsible for the management of about 25,000 tonnes (dry weight) of biosolids per year from Adelaide's wastewater treatment plants. Biosolids are rich in nutrients such as nitrogen, phosphorus and potassium, although they do also contain traces of heavy metals such as nickel and lead as a result of industrial wastewater also being disposed of in the sewer system.

In conjunction with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), a three year trial period was undertaken to assess the impacts and benefits of applying biosolids in different agricultural applications. As the organic matter in the biosolids decomposes on the land, the nutrients it contains become available for take up by crops. The trials demonstrated that farmers benefited from nitrogen, phosphorous and other nutrients, achieving economic benefits in the form of grain yield and a higher grain protein content.

The application of biosolids to land is regulated by the *SA Biosolids Guideline for the safe handling and Reuse of Biosolids.* The CSIRO trials found that when applied in accordance with these guidelines, there was no detrimental uptake of metals by the crops.

In the region of 30,000 tonnes of biosolids from SA Water's metro and country wastewater treatment plants are used every by farmers across SA. In addition to agricultural uses, SA Water also makes biosolids available for use in large scale landscaping projects. The use of biosolids in commercial landscaping is regulated by the SA EPA.

7.3 SWOT Analysis of Anaerobic Digestion

Table 7—2: SWOT Analysis of Anaerobic Digestion

Technology	Strengths	Weaknesses	Opportunities	Threats
Anaerobic Digestion	+ Proven, established technology on wide range of waste derived feedstocks + Raw material in plentiful supply + Process can be used to generate both electricity and heat	+ Some feedstocks have relatively low energy density + Yield can be variable + Technology subject to changes in feedstock composition and other external factors + Emissions from biogas combustion + Requires pre-treatment of waste + Lack of protocols or standards for digestate use in Australia	+ Seen as Best Available Technology by many international waste strategies for the treatment of domestic food waste + Can be small scale or larger centralised facilities + Different feedstocks can be co-digested. + Digestate has the potential to be used as a high value soil conditioner.	+ Disposal and treatment of digestate can be a barrier

8 Mechanical Biological Treatment

8.1 Technology Overview

Mechanical Biological Treatment (MBT) is a general term for a combination of mechanical sorting and biological treatment of MSW or similar waste streams, and which may be configured to produce a variety of outputs.

During the mechanical part of MBT, waste particles are reduced in size and/or waste is separated into various fractions based on screens sizes. Specific fractions may be removed e.g. ferrous metals by magnets. The main aim is to remove valuable recyclables, remove materials unsuitable for biological treatment and homogenise the physical and chemical properties of the remaining fraction. The mechanical treatment may involve a wide range of process stages, including manual removal of recyclable materials, screening, shredding, magnetic separation, mixing using conveyors, eddy current separators, drums, shredders, air knives, hammer mills, flays and other size reducing equipment, screening for different sized components and other tailor made systems.

The biological stage may include aerobic decomposition, anaerobic decomposition or both, depending on the process output requirements. Composting in MBT systems typically takes place in in-vessel systems, although final maturation of partially stabilised waste may be carried out in open windrows. A number of factors dictate the composting process including particle size, moisture, temperature and oxygen. An alternative option for the biological treatment stage is AD. These AD systems will produce energy from the biogas that typically offsets much, but not all, of the energy required to operate the MBT facility.

Figure 8-1: Schematic of a potential MBT option. (Source: Defra, Mechanical Biological Treatment of Municipal Solid Waste)

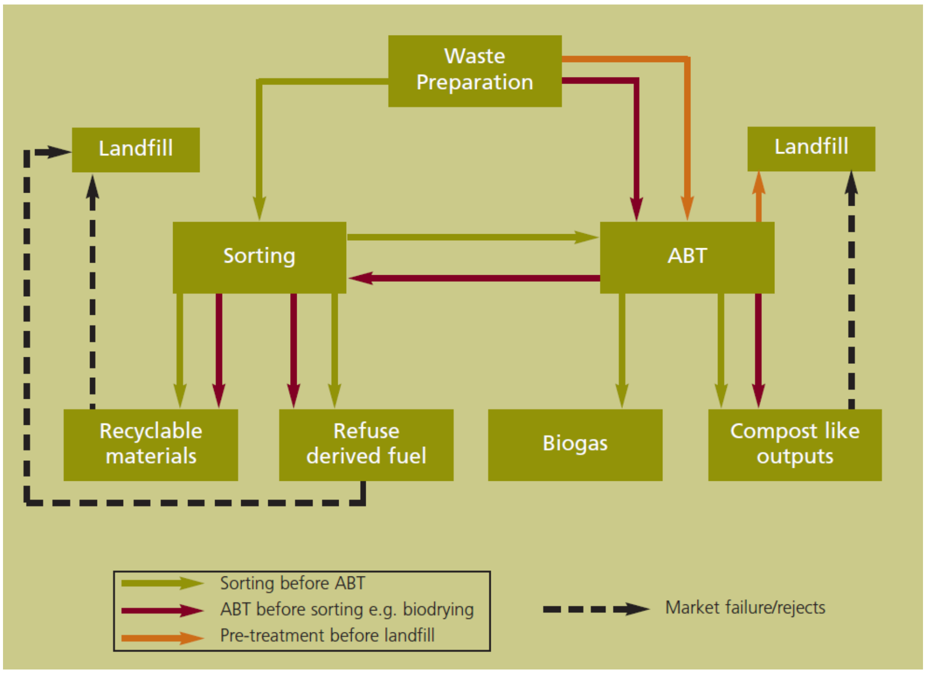


Table 8—1: Thermal Treatment Technology 8: Mechanical Biological Treatment

Technology	Mechanical Biological Treatment
Concept	MBT can be a combination of several processes found in other waste treatment technologies such as Material Recovery Facilities (MRF) and composting or AD. MBT is neither a single technology nor a complete solution to waste treatment. The process complements existing treatment infrastructure by leading to improved recycling rates through the extraction of suitable materials from the residual waste stream. In addition, the process may produce a biologically stabilised waste or residues appropriate for end markets (e.g. RDF, SRF, stabilised for landfill disposal or combustion). MBT is used as a pre-treatment to comply with the landfill acceptance criteria or to enhance the calorific value for incineration.
Configurations	The design of the MBT plant can be configured to reflect the final use of the outputs. Six generic MBT configurations are generally considered as operational: + MBT with RDF production and composting; + MBT with RDF production and anaerobic digestion; + MBT with anaerobic digestion and recovery of recyclable fractions; + MBT with biodrying for SRF production; + MBT with rapid composting and recovery of recyclable fractions; and + MBT with biostabilisation.
Commercialisation	MBT has provided a substantial contribution to EU waste management practices since the 1990's. There are an estimated 330 major MBT facilities in the EU, mainly in Spain, Italy and Germany
Size (per installation)	MBT systems are typically modular in design and can be switched from processing mixed MSW to processing source separated organic waste if collection systems change from a mixed waste collection to a source segregated collection.
Inputs / Feedstocks	Sites processing both mixed/residual MSW and to an increasing extent separately collected bio-waste are often known as "double duty" sites, these sites, are quite diffused across Europe, and may provide a flexible answer to the need to tackle changes in schemes and of local strategy.
Outputs	Assuming inputs of MSW and C&I wastes, the principal outputs from an MBT process are: + 'Biostabilised' output which can be sent to landfill; + RDF or SRF to be used in energy production; and + Compost-like output (CLO) to be used in land restoration projects

8.2 Outputs from MBT

8.2.1 Recyclable Materials

Some MBT plants recover only metals for recycling, whereas others are designed to recover other recyclable materials such as glass, textiles, paper and cardboard and plastics. Recyclables are likely to be of lower quality than materials separated at source, and therefore it is often preferred to leave materials such as paper and plastics in the fuel fraction. Depending on its configuration (as listed in the table above) a typical MBT may recover between 5-8% recyclable materials.

Increasingly sophisticated automated techniques, such as Near Infra-Red and polymer identification, are being used to separate plastics by polymer type, ensuring a higher value than for mixed plastics.

8.2.2 Compost Like Output (CLO)

Compost Like Output (CLO) is the term used to describe the output from an aerobic process such as bio-drying or in-vessel composting. CLO will be sanitised or part-sanitised depending on the process. The potential markets for CLO will depend on its quality, and legislation impacting on its use, for example as a soil enhancer. CLO is likely to be of lower quality than compost produced from source segregated organic waste and may contain both physical and chemical contaminants. If a market cannot be determined, it is likely that the CLO fraction of an MBT plant will be landfilled.

8.2.3 Refuse Derived Fuels

Where a MBT plant is configured to produce a high calorific value waste stream, it is likely that this will consist of combustible materials such as paper and cardboard and plastics. This fraction of material is generally referred to as a Refuse Derived Fuel (RDF).

Markets for RDF could include:

+ Co-firing in cement kilns;
+ Co-firing in coal power stations;
+ Incineration in purpose built facilities; and
+ Conversion in Advanced Thermal Technologies such as pyrolysis and gasification.

8.3 SWOT Analysis of MBT

Table 8—2: SWOT Analysis of MBT

Technology	Strengths	Weaknesses	Opportunities	Threats
MBT	+ Combines proven and well established technologies + Further recovery of recyclable waste and diversion of biodegradable BMW from landfill + Provides an alternative to landfill and incineration + Can be tailored to meet local requirements + Can have built in flexibility to respond to changing inputs	+ Quality of outputs may be low, i.e. recyclables may be low grade + Potential lack of benchmarks and quality standards for some outputs + May still result in a fraction that will need to be landfilled + Is dependent on market demand for outputs + High cost	+ Offers a flexible and versatile solution + May be perceived as a more publically acceptable solution + Can be designed at appropriate scales, and is not as influenced by economies of scale as incineration + Can treat a wide range of waste streams, i.e. MSW, C&I + Can preserve nutrients in Compost Like Output (N,P,K)	+ Market volatility + Product risk + Discourages source segregation of waste streams + Uncertainty of biodegradability of outputs

9 Investment Profiles of W2E Technologies

Key Implications for W2E in South Australia

Financial cost is a critical consideration when deciding which waste treatment technologies to promote. Unfortunately, it is also a complex and dynamic issue, requiring knowledge of many discrete cost streams and market elements including:

- costs of construction (capital expenditure – CapEx);
- operating costs (operating expenditure – OpEx);
- market value of physical products (recyclates, composts);
- costs of disposal of waste outputs (ash, rejects);
- market value of other products (electricity, heat); and
- costs of and revenues from government policies, such as waste disposal levies and renewable energy certificates.

Some of these items, such as the market value of products, are set according to local, national and international trade prices, and subject to market fluctuations. In contrast, the costs and revenues from government schemes provide more investment certainty.

The analysis undertaken in this section identifies that there are very many contributory factors that must be considered in assessing the investment profiles of waste treatment technologies. While we believe this summary table is instructive, we would emphasise careful consideration of the assumptions on which it is based.

The final figures (in $/tpa) are, in effect, the break-even gate fees for the facilities, and indicate that a W2E plant is most often the most desirable option financially, as its ferrous, electricity and LGC revenues appear to exceed the capital, operating and other associated costs. In contrast, AD and ATT plants need gate fee revenues in order to be financially viable.

What is also clear is that the margins are very tight, and for that reason, individual projects must make a careful assessment of their own merits and against their specific local environmental and economic circumstances.

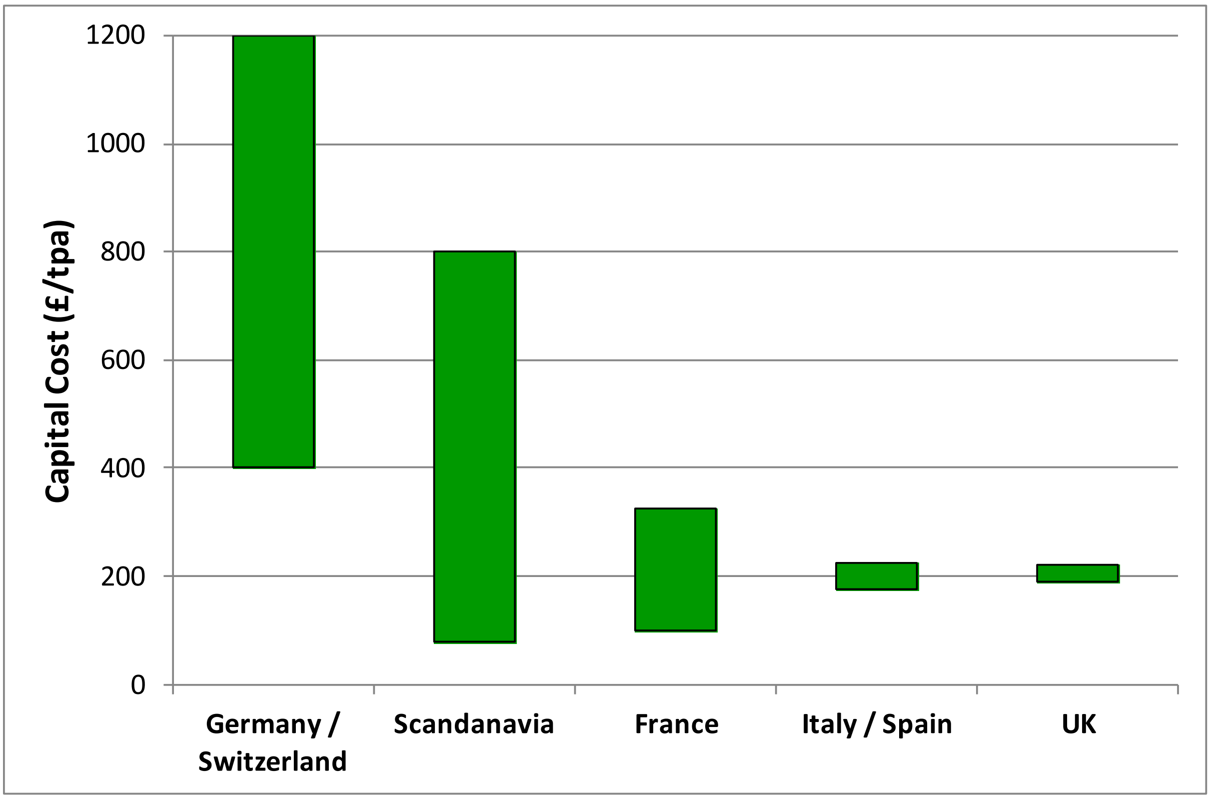
In the following sections, any prices initially quoted in GBP (Great Britain Pounds, or £) are converted to AUD (Australian Dollars, or $) using an exchange rate of 1.55 AUD per GBP.

9.1 CapEx

It might be expected that CapEx and OpEx costs are relatively predictable, but experience suggests that it is far from straightforward. A previous study by Juniper[11] (see Figure 9-1) revealed that the range of capital costs (in pounds sterling per tonne per annum [tpa]) of thermal treatment plants across Europe varied considerably, despite all facilities having to comply with the Waste Incineration Directive, whose emission limits were a principal driver, because of the abatement equipment required. Equivalent information about landfill costs was not provided.

[11] This data appeared in a slide delivered by Kevin Whiting of WSP, during a lecture on the Thermal Treatment of Waste course 2012, at Leeds University (Sep 2012).

Figure 9-1: Range of Western European Capital Costs for Incineration Plants [Juniper]



RICARDO-AEA tracks all major waste infrastructure developments in our FALCON software.[12] News articles, press releases and operator websites often mention the capital costs of facilities, and this information is recorded in the database that underpins FALCON. The CapEx as a function of associated throughputs of anaerobic digestion (blue), advanced thermal treatment (red) and conventional combustion plants (green) in the UK are presented in Figure 9-2 (AD and ATT only) and Figure 9-3.

[12] FALCON (Facilities, Arisings, Locations, Contracts) is RICARDO-AEA's GIS-based service that provides users with a map of the UK, showing all the waste treatment facilities (proposed, in planning, consented, in construction and operational) and also presenting waste arisings and rates by local authority, and the status of residual waste procurement contracts.

Figure 9-2: CapEx as a function of Throughput for UK AD and ATT Plants

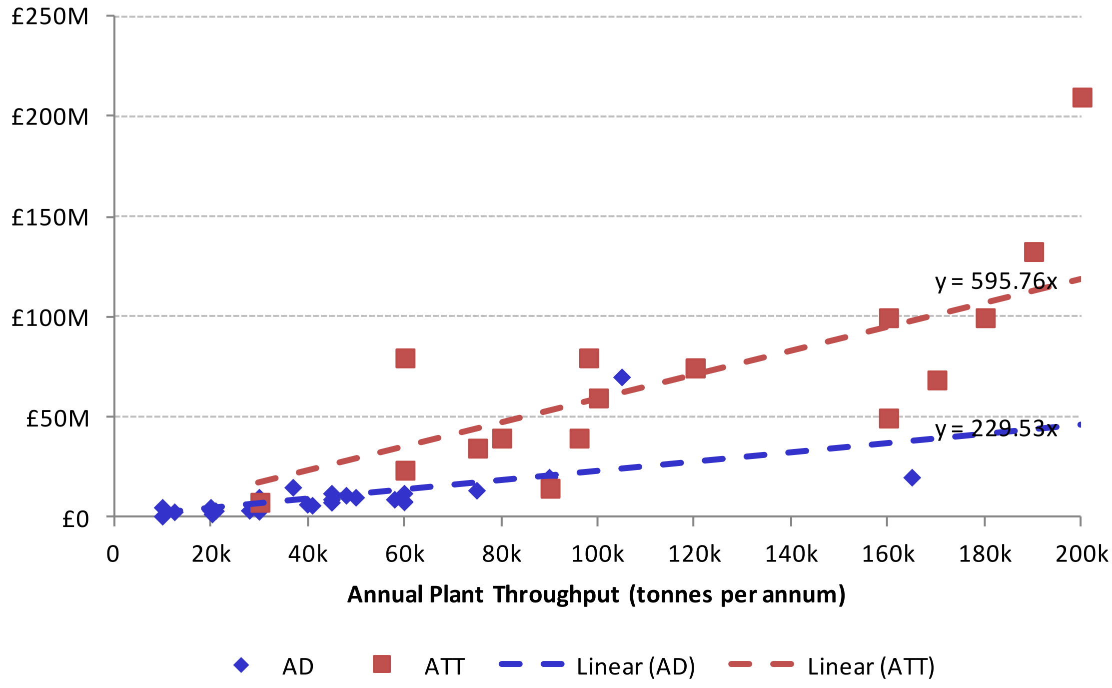
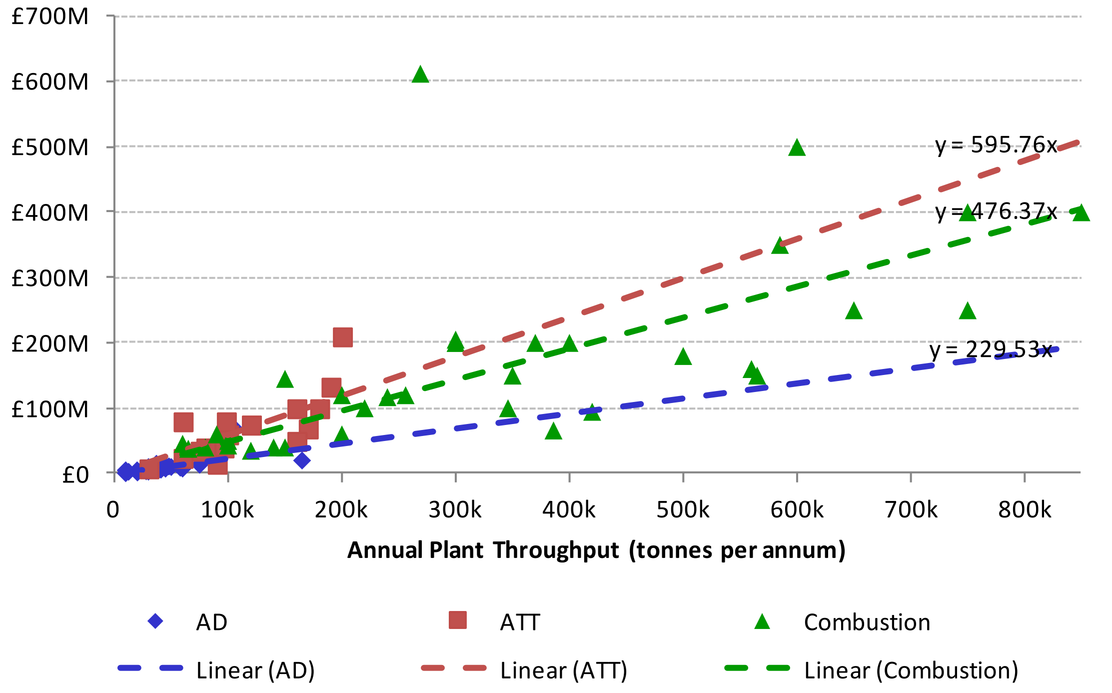


Figure 9-3: CapEx as a function of Throughput for UK AD, ATT and Combustion Plants



The first conclusion to draw from these plots is that, although the data points lie very roughly on a line of proportionality, they are well scattered for all three series, indicating that the correlation between waste throughput and CapEx is at best approximate. However, the relative positions of the data points suggest that the average costs per tpa are smallest for AD processes, and largest for ATT processes.

Australian Experience

It is difficult to calibrate the UK figures with estimates from Australia, because of the latter's limited experience of comparable facilities. The data points we have found are presented in Table 9—1. An immediate point to note is that several of these plants have suffered operating difficulties, which are likely to increase the capital costs.

Table 9—1: Comparative CapEx and Energy Efficiency Data on Australian Facilities

<table>
<tr><th>Operator</th><th>Location</th><th>Tech</th><th>Through put (ktpa)</th><th>CapEx ($M)</th><th>$MW_e$</th><th>Eff ($MW_e$ / ktpa)</th><th colspan="2">CapEx $/tpa</th></tr>
<tr><td>Global Renewables (1)</td><td>Eastern Creek, Sydney</td><td>MBT / AD</td><td>175</td><td>110</td><td>2.1</td><td>0.01</td><td>629</td><td rowspan="4">834</td></tr>
<tr><td>Earthpower (2)</td><td>Camellia, Sydney</td><td>AD</td><td>50</td><td>40</td><td>3.9</td><td>0.08</td><td>783</td></tr>
<tr><td>WSN (3)</td><td>Jacks Gully, Sydney</td><td>MBT / AD</td><td>90</td><td>80</td><td>2.5</td><td>0.03</td><td>889</td></tr>
<tr><td>WMRC (4)</td><td>Shenton Park, Perth</td><td>AD</td><td>55</td><td>57</td><td>2</td><td>0.04</td><td>1,036</td></tr>
<tr><td>Phoenix Energy (5)</td><td>Kwinana, Perth</td><td>W2E</td><td>400</td><td>400</td><td>80</td><td>0.20</td><td>1,000</td><td>1,000</td></tr>
<tr><td>Brightstar (6)</td><td>Wollongong, Sydney</td><td>AC / Gas</td><td>150</td><td>160</td><td>15</td><td>0.10</td><td>1,067</td><td>1,067</td></tr>
</table>

Sources

(1) http://www.globalrenewables.eu/ur3r-process
(2) http://www.earthpower.com.au/creating_green_energy.aspx
(3) http://www.oaktech-environmental.com/ArrowBioPlantUnderDevelopmentinFalkirkScotland.htm
(4) http://www.anaeco.com/images/stories/Media/anaeco-prepares-.pdf
(5) Article from Inside Waste, Issue 51. Page 4, December 2012
(6) http://www.wastedisposal.com.au/waste-disposal-articles/2004/12/4/swerf-effort-goes-to-waste/

The above are all waste treatment facilities. By looking at the broader category of biomass plants, we can gather further Australian context, though the different technology and feedstock involved must be taken into account. In November 2012, Bioenergy Australia published its "Bioenergy in Australia – Status and Opportunities" report[13]. This included the information in Table 9—2 about capital costs for different sized biomass plants.

Table 9—2: Breakdown of Biomass Facility Capital Costs (AUD)

<table>
<tr><th colspan="2">Parameter</th><th>500 kW</th><th>5 MW</th><th>20 MW</th></tr>
<tr><td colspan="2">Feed requirements (green ktpa)</td><td>9.1</td><td>78.7</td><td>280.8</td></tr>
<tr><td colspan="2">Feed handling</td><td>Included</td><td>400,000</td><td>6,700,000</td></tr>
<tr><td colspan="2">Gasifier</td><td>2,600,000</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Boiler</td><td>0</td><td>14,600,000</td><td>20,600,000</td></tr>
<tr><td colspan="2">Steam turbine</td><td>0</td><td>4,000,000</td><td>9,600,000</td></tr>
<tr><td colspan="2">Auxiliary equipment</td><td>200,000</td><td>200,000</td><td>3,300,000</td></tr>
<tr><td colspan="2">Grid connection</td><td>200,000</td><td>2,100,000</td><td>3,100,000</td></tr>
<tr><td colspan="2">Civils and infrastructure</td><td>300,000</td><td>1,300,000</td><td>6,800,000</td></tr>
<tr><td colspan="2">Design and project management</td><td>400,000</td><td>1,000,000</td><td>2,100,000</td></tr>
<tr><td colspan="2">Contingency</td><td>500,000</td><td>3,500,000</td><td>10,400,000</td></tr>
<tr><td colspan="2">Total</td><td>4,200,000</td><td>27,100,000</td><td>62,600,000</td></tr>
<tr><td rowspan="2">Unit costs</td><td>($M/MW)</td><td>8.4</td><td>5.4</td><td>3.1</td></tr>
<tr><td>($/tpa)</td><td>462</td><td>344</td><td>223</td></tr>
</table>

[13] http://www.bioenergyaustralia.org/reports/BIOENERGY%20IN%20AUSTRALIA%20Rev%201.pdf

The most significant omission from this biomass plant information is the cost of air pollution control (APC) equipment. If the relevant local emissions standards are comparable to Europe, we can assume similar levels of APC equipment. A useful rule of thumb for estimating such prices is that **the total cost of APC equipment is about as much as the rest of the plant**, thereby doubling the previous totals. ATT costs then rise to about $900/tpa, while conventional combustion sits at $450-700/tpa, depending on throughput.

The other point to note in passing is the very significant economies of scale that are indicated – economies that are exacerbated when the APC equipment costs are added. There is clearly a benefit from building larger plants, if the demand can be proven.

The points from the Australian plant data above can be compared with the best-fit lines through the UK data, leading to the figures in Table 9—3.

Table 9—3: Estimated CapEx costs per tonne per annum

Technology	Estimations from UK Data		Australian Experience: $/tpa	
	£/tpa	$/tpa	Waste	Biomass
Anaerobic Digestion	225	350	834	
Conventional Combustion	475	735	1,000	450 - 700
Advanced Thermal Treatment	600	930	1,067	900

The immediate conclusion is that Australian CapEx prices are somewhat higher than equivalent figures in the UK. As well as the performance issues, which are inevitably likely to have pushed costs up, we suggest that costs in the UK are lower because the technologies are more mature and economies of scale are greater due to the larger plants that have been developed. Furthermore, borrowing (interest rates and fees) and materials costs (including energy/electricity costs) are also higher in Australia than the EU or US.

We therefore conclude that the likely capital costs for future plants in Australia will be higher than the equivalent plants in the UK, but perhaps not as high as previous Australian experience would suggest. For the purposes of further calculations, we have chosen for the capital costs the upper quartile of the differences between UK and Australian figures[14], namely **$713/tpa (AD), $934/tpa (W2E) and $1033/tpa (ATT)**.

9.1.1 Plant Lifetimes

In order to bring all the costs to a net present value, it will be necessary to estimate the typical lifetimes of the different technologies, so that the capital costs can be amortized over the project lifetime. For the purposes of our later calculations, we have assumed the following lifetimes:

+ Anaerobic Digestion: 20 years
+ Conventional Combustion: 25 years
+ Advanced Thermal Treatment: 30 years

9.1.2 Heat Transfer Network

Another rule-of-thumb figure worth knowing is the typical cost to install a heat transfer network, suitable of transmitting heat (in the form of hot water or steam) from the point of generation to its point of use. There are obviously endless parameters involved in such a calculation, but a popular rule-of-thumb is that each kilometre of heat transfer network costs £1M to construct [15].

[14] Estimation = UK Price + 75% of [AU – UK Prices]
[15] See, for instance, page 6 of *"Decentralised Energy Masterplanning"* from Ove Arup, available here: http://www.chpa.co.uk/medialibrary/2012/01/05/46ccc22e/DENet_manual_lo_v1%200.pdf

However, district heading is likely to be less in demand for South Australia, whose climate is much milder than Northern Europe. In fact, in the summer months, there is a demand for cooling duty, which raises the potential of district cooling. This is not very prevalent in Europe, though one company reports that systems in Helsinki (25), Stockholm (123), Gothenburg (21), Amsterdam (13), Paris (62), Vienna (10) and Barcelona (11) together saved 265 kte of CO_2 in 2010.[16]

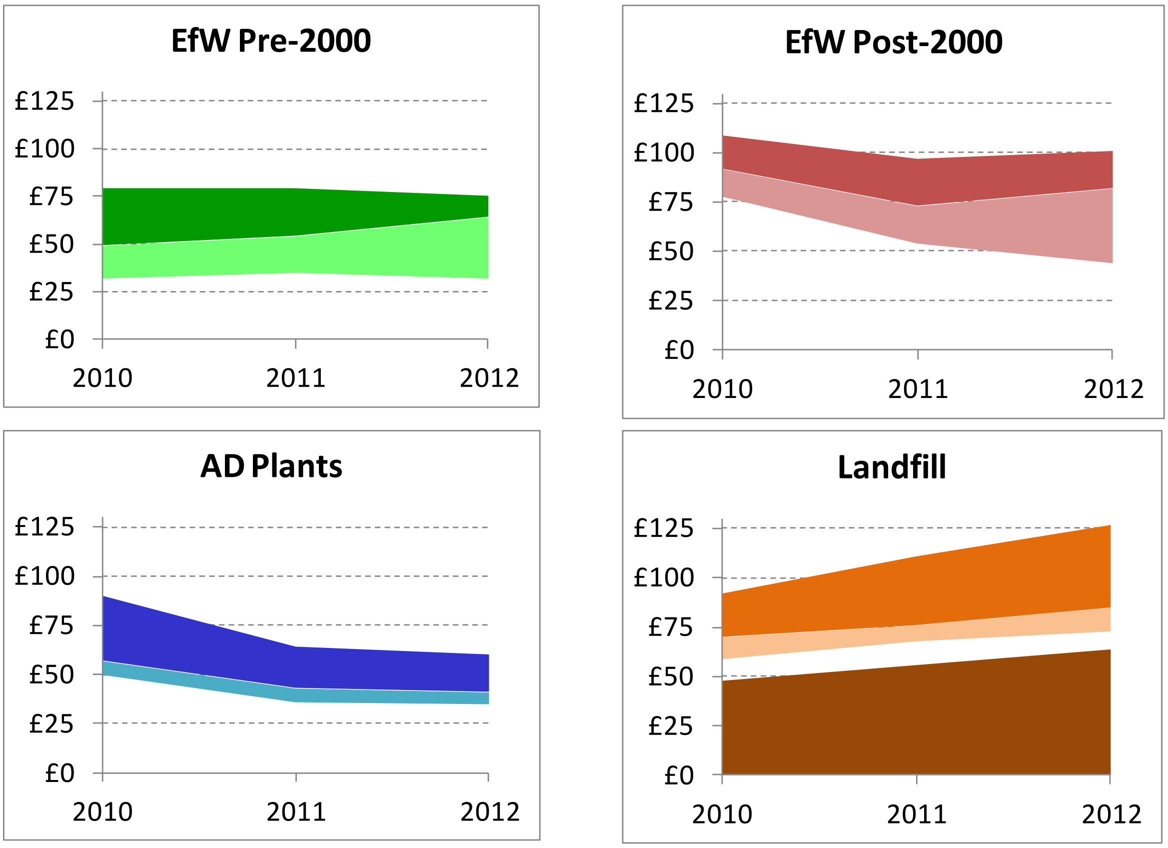
Apart from the equipment used to convert the heat into cooling duty, in the form of cold/chilled water, the infrastructure required is broadly the same, so the figure of **$1.5M per kilometre** remains a valid ballpark figure.

9.2 OpEx

Despite the caveats above about CapEx figures, they are in fact much more readily available than data on operating costs of waste facilities, which are frequently commercially sensitive. In the UK, this barrier is overcome to some extent by an annual report by the Waste and Resources Action Programme (WRAP) on Gate Fees. Gate fees are the cost per tonne charged by waste operators to accept waste, and are a reasonable proxy for plant operating costs.

Data from WRAP over the past three years (presented graphically below) show falling gate fees for AD plants over this period, as the technology matures and competition for feedstocks increases. For pre-2000 incinerators, gate fees look relatively stable over the same period, while post-2000 incinerators are also showing falling prices. WRAP does not split out costs for ATT plants, as there are so few such facilities operational in the UK.

Figure 9-4: UK Facility Gate Fees in GBP per tonne [WRAP]



The shading shows the range between the lowest and highest prices, with the colour change denoting the median. The extra, darkest band for landfill shows the underlying contribution from the UK landfill tax.

[16] From EuroHeat. See http://www.euroheat.org/Files/Filer/documents/District%20Heating/Cooling_Brochure.PDF

The median prices for 2012 are as follows:
- Anaerobic Digestion: 41 £/tonne
- Energy from Waste (pre-2000): 64 £/tonne
- Energy from Waste (post-2000): 82 £/tonne
- Landfill (including £64/t Landfill Tax): 85 £/tonne

As already noted, these figures do not differentiate between conventional combustion and ATT. For the purposes of our calculations, we have assumed that the former's gate fees are the average of the pre- and post-2000 prices, whereas ATT is just the post-2000 prices, which presents the expected differentiation in prices:
- Anaerobic Digestion: 41 £/tonne 64 $/tonne
- Conventional Combustion: 73 £/tonne 113 $/tonne
- Advanced Thermal Treatment: 82 £/tonne 127 $/tonne

Australian Experience

The lack of many treatment plants in Australia make it difficult to assess local gate fees, but the Bioenergy Australia report does include operating costs, which begin with the labour costs presented in Table 9—4. A Waste to Energy plant would require additional operators – our estimations are at the foot of the table.

Table 9—4: Australian Biomass Labour Cost Breakdown

Position	Salary / $	500 kW	5 MW	20 MW
Clerk	60,000		0.2	1
Plant Manager	100,000		0.5	1
Tradesman	80,000		0.5	1
Plant Operator	70,000	0.5	1	4
Boiler Attendant	80,000		4	4
Shift Relief	90,000		0.5	1
Head Office Costs	80,000	20,000	0	0
Biomass Total		**55,000**	**537,000**	**930,000**
Waste Plant				
Additional Operators	70,000	1	2	4
Waste Total		**125,000**	**677,000**	**1,210,000**

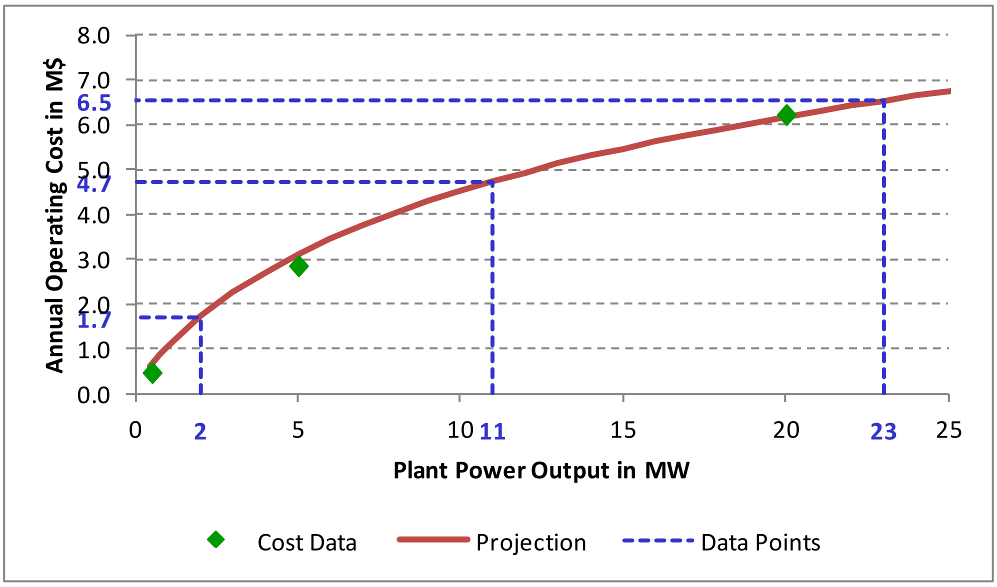
Furthermore, the Bioenergy Australia reports estimates that maintenance and consumable costs are, respectively, 3% and 1% of the CapEx costs. Adding these factors, we arrive at the total annual operating costs presented below.

Table 9—5: Total Estimated Operating Costs

Aspect		500 kW	5 MW	20 MW
CapEx		8,400,000	54,200,000	125,200,000
Operational Labour		125,000	677,000	1,210,000
Maintenance	3%	252,000	1,626,000	3,756,000
Consumables	1%	84,000	542,000	1,252,000
Total OpEx		**461,000**	**2,845,000**	**6,218,000**
Throughput (ktpa)		9.1	78.7	280.8
Unit costs ($/tpa)		**50.7**	**36.1**	**22.1**

These unit operating costs are somewhat lower than the gate fee figures previously calculated, principally because not all aspects involved in the gate fee figures are included above. Notably, no account is taken of the profit that the operator might wish to realise from the facilities.

For the purposes of further calculations, we have created a best-fit approximation through the above Australian data, arriving at annual operating costs of **$1.7M (2MW AD plant), $6.5M (23MW W2E plant) and $4.7M (11MW ATT plant)**.



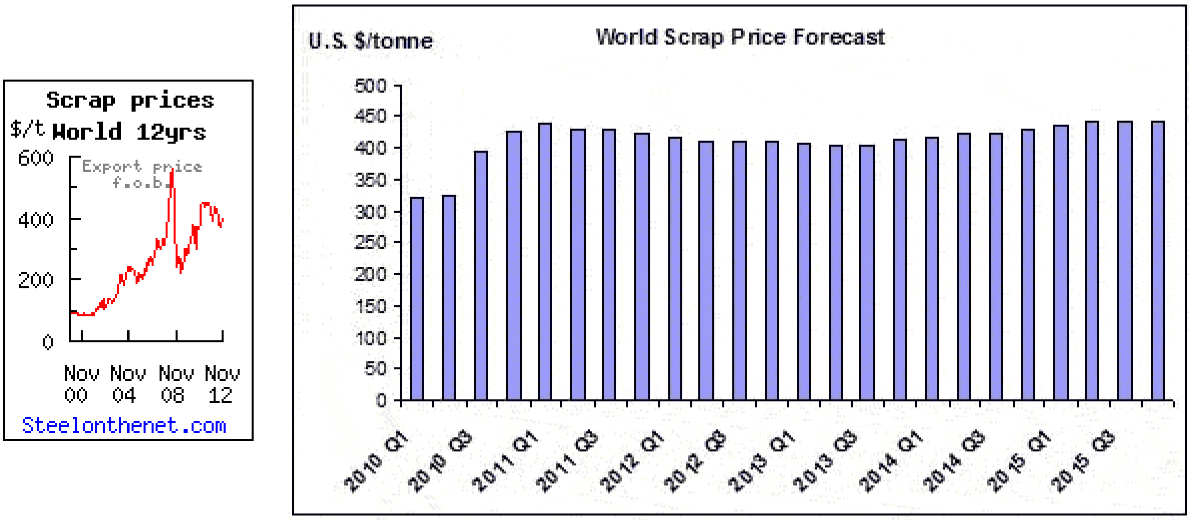
9.3 Product Prices

Experience in the UK is that the prices available to plant operators for the physical outputs from their processes are affected to varying extents by local, national and international market prices, so the materials are considered separately below.

9.3.1 Metals

Prices for ferrous and non-ferrous metals from thermal treatment plants behave like other traded commodities, rising and falling with the market. To give an example, prices in the UK fell 20% between January and October 2012. This is typical of the fluctuations seen in this market. Australian scrap metal merchants told us that their prices follow international trends, but were unwilling to share historical data. For this reason, we have looked to historical world trade prices (see Figure 9-5). From this, we conclude a trade price of US$400/t looks typical, which corresponds to about AUD $380/t).

Figure 9-5: World Scrap Steel Prices Over Recent Years



Source: http://www.steelonthenet.com/scrap-prices.html

The waste feed into the thermal treatment plant is unlikely to be any more than 5% ferrous metals, and the non-ferrous metal content is practically negligible for the purposes of these calculations. If we assume that 80% of the incoming ferrous can be recovered, we conclude that 4% of the incoming waste will earn the scrap metal income. **This implies that the value of the ferrous metal in the waste is about $15 per tonne of incoming waste.**

9.3.2 Incinerator Bottom Ash Aggregate

IBAA competes in the market with other secondary aggregates, but that market is local, because the materials are heavy and transportation quickly becomes a factor. It has been assumed that IBAA will not currently be able to command a value in the Australian market, and that there may even be a disposal cost instead. **For the purposes of the calculations here, it has been assumed that IBA is revenue neutral.**

9.3.3 Digestate

Anaerobic digestion processes produce a (semi-)solid digestate that has similar properties to composts. Whether digestate can command a price, or producers have to pay to have it taken away, depends once both on local market conditions and on the quality of the material. To promote the value of digestate, the Environment Agency in England and Wales has developed a "Quality Protocol" [17] defining the criteria that digestate must achieve in order to no longer be considered a waste material but a product.

South Australia's public water utility SA Water, operate several AD plants (trade and domestic wastewater treatment) and provide the digest (commonly known as bio-solids) to farmers and other land holders at no cost. The compost market in SA is well established, with operators undertaking good practice to produce quality soil conditioners. Digestate would have to compete for a share of this market. **Neutral revenue has been assumed in this instance.**

9.4 Waste Disposal Costs

Assuming that IBAA and digestate are, at worst, revenue neutral, the principal waste disposal costs that arise from thermal treatment plants are associated with the air pollution control residues (APCr) from incinerators, and any rejects at the front end of facilities arising from non-compliant waste. The latter is as much as function of the efficacy of the waste collection system as the operation of the facility, and typically involves minimal volumes, so is not a significant factor for these calculations.

9.4.1 APCr Disposal

During waste incineration, a certain fraction of the ash materials is entrained in the gas stream and carried away from the grate and into the boiler system. The emissions of modern incinerators are strictly controlled, and the gases have to pass through several air pollution control stages, including acid neutralisation with caustic soda (or equivalent), the removal of heavy metals using activated carbon, and the capture of entrained particulates using bag filters. All the solid residues from these treatments end up in the air pollution control residue (APCr), which is a hazardous material, because of its high pH (from the caustic soda) and heavy metal content.

The usual fate of this material is to be landfilled in hazardous waste landfills. However, some treatment technologies now exist that either reduce the APCr's hazardous nature prior to landfill, or seek to create a product from it.

[17] See http://www.environment-agency.gov.uk/static/documents/Business/W524AnaerobicDigestatev4(1).pdf

Regardless of the fate chosen, the handling of APCr represents a sizeable cost per tonne, though the overall tonnages, at about 5% of the incoming waste, are relatively small.

According to the 2010 Australian National Waste Report[18], a 2009 study by the BDA Group[19] found that total costs for putrescible landfills ranged between $42 and $102 per tonne of waste in urban areas, and between $41 and $101 per tonne in rural areas, depending on the level of management controls and prevailing climate. The price charged for APCr landfill varies by State in Australia. Our research has revealed the data presented in Table 9—6.

Table 9—6: State-by-State APCr Landfill Costs

State	Possible Classification for APCr (20)	Disposal Levy / Tax Component	Range of Landfill Disposal Costs
SA	Any facility accepting a waste will be classed as a 'waste depot' and therefore subject to a levy. Waste APCr are therefore subject to a levy.	**2012-2013 Rates:** Metropolitan Adelaide: $42/t Non-metropolitan : Adelaide: $21/t Further increases after 2011-2012 are forecast at up to $50/t in Metropolitan Adelaide.	MSW Adelaide: $100/t Elsewhere: $75/t C&IW: $75-185/t
NSW	Under the Protection of the Environment Operations Act 1997, APCr are unlikely to be classified as Hazardous Wastes (see Part 3).	**2012-2013 Rates:** Sydney Area: $95.20/t Extended Area: $93.00/t Regional: $42.40/t	$80-250/t
QSD	APCr due to their constituents will be classified as Regulated Wastes	Currently (0) Zero (21)	$0-230/t
VIC	Most APCr likely to be classed a Prescribed Industrial Waste (PIW) Category C.	**2011-2012 Rates** PIW Cat C: $70/t	$85-160/t/t
WA	To be advised	**January 2010-current** $28/t putrescible landfills $12 inert landfills per m^3.	$40-170/te

NT and TAS not included in analysis due to absence of mandated levy (voluntary levy of $2/t in Northern and Southern TAS) and poor data availability.

The combination of landfill disposal costs and the disposal levy in South Australia yields a possible range of costs from ($21+$75=) $96/t to ($42+$100=) $142/t, indicating a mid-range of about $120/t. **That would correspond to an additional fee per tonne of incoming waste of $6/tonne**.

9.5 Electricity and Heat Prices

The value of any electricity and heat generated can make a substantial difference to the on-going economics of a W2E plant, but the practical uses of the two energy forms are very different. Electricity is easy to transmit from the point of production to the point of use (as long as a local grid connection is feasible). In contrast, heat energy needs a user close to the point of generation, otherwise the transmission losses (and infrastructure costs) quickly become prohibitive.

RICARDO-AEA's FALCON database again offers useful information here, with the claimed heat and electrical energy generation levels for every plant built or proposed in the UK. The plots of the electrical energy produced as a function of throughput, with symbols denoting different status levels, are provided in Figure 9-6 (anaerobic digestion), Figure 9-7 (advanced

[18] National Waste Report 2010, Australian Government Dept of the Environment, Water, Heritage and the Arts, available here: http://www.ephc.gov.au/sites/default/files/WasteMgt_Nat_Waste_Report_FINAL_20_FullReport_201005_0.pdf
[19] BDA Group, The full cost of landfill disposal in Australia, 2009
[20] Decision at the discretion of the Administering Authority.
[21] From 01Dec11 to 01Jul12, a Waste Levy was applied to landfill disposal only ($50/te for lower hazard waste such as APCr).

thermal treatment) and Figure 9-8 (combustion facilities). Putting a best-fit line through these points and the origin is clearly an approximation, but leads to the predictions below on electrical energy generation.

Electricity costs are usually quoted in units of MWh, so we need an average annual availability for the plants to make the conversion, and a figure of 90% leads [22] to the second set of quoted figures here:

- Anaerobic Digestion: 0.040 MW_e per ktpa or 314 MWh per ktpa
- Conventional Combustion: 0.092 MW_e per ktpa or 722 MWh per ktpa
- Advanced Thermal Treatment: 0.108 MW_e per ktpa or 853 MWh per ktpa

[22] 1 MW[yr] = 365 MWd = (365x24=) 8760 MWh [100% availability] = 7884 MWh [90% availability]

Figure 9-6: Energy Generated (in MWe) by UK AD Facilities vs. Throughput (tpa)

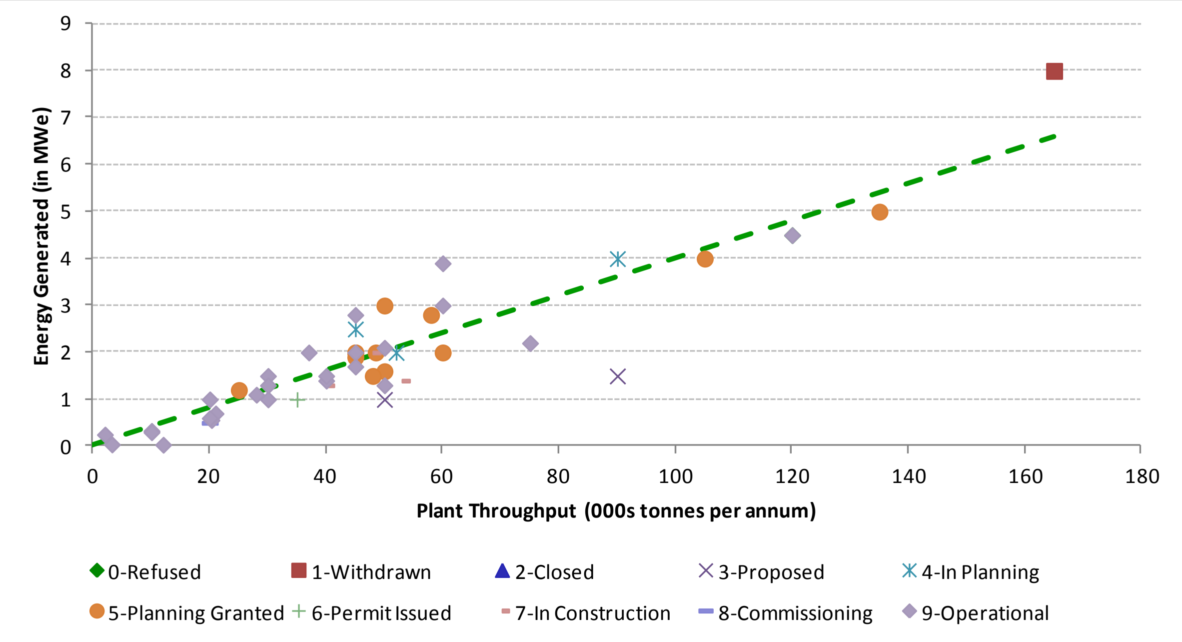


Figure 9-7: Energy Generated (in MWe) by UK ATT Facilities vs. Throughput (tpa)

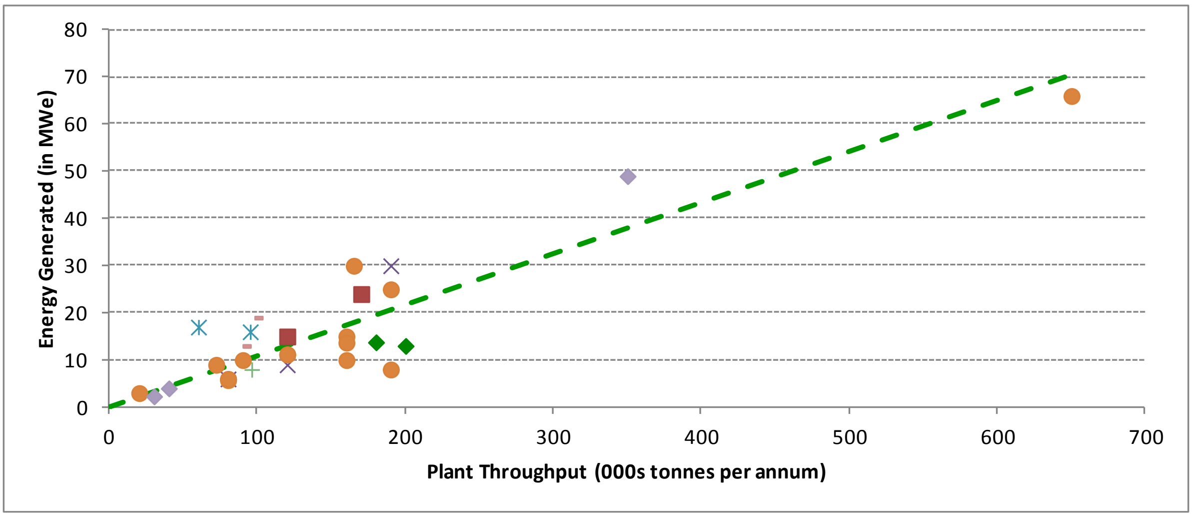
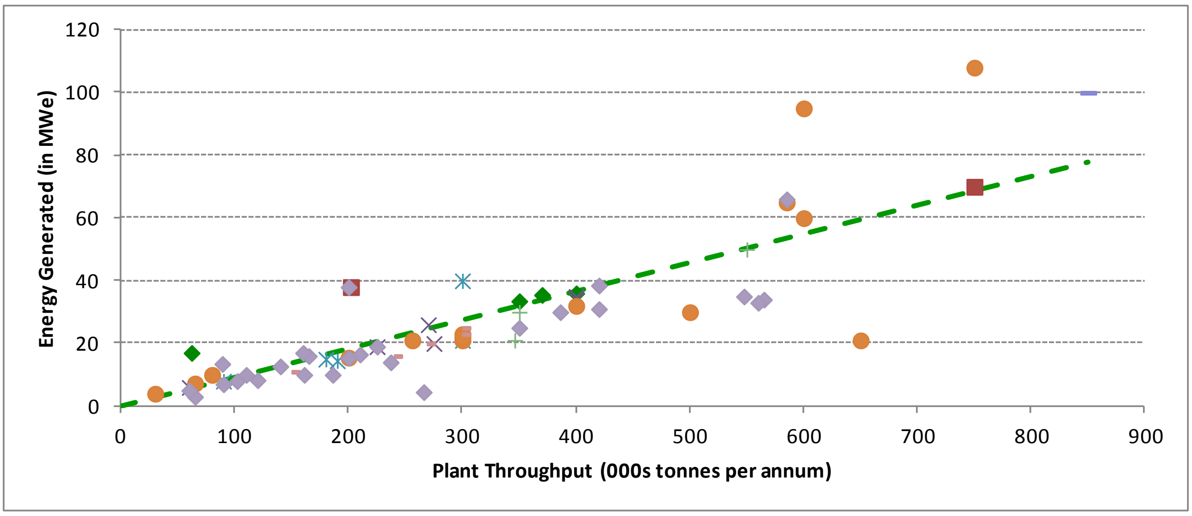


Figure 9-8: Energy Generated (in MWe) by UK W2E Facilities vs. Throughput (tpa)



The above assessment leads to estimations of the amount of electricity that may be generated by the different technologies, depending on the amount of incoming waste. The value of that electricity depends on the contract struck with the Australian Energy Market Operator (AEMO), established in 2009 to manage the Australian National Electricity Market (NEM). For the purposes of these calculations, the quoted [23] **average spot market price in 2007-08, of $52/MWh** has been used. More up to date plots on the website of the Energy Users Association of Australia (EUAA) [24] seem to suggest that this figure is not unreasonable, though the price is quite dynamic.

9.5.1 Heat (or Cooling) Energy

Estimating the value of any heat generated (and what follows applies equally to cooling duty) is much more difficult, for three particular reasons:

+ firstly, the useful heat generated is usually dependent less on how much heat the facility can produce than how much heat the receptor requires, and how close that receptor is to the generating point;
+ secondly, whilst electricity is the same regardless of how it was generated, there are endless degrees of heat, depending on the temperature and pressure of the water or steam (or other fluid) used; and
+ finally, few heat-producing waste treatment facilities are designed as heat-only plants, instead operating as combined heat and power plants. Thereby, within certain limits according to the plant design, the amount of heat generated can be varied according to demand, with the balance converted to electricity.

For these reasons, no values have been assigned to the heat energy produced by the waste facilities, assuming instead that the plants will be configured to maximise the amount of electricity generated. If, in practice, useful heat can also be harnessed from the plant, which will of course increase the potential profitability of the facility.

9.5.2 Grid Connection

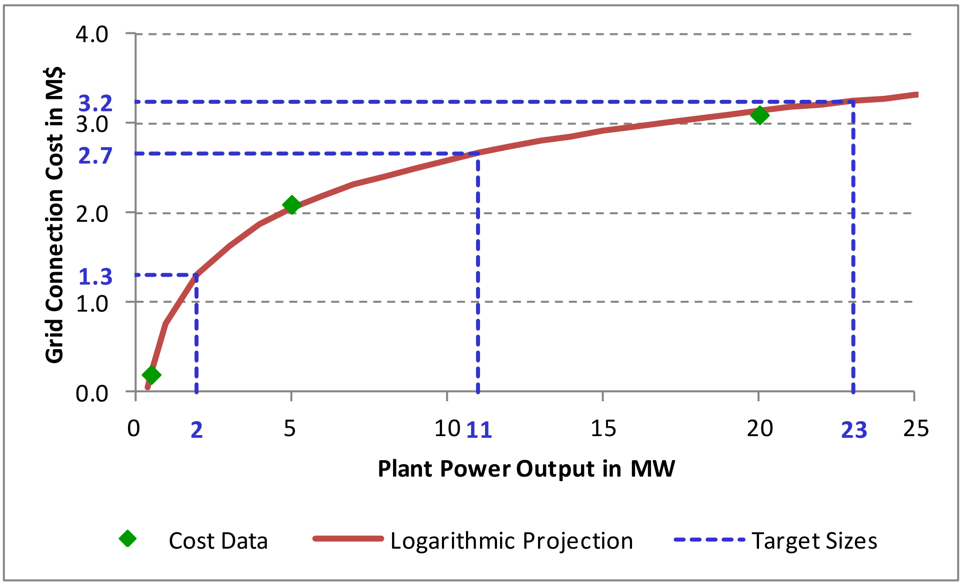
The other factor that must be taken into consideration when selling electricity is the cost of connecting to the national grid. Table 9—2, taken from the BioEnergy in Australia report, includes three prices for grid connections of different sized plants. A logarithmic projection through these three data points yields the following estimation:

$$\text{Cost of connection (M\$)} = 0.790 \times \log_e[\text{Power in } MW_e] + 0.770$$

For the purposes of further calculations, the grid connection costs used were **$1.3M (2MW AD plant), $3.2M (23MW W2E plant) and $2.7M (11MW ATT plant)**, derived from the projection in Figure 9-9.

[23] Page 12 of "An Introduction to Australia's National Electricity Market", June 2010, from AEMO: www.aemo.com.au/corporate/0000-0262.pdf
[24] See http://www.euaa.com.au/spot-market-prices/

Figure 9-9: Estimated Australian Grid Connection Costs as a function of Power



9.6 Revenues and Costs from Government Schemes

Possible government schemes that might be considered in South Australia are detailed in Sections 12. The options are so diverse that it is difficult to estimate what revenues and costs might accrue for the various interventions. However, for the purposes of the illustrative calculations below, we have assumed that “Large-scale Generation Certificates” (LGCs) are available, and that the SA Waste Levy continues to be active. More details on these two schemes are provided below.

9.6.1 SA Waste Levy

The SA Environment Protection Regulations 2009 falls under the Environmental Protection Act 1993 and requires all premises that receive, store, treat or dispose of waste (e.g. waste depot) to be licensed by the SA EPA and pay the waste levy for all waste received for disposal. The levy is collected on behalf of the SA Government and a portion is used to fund resource recovery and waste minimisation programmes. Current levies per tonne of solid waste are:

+ For a non-metropolitan depot disposing of non-metropolitan waste (non-metro rate) $21
+ For a metropolitan depot disposing of non-metropolitan waste brought to the depot by or on behalf of a wholly non-metropolitan council (non-metro rate) $21
+ Any other case (metro rate) $42

9.6.2 The Renewable Energy Target Scheme

The Renewable Energy Target (RET) Scheme is legislated under the Renewable Energy (Electricity) Act 2000 and the Renewable Energy (Electricity) Regulations 2001. The RET was introduced to drive investment and innovation in renewable energy. The RET is split into two schemes, namely the Small scale Renewable Energy Scheme (SRES) and the Large scale Renewable Energy Target (LRET).

The SRES creates a financial incentive for owners to install eligible small-scale installations such as solar water heaters, heat pumps, solar panel systems, small-scale wind systems, or small-scale hydro systems. Therefore, the SRES is not relevant to the sort of facilities being considered in this report, and is not discussed any further.

Eligible Renewable Energy Sources from LRET, as defined in the Act, are listed below, with waste derived fuels highlighted in bold text:

- hydro;
- wave;
- tide;
- ocean;
- wind;
- solar;
- geothermal-aquifer;
- hot dry rock;
- energy crops;
- **wood waste;**
- **agricultural waste;**
- **waste from processing of agricultural products;**
- **food waste;**
- **food processing waste;**
- **bagasse;**
- **black liquor;**
- **biomass-based components of municipal solid waste;**
- **landfill gas;**
- **sewage gas and biomass-based components of sewage**;
- other, as specified by the Regulation

Guidelines are provided on how to determine the renewable components in waste used for electricity generation, in order to calculate how much of the electricity produced is eligible for LGCs.[25] The calculation requires any electricity generated from fossil fuels to be subtracted from the calculations, as well as auxiliary and transmission losses.

Since 2010, the commodity traded under the LRET has been the “Large-scale Generation Certificate” (LGC). LGCs are created by renewable energy power stations in an online market-based system, known as the REC Registry, which is operated by the Clean Energy Regulator. One LGC is equivalent to 1 MWh (megawatt hour) of eligible renewable electricity generated above the power station’s baseline.

LGCs have value to a W2E operator, as they can be sold or transferred to liable entities (i.e. electricity retailers). Selling and transfer of LGCs is done via the REC Registry.

The market price of LGCs is dependent on supply and demand and can fluctuate daily; it has varied between $10 and $60 in the past.[26] The Clean Energy Regulator is required to publish a volume-weighted average market price for an LGC. Recent average prices have been $38.39 (in 2011) and $35.24 (in 2012), and the projected figure for 2013 is $38.69.[27]

For the purposes of our calculations, we have used this last figure of $38.69/MWh.

[25] http://ret.cleanenergyregulator.gov.au/For-Industry/Renewable-Energy-Power-Stations/LGC-Eligibility-Formula/lgc-eligibility-formula
[26] http://ret.cleanenergyregulator.gov.au/about-the-schemes
[27] http://ret.cleanenergyregulator.gov.au/For-Industry/Emissions-Intensive-Trade-Exposed/Volume-Weighted-Average-Market-Price/market-price

Table 9—7: Summary of Estimated Costs and Revenues

Detail		Units	AD	W2E	ATT	Comments
Typical Plant Throughput		ktpa	50	250	100	
Typical Plant Power		MW	2.0	23.0	11.0	
Plant Lifetime		years	20	30	25	
CapEx	Plant (Rate)	$ / tpa	713	934	1,033	
	Plant (Total)	M$	36	233	103	
	Grid connection	M$	1.3	3.2	2.7	
	CapEx (Annualised)	**M$ / yr**	**1.8**	**7.9**	**4.2**	
Opex Annual		M$ / yr	1.7	6.5	4.7	
Ferrous Metals		$ / tpa waste	0	-15.0	-15.0	Negative because income
	Total per year	M$ / yr	0	-3.8	-1.5	
Non-Ferrous Metals		M$ / yr		0		Negligible in these calculations
IBAA		M$ / yr		0		Could be a cost or a revenue, depending on local factors
Digestate		M$ / yr				
APCr Disposal		$ / tpa waste	0.0	6.0	6.0	
	Total per yr	M$ / yr	0.0	1.5	0.6	
Electricity	Generation Rate	MWh / ktpa	314	722	853	
	Total Generation	MWh	15,700	180,500	85,300	
	Market Price	$ / MWh		-52		Negative because income
	Revenue	**M$**	**-0.8**	**-9.4**	**-4.4**	
Gov't Incentives	LGC Price	$ / MWh		-38.69		Assume that only the biogenic fraction qualifies
	Biomass Content	%	100%	67%	67%	
	Adjusted LGC Price	$ / MWh	-38.69	-25.92	-25.92	Negative because income
	Annual Revenue	M$ / yr	-0.6	-4.7	-2.2	
Summary	CapEx	M$ / yr	1.8	7.9	4.2	
	OpEx	M$ / yr	1.7	6.5	4.7	
	Ferrous	M$ / yr		-3.8	-1.5	
	Non-Ferrous	M$ / yr				
	IBAA	M$ / yr				
	Digestate	M$ / yr				
	APCr Disposal	M$ / yr	0.0	1.5	0.6	
	Electricity	M$ / yr	-0.8	-9.4	-4.4	
	Gov't Incentives	M$ / yr	-0.6	-4.7	-2.2	
	Net Total	**M$ / yr**	**2.1**	**-1.9**	**1.4**	
	Net Total pro-rata	$ / tpa	42.65	-7.56	14.24	

10 Environmental and Social Impacts

Implications on W2E in South Australia

- W2E can play an important role in an integrated waste management solution, providing an alternative to landfill for wastes which have no further recovery or recycling value;
- W2E can make an important contribution to SA's energy security and renewable energy targets;
- W2E can also contribute to greenhouse gas emission reduction, by substituting fossil fuel use and by avoiding the emission of greenhouse gases from landfills;
- W2E processes themselves impact on the environment, through emissions of greenhouse gases, pollutants, noise, dust and traffic. However modern, regulated W2E facilities pose no risk to human health and operate at levels commensurate with other industrial facilities;
- Public concerns are predominantly focussed on visual impact and impact on human health. Early engagement with the community is an essential part of the development of W2E facilities;
- W2E can provide community benefits and social value, in the form of lower energy prices, community benefit funds and district heating/cooling; and
- W2E technologies create more jobs than landfill operations.

10.1 Positive impacts of W2E

10.1.1 Contribution to a sustainable waste management solution

Even countries with high recycling rates and zero waste targets are beginning to recognise the role that W2E has in a long term, sustainable waste management strategy. W2E offers an alternative to landfill, and whilst it may be towards the bottom of the waste hierarchy, it still has a role to play in treating residual waste materials.

Countries with well-established W2E infrastructure tend to have much lower rates of waste sent to landfill, for example Denmark, Sweden and Germany. However these countries also achieve high levels of recycling, recovery and composting, demonstrating that W2E can work in synergy with other recycling and recovery facilities towards SA's ultimate goal of zero waste.

10.1.2 Contribution to energy security and renewable energy

Many countries have previously considered W2E to be a waste management solution first and foremost. However, increasingly W2E is being seen as a valuable energy source. In Europe, drivers to both divert waste from landfill and increase the amount of energy produced from renewable sources have acted in tandem to increase W2E. The drivers to divert waste from landfill are relatively recent, but recovery of energy from waste became a focus in Europe during the oil crisis in the 1970's. As a result of this, W2E capacity quickly developed.

Australia is a country rich in energy resources, but energy security is still a major priority for both national and state governments. As the country benefits from economic growth, a corresponding demand in energy increase will occur. In 2011, Australia's overall oil production declined by 14.5% on the previous year, whilst oil consumption increased by 5.7%[28] and there is a growing reliance on oil imports.

Electricity in South Australia is currently dominated by gas, which supplied 51% of electricity in 2011-12.[29] This was followed by wind which generated 26% of electricity in 2011-12, exceeding coal-fired electricity generation for the first time. Diesel-fired power stations service remote off-grid communities. Should SA power stations not produce enough electricity to meet local demand, electricity can be imported from its eastern state neighbours. Electricity is also imported from an adjoining region when the electricity price is low enough to compete with local supply.

Recovering heat and electricity from waste which would otherwise have been landfilled can replace the use of fossil fuels, reduce the need to import energy and add to the diversity of energy sources used.

Many sources of waste are deemed renewable in terms of energy recovery, and therefore utilising these feedstocks as a fuel will contribute to SA's renewable energy target of 33% of the state's electricity production by 2020 (milestone of 20% by 2014)[30].

10.1.3 Climate Change and Greenhouse Gas Emissions

In addition to energy security, a further priority is for Australia to make the transition to a lower-carbon energy sector. W2E can play an important role in contributing to greenhouse gas emissions in different ways. Treating biodegradable waste by Anaerobic Digestion will avoid the production of greenhouse gases that this waste would emit in a landfill site. Utilising the biogas to produce electricity or as a vehicle fuel will substitute more traditional solid or liquid fossil fuels, further contributing to the reduction of greenhouse gas emissions. Similarly, high efficiency combustion or Advanced Thermal Treatment of residual waste can reduce consumption of fossil fuels, by utilising power for electricity and heat (or cooling).

Therefore it is clear that W2E could contribute to SA achieving the Kyoto target by reducing greenhouse gas emissions by 60% by 2050, as outlined in the SA Climate Change and Greenhouse Gas Emissions Reduction Act 2007 and South Australia's Strategic Plan.

10.2 Environmental impacts

As outlined above, whilst the aim of treating waste in W2E technologies may be to reduce environmental impact of waste disposal, or contribute to energy production, W2E technologies and processes will themselves give rise to environmental impacts that will need to be managed.

Table 10—1 summarises the environmental impacts of the different W2E technologies discussed in this paper.

One of the major environmental impacts of W2E technologies is emissions to air. Australia (unlike Europe, under its Directives), does not have national air quality emissions standards. Instead, it is the Environment Protection Authorities in individual States and Territories who have responsibility for setting such standards. These standards will be based on the individual States legislation and will apply to various facilities based on their deemed risk. For

[28] BP Statistical Review of World Energy Report, June 2012
[29] South Australia Electricity Report 2012
[30] South Australia's Strategic Plan 2011, Target 64.

example, in South Australia, Schedule 1 of the *Environment Protection Act 1993* sets out a list of activities that may require a licence and would have specific conditions attached to their operation. Identification of such activities is based on their potential to cause environmental pollution.

National Environment Protection Measures (NEPMs) are broad framework-setting statutory instruments defined in the National Environment Protection Council (NEPC) Act 1994, which outline agreed national objectives for protecting or managing particular aspects of the environment. A NEPM will become law in each participating jurisdiction once it is made by NEPC.

There are currently five NEPMs in place that relate either entirely or partly to air quality:

- Ambient Air Quality
- Particles Standard PM2.5
- Diesel Vehicle Emissions
- Air Toxics NEPM
- National Pollutant Inventory NEPM

Table 10—1: Summary Matrix of Environmental Impacts of W2E Technologies

Aspect	Conventional combustion treatment (CCT)	Advanced thermal treatment (ATT)	Anaerobic digestion (AD)
Greenhouse gas emissions	CCT can perform reasonably well in relation to GHG emissions, provided appropriate materials are burnt. Modelling systems should be used to identify appropriate waste streams.	Similar to CCT, but typically higher energy requirement may reduce performance in relation to GHG emissions.	Effective in reducing carbon footprint of materials which can be processed by anaerobic digestion compared to landfill disposal. Balance in relation to CCT depends on system and waste stream details.
Traffic	Traffic flows are mainly linked to the quantity of waste received at a facility. All waste facility types require removal of residues. Attention must be given to appropriate location of facilities to avoid local traffic impacts and minimise distances from waste arisings.		
Noise	Fully enclosed facility. Noise impacts can normally be controlled by design, although may be some residual noise e.g. from fans or cooling systems.		
Dust	Fully enclosed facility. Dust control facilitated by use of combustion air. Dust not usually a significant issue.	Fully enclosed facility. Dust control is facilitated by use of combustion air for most facility types. Dust not likely to be a significant issue.	Fully enclosed facility. Materials treated at AD site not likely to be dusty. Dust not likely to be a significant issue.
+ Pollutants	Pollutants include: + Particulate matter, (including PM_{10}) are present in fine ash entrained in flue gas. + Products of incomplete combustion, including carbon monoxide and organic compounds (VOCs, TOCs) + Acidic substances (NO_x, SO_x) – present in flue gas, either from the conversion of nitrogen present in the waste stream, or conversion of atmospheric nitrogen. Sulphur Dioxide – occurs in flue gas if sulphur is present in waste stream (i.e. in waste paper) + Heavy metals - can be present in particulate matter in the form of metal oxides and chlorides. Also present in bottom ash and fly ash. + Dioxins and Furans		Potential for effluent to be a pollution risk to watercourses, if not properly managed and treated. + Pollutants from combustion of biogas, including NO_x, CO, VOCs, SO_x.
Localised and regional air pollution impacts	CCT facilities result in emissions to air of a range of pollutants. Emissions have been extensively monitored, and can normally be controlled to avoid significant localised or regional impacts.	ATT facilities result in emissions to air of a range of pollutants. Emissions may in principle be lower than those associated with CCT, but there is little information to substantiate this. Emissions can normally be controlled to avoid significant localised or regional impacts.	AD facilities typically result in emissions to air of a narrower range of pollutants due to the combustion of biogas. Control of local impacts may be more challenging than for CCT because of relatively high emissions of pollutants including NOx and particulates.

Aspect	Conventional combustion treatment (CCT)	Advanced thermal treatment (ATT)	Anaerobic digestion (AD)
Visual impact	Engineering requirements for combustion and abatement plant result in buildings and structures of significant size. CCT facilities typically have chimneys of height 50-80 m depending on scale and location of facility. There may be a visible plume for some of the time. Hence, visual impacts can be significant.	Engineering requirements for combustion and abatement plant result in buildings and structures of significant size. Chimneys serving ATT facilities are typically similar to CCT facilities – while in principle chimneys could be lower reflecting lower emissions, this has not been borne out in practice. There may be a visible plume for some of the time. Hence, visual impacts can be significant.	Engineering requirements for combustion and abatement plant result in buildings and structures of significant size. AD facilities typically have lower chimneys for dispersion of emissions from combustion of biogas. There may be a visible plume for some of the time. Hence, visual impacts can be significant, but are typically lower than for CCT or ATT facilities.
Health impacts	Although public concern remains high, incineration has been extensively studied. Recent guidance and scientific evidence indicates that the current generation of facilities in Europe have no detectable effect on health, provided they are properly located, designed and operated.	Waste management in general has a minor impact on health. No specific information available on health impacts of ATT, but analogy with CCT processes indicates that health impacts are unlikely to be significant.	Waste management in general has a minor impact on health. No specific information available on health impacts of AD, but analogy with CCT processes indicates that health impacts are unlikely to be significant.
Odour	Fully enclosed facility. Odour control facilitated by use of combustion air. Odour not usually a significant issue.	Fully enclosed facility. Odour control is facilitated by use of combustion air for most facility types. Odour not likely to be a significant issue.	Fully enclosed facility. Odours can result from breakdowns in process control, from fugitive emissions of biogas, or from storage/transportation of raw materials or digestate. Detailed attention needed to avoid odour problems.

10.3 Social impacts of W2E

10.3.1 Public perception

Public perception of W2E facilities has historically been far from positive, and there is often significant opposition to their development.

The main concern of the public is normally impacts to health, namely the impact of process emissions on health issues such as infant mortality, carcinogens and cancer risk, and respiratory diseases. There is no disputing that W2E facilities do result in emissions to air, land and water, however modern process controls and abatement facilities are used to ensure that emissions are kept within permitted limits. As outlined in Table 10—1 above, recent guidance and scientific research in Europe indicates that current W2E (thermal) facilities have no detectable effect on health, provided they are properly located, designed and operated[31].

In addition to health impacts, communities are likely to have concerns about the increase in traffic, visual impact, noise and dust. The negative opinion regarding W2E plants has resulted in planning permissions being withdrawn in some cases in Europe. This risk can be mitigated by effective and early consultation with local communities. Recognising the importance of delivering new waste infrastructure to meet its' landfill diversion targets, the Welsh Government commissioned the development of a Waste Infrastructure Community Engagement Toolkit. This has been made available to all local authorities in Wales to help get the public engaged and 'on-side' to try and avoid length and expensive planning appeals. The toolkit considers different stages of the consultation, from initial awareness raising of the need for a new facility, an evaluation of the different technology options, and decisions on site selection criteria. The toolkit itself is a step-by-step guide to consulting with all stakeholders on waste infrastructure issues.

Further into the consultation process, the local community can also input in to the physical appearance of the facility. The Veolia W2E facility at Marchwood in the UK was designed in consultation with local residents, local authorities and architects (see image on front cover). Whilst the facility uses the same combustion technology as in other facilities, the plant is housed under an aluminium-cladded dome, which has become an iconic local landmark.

The Spittelau W2E facility in Vienna, Austria, has also become a famous landmark.

[31] http://www.esauk.org/energy_recovery/EfW_Health_Review_January_2012_FINAL.pdf

Figure 10-1; Spittelau W2E facility, Vienna, Austria

In Paris, attractive architecture was one of the core concerns of planners in the development of the Isséane W2E facility on the banks of the river Seine. Whilst the building is 52 metres high, only 21 metres of the building are visible, with the remaining 31 meters being underground. The external fascia of the building was designed to blend in with local architecture.

10.3.2 Community benefits and social value

Many people give little thought to what happens to their waste after it is collected from the kerbside, and would not perceive to gain any benefits from any waste infrastructure in their locality. However, waste management can play a role in adding social value and delivering community benefits. In addition to contributing to renewable energy targets and reducing greenhouse gas emissions, W2E facilities could potentially deliver lower energy bills for the host community, and in some cases lower cost heating/cooling through district heating/cooling schemes.

In Europe, community ownership of waste management facilities has been successful in delivering community benefits. This could be in the form of a group of local farmers joining together to purchase a small-scale anaerobic digestion plant, or local groups of residents investing together to install biomass heating systems.

In 2011, waste management company SITA UK published a report looking at public opinion of community incentives[32]. The report concluded that support for a new facility increased if there would be a community fund or energy discounts.

Community funds consist of the operator of the W2E facility setting aside an annual sum of money to be donated to the local community. A local committee is set up to decide how this money is invested, and could include supporting local charities, or investment in community facilities such as parks and community centres.

10.3.3 Job Creation

Investment in W2E is likely to create direct jobs as well as indirect jobs across the entire supply chain of the industry including environmental monitoring, development design, commissioning and procurement, manufacturing, installation, project management, transport and delivery and operations and maintenance.

A number of studies have found a positive net impact on jobs as a result of substitution of energy derived from fossil fuels to renewable sources of energy. This is mainly due to longer and diversified supply chains, higher labour intensity and higher net-profit margins for renewable energy compared to non-renewable energy generation. Increased spending attributed to net new jobs would lead to additional output thus creating a ripple effect in the economy.

A European Commission (2007)[33] study found that the overall net impact of a 10% substitution towards renewable energy sources compared to non-renewable sources has a positive impact on jobs.

A renewable supply chain gap analysis carried out by the UK Department of Trade and Industry (DTI) in 2004 estimated jobs created per MW for a number of renewable technologies in the UK as shown in Figure 11-1 below. While this study is now 6 years old, it provides valuable data on employment per MW of installed capacity across several of the key renewable heat technologies, including biomass and W2E.

[32] http://www.sita.co.uk/news-and-views/press-releases/sita-uk-launches-ground-breaking-report-into
[33] European Commission (2007), DG Environment, Links between the environment, economy and jobs.

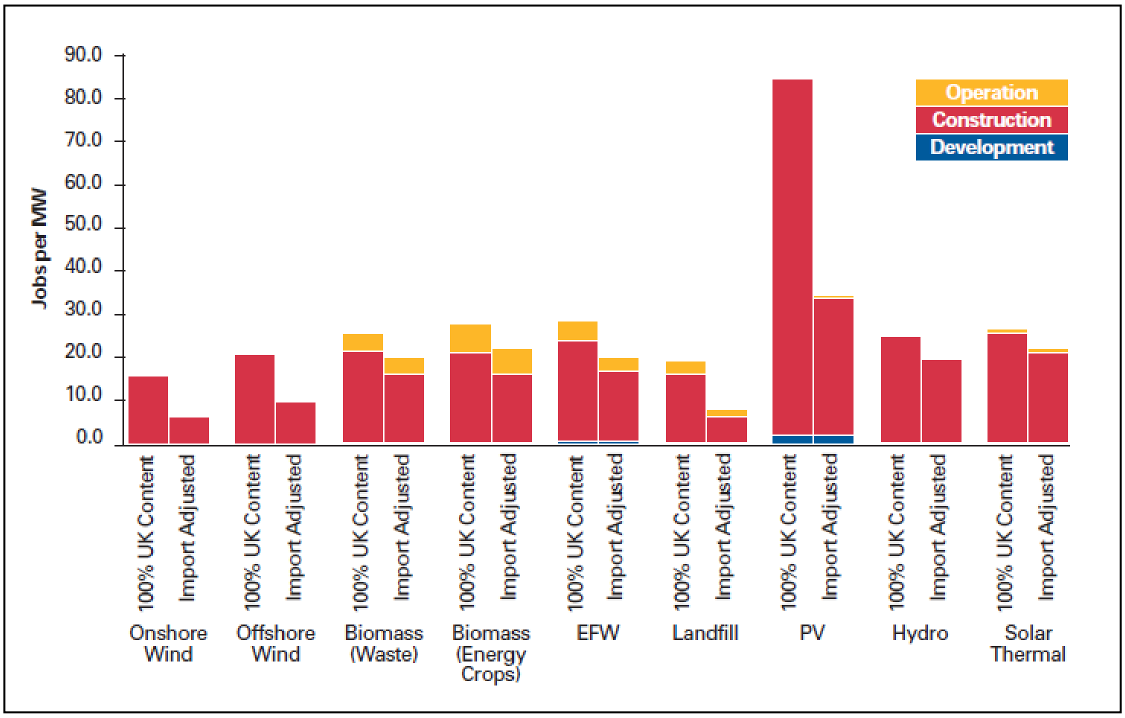


Figure 10-2 Jobs created per MW produced by each renewable energy technology[34]

As can be seen in Figure 10-2 above, the number of jobs created varies with each technology. The majority of jobs are created during the construction phase of a project, which could include the installation phase of a biomass boiler.

Biomass and Bioenergy schemes in particular offer the greatest potential for jobs relating to the on-going operation of a facility. Jobs may be created both from the operation of larger plants, and also from the on-going management and supply of fuels.

[34] Renewable Supply Chain Gap Analysis, DTI, 2004

11 Existing W2E Facilities

Implications for W2E in South Australia

The recovery of energy from biogas, including sewage and landfill gas, is well established across Australia. In terms of landfill gas technology, Australia can be considered a world leader. The use of fuels derived from agricultural and food processing wastes is also common in some states. However, there are very few examples of W2E involving solid wastes such as residual MSW or C&I wastes, compared to Europe, the US and Japan. This results in a current lack of local reference facilities and technologies, which are considered well established in some countries, which may appear still be unproven in Australia.

Learning from both successful projects and projects that have failed is equally important. In 2004, an experimental Solid Waste and Energy Recycling Facility (SWERF) closed, incurring significant financial losses. The facility aimed to convert the organic fraction of MSW in to a syngas, and into electricity. However, due to engineering and technical difficulties the project failed to achieve full commercialisation. The developer, Brightstar, claimed that the concept was sound, but that the company had been over ambitions, and could not get the technology to work at a commercially viable level.

South Australia can take advantage of experiences in other countries, particularly those in Europe, to ensure that any new W2E facilities are designed and developed to deliver safe, modern and efficient energy recovery from waste.

11.1 Overview

Despite increases in landfill diversion across most states in Australia, this has largely been achieved by increased recycling, with energy recovery still playing only a very minor role (less than 0.5% in 2008-09)[35]. A report commissioned by the Australian Government Department of Sustainability, Environment, Water, Population and Communities compiled data on Australia's national performance in waste management and recycling, including identifying quantities of waste used for energy recovery[36]. The 2011 report identified that for most states, the majority of energy recovery was through methane capture at landfills and sewage treatment plants. There were few solid waste combustion plants identified, although the report excluded some agricultural and wood wastes which are used for energy recovery. In some states, such as New South Wales, Queensland and Victoria, energy recovery from wood, bagasse and agricultural wastes are common. There are fewer cases of energy recovery from municipal and commercial and industrial wastes. One example of energy recovery from commercial and industrial wastes is the manufacture of a Processed Engineered Fuel by SITA ResourceCo for use in the Adelaide Brighton Cement kiln, see boxed text in Section 3.1.2.

There is no centralised listing of W2E facilities in Australia, due to the different ways in which they are regulated and licensed across different states. The Clean Energy Regulator's Accredited REC Registry identifies some facilities, but only those registered on the scheme. Table 11—1 details the number of currently accredited electricity generators using waste as a fuel source across Australia.

[35] Waste and Recycling in Australia, 2011
[36] http://www.environment.gov.au/wastepolicy/publications/waste-recycling2011.html

Table 11—1: Accredited Renewable Energy Facilities (energy from waste only) in Australia.

	ACT	QLD	NSW	NT	SA	TAS	VIC	WA
Landfill Gas	2	13	13	1	4	3	13	9
Sewage Gas		4	8			1	4	1
Bagasse/Co-Generation		23	2					1
Other Biomass Classifications including Food Processing Waste/Agricultural Wastes/Crops/Wood/Black Liquor/MSW and Coal		7	16	1	1 (wood)	2	5	4

Currently Accredited Renewable Energy Power Stations Operating in Australia, grouped by type (source: https://www.rec-registry.gov.au/ Retrieved 3 October 2012).

Note: Some bagasse generators are included in the 'other biomass' category as they accept other organic streams.

Table 11—2 summarises known examples of Australian W2E facilities

Table 11—2: Examples of W2E facilities in Australia

Site	Location	Technology	Feedstock	Status	Output	Cost	Developer
Earthpower Technologies Sydney	Camellia, Sydney	Anaerobic digestion, 2x 5000m^3 digesters	Up to 80,000 tonnes per year of food waste, including waste from food manufacturing, catering and hospitality, and source-separated food waste from households	Operational	3 x 1.3 MW electrical output. Recovered biogas for electrical production for 3,600 homes and AD produces high nutrient (dried and granulated) fertilizer for agriculture and horticulture	N/A	Joint venture between Transpacific and Veolia Environmental Services
Bromelton Bioenergy Plant 1 - QLD	Beaudesert, Bromelton, Queensland	Anaerobic lagoons and biogas generators	Food processing waste (meat and poultry co-products)	Under construction/ operational	500 kW to be increased to 1.7 MW progressively over the next 6 months	N/A	Quantum Power
Leongatha Bioenergy Plant - VIC	Leongatha, Victoria	Biodigester and biogas engines	Waste streams generated from on-site production of dairy products	Commissioned: 2010	760 kW	$1.82 million (over 18months)	Murray Goulbourn Co-Operative
Hume Highway Woomargama Biodiesel - NSW	Woomargama, New South Wales	Semi-permanent electrical generators that are fully fuelled by renewable energy	Abattoir tallow based biodiesel	N/A	330 kW of electricity for 120 staff	$320,000	Green Power Solutions
Vales Point	Lake Macquarie, New South Wales	Co-firing with coal	Biomass sourced from plantation sawmill residue and clean timber waste	Biomass programme from 2009	1,320 MW	N/A	Delta Electricity
Vales Point	Lake Macquarie, New South Wales	Pyrolysis	Biomass	Trial underway since 2010	1 MW	N/A	Crucible Group
Big River Timbers Grafton	NSW	Incineration to generate steam to produce electricity	Wood Waste	Operational	500kW providing 40 - 50% of the company's energy needs	N/A	Big River Timbers
Gympie Timber Wood Waste Power Station 1 - QLD	Gympie, Queensland	Incineration to generate steam to produce electricity	Wood Waste	Operational	240 kW	N/A	N/A
Carter Holt Harvey Wood Products Australia Pty Limited	Mt Gambier SA	Incineration to generate steam to produce electricity	Wood Waste	Operational	provides 70% of Carter Holt total energy needs	N/A	Carter Holt Harvey
Visy WW Biomass Generator No 1 - VIC	Tumut, NSW and Coolaroo, Victoria	N/A	Wood Waste, Biomass-Based Components of Municipal Solid Waste	Construction	30MW Tumut Plant alone	N/A	N/A
Eastern Creek UR-3R	Sydney	MBT and AD to produce energy	Municipal Solid Waste Combustion, Biomass-Based Components of Municipal Solid Waste	Operational	2.1 MW produce 23,500 tonnes of compost & fertiliser products; and produces 17,000 megawatt hours of green electricity a year	$100m	Global Renewables

Site	Location	Technology	Feedstock	Status	Output	Cost	Developer
Spring Farm ARRT Facility (Formerly the Macarthur Resource Recovery Park)	NSW	AD	Landfill Gas, Biomass-Based Components of Municipal Solid Waste	Operational	N/A	$150 million	SITA
ResourceCo PEF manufacturing plant	Wingfield, SA	Manufacture of Processed Engineered Fuel for use in Adelaide Brighton cement kiln	Commercial and Industrial waste	Operational	Converts up to 350,000 tonnes of raw material into 100-150,000 tonnes of Process Engineered Fuel	$20m for fuel processing plant	ResourceCo, Sita, Adelaide Brighton Cement
Phoenix Energy, Perth	Perth, WA	Conventional mass burn incineration and plasma arc gasification	MSW	Construction due to commence 2013, estimated to be operational by late 2015	400,000 tonnes, 80MW	$400m	Phoenix Energy
Visy Pulp & Paper Mill	Tumut, NSW	Pyrolysis	Bark, wood waste, black liquor	Operational	20 MW	N/A	Visy
CSR Sugar	Brandon, QLD	Cogeneration	Bagasse	Operational	68 MW	$160m	CSR Sugar
Prosperine Sugar	Prosperine, QLD	Cogeneration	Bagasse	Operational	16 MW	N/A	Prosperine Sugar
Bundaberg Sugar Ltd	Tableland, QLD	Cogeneration	Bagasse	Operational	7 MW	N/A	Bundaberg Sugar Ltd
Green Pacific Energy	Stapylton, Brisbane	Fluidised bed combustion	Wood waste	Operational	5 MW	$12m	TechComm Simulation
Sydney Water Corporation	Sydney, NSW	Anaerobic Digestion	Sewage wastewater	Operational	485 kW	N/A	Australian Water Services (for Sydney Water Corporation)
Suncoast Gold Macadamias	Gympie, QLD	Cogeneration	Macadamia nut shells	N/A	1.5 MW	$3m	Ergon Energy
ITC	Launceston, TAS	Water tube boiler	Dry chip and wood shavings	Operational	3 MW thermal	N/A	N/A
Nestle	Gympie, QLD	Water tube boiler	Coffee waste, wood waste	Operational	16 MW thermal	N/A	N/A
FEA	Georgetown, TAS	Water tube boiler	Wood waste	Operational	20 MW thermal	N/A	N/A
Hyne & Son	Tumbarumba,NSW	Thermal oil heater	Wood waste	Operational	15 MW thermal	N/A	N/A
Visy Paper	Gibson Island, QLD	Pyrolysis	Black liquor (paper industry)	Operational	2 MW	N/A	Visy
Paperlinx	Maryvale, Victoria	Pyrolysis	Black liquor (paper industry)	Operational		N/A	
AnaeCo	Shenton Park, WA	Anaerobic Digestion	Biomass-Based Components of Municipal Solid Waste	Due to commence in early 2013	2 MW	$57m	Western Metropolitan Regional Council
Bolivar EIP	Adelaide, SA	Wastewater Treatment	Wastewater	Operational	N/A	$100m (for Bolivar Environment Improvement Program)	SA Water
Glenelg	Adelaide, SA	Wastewater Treatment	Wastewater	Operational	N/A	N/A	SA Water

12 Strategies, Plans and Policy

This section considers some keys policies that may impact on the development of W2E in SA, and examines and reviews National, State and International examples where appropriate.

Implications for W2E in South Australia

- South Australia's Waste Strategy 2011-15 recognises a role for energy recovery enterprises where these are consistent with the waste management hierarchy. The intention to develop a W2E policy foreshadowed in ZWSA's Business Plan is well aligned with the National Waste policy stance on W2E, which outlines high level strategies to enhance biodegradable resource recovery and diversion from landfill and reduce GHG emissions. Increasing AWTs, W2E plants and bio-digesters are highlighted as potential means of doing so;
- Whilst all other States have developed waste strategies, there is little specific or detailed policy on W2E priorities at this stage;
- W2E can play a role in achieving the targets set out in the *South Australia's Strategic Plan*, through contributing to greenhouse gas emissions reductions, renewable energy production, and achieving waste diversion targets;
- The *SA Environmental Protection (Waste to Resources) Policy 2010 (W2R EPP)* also includes policies which may impact on future W2E development. The EPA standard for RDF should provide clarity to investors that RDF is an acceptable and beneficial fossil fuel substitute, and may help generate markets for RDF usage;
- The phased landfill bans in the W2R EPP may not greatly impact on W2E, but are more likely to increase recycling and waste recovery due to many materials being banned from landfill not being suitable for energy recovery;
- International experience has demonstrated that landfill bans can incentivise landfill diversion, but usually for biodegradable and combustible materials in particular;
- Landfill diversion in Europe has been achieved primarily as the result of one overriding policy instrument – the EU Landfill Directive and the perception of associated financial fines for non-compliance;
- Many EU countries are using landfill bans, coupled with landfill tax / levies, to further divert waste from landfill, with energy recovery playing a significant role as an alternative; and
- US policy has focussed on incentivising a wider suite of renewable technologies as opposed to W2E specifically. W2E does receive some support in the form of new technology funding programmes and grants but this is not a significant programme.

12.1 National Policy on W2E Projects

12.1.1 National Waste Policy: Less Waste More Resources (2009)

The National Waste Policy sets a clear direction for Australia for the next 10 years and will update and integrate Australia's policy and regulatory framework. It will build on existing settings by providing a nationally agreed direction and focus that will be implemented by individual jurisdictions within their borders and collective action by the Commonwealth and state and territory governments. The policy encompasses wastes, including hazardous wastes and substances, in the municipal, commercial and industrial, construction and demolition waste streams and covers liquid, gaseous and solid wastes.

The document outlines sixteen National Waste Policy Strategies. Of these strategies, there are two specifically relating to W2E:

Strategy 7: To enhance biodegradable (organic) resource recovery and reduce GHG emissions from landfill. A desired result is to divert biodegradable wastes from landfill….and increase AWTs, WtE plants and bio-digesters.

Strategy 9: States and Territories have initiatives for diverting organic wastes from landfill and energy production.

12.1.2 Other State policies and strategies for W2E

Few, if any, States in Australia have a specific W2E strategy. The extent to which W2E is addresses in state waste strategies varies, although it is almost always recognised as a waste recovery option in accordance with the waste hierarchy.

ACT's waste strategy perhaps most clearly defines the role of W2E in achieving its goals. The strategy recognises that new technologies for creating energy from waste can provide a safe renewable energy source, and could meet approximately 6% of base-load power. One of the objectives of the strategy is to achieve 'a carbon neutral waste sector'. To meet this objective, the government have pledged to:

+ Continue methane capture from landfill;
+ Minimise organic waste going to landfill
+ Investigate options to adopt Energy-from-Waste technologies;
+ Increase recycling to avoid greenhouse gas emissions; and
+ Promote energy efficient waste collection and transport systems.

The strategy states that some waste streams may have little value in recycling markets, but may have significant energy value that can be used to generate electricity.

In April 2012, Western Australia's Environment Minister announced an international review of W2E facilities around the globe, in order to provide the state government with the most up-to-date information on W2E technologies. This is in light of a number of proposed W2E facilities currently being assessed by the WA EPA.

Recent consultation on waste policy in Victoria identified that more could be done to encourage investment in advanced technology, and that a lack of policy has limited the uptake of major recovery facilities and new technology in the state. The proposed new policy will encourage and support industry investment in advanced technology that can convert waste into energy or fuel products. In order to do this, Victoria has pledged to prepare and publish reports on national and international trends on recovery technologies and the potential for uptake in Victoria. Victoria will also provide clear assessment requirements for waste to energy proposals, and will update the State Planning Policy Framework to ensure the Government's policy on W2E is embedded in the planning scheme.

Table 12—1: Summary of Other State policies and strategies for W2E

State	Key programs and strategies impacting on W2E
New South Wales	Energy from Waste Draft Policy Statement for Public Consultation, 2013 + Document has been prepared as a basis for consultation with industry, local councils and wider community + Recognises that energy recovery from waste by thermal processing can be a valid pathway for residuals + Outlines how facilities proposing to recover energy from waste will need to meet current international best practices techniques Waste Avoidance and Resource Recovery Strategy 2007. Waste Avoidance and Resource Recovery Strategy – Strategic Directions and Implementation Plan 2011-2015 + Includes a focus on facilitating investment in new waste infrastructure; + Strategy to actively promote and assist waste and resource recovery infrastructure operators; + A review of existing waste funding priorities to stimulate investment in waste and resource recovery systems and infrastructure; and
Victoria	Getting Full Value: The Victorian Waste and Resource Recovery Policy Aims to help the state get the best value it can from waste resources + Foster investment in a diversified portfolio of infrastructure that can manage the projected mix and volumes of waste materials. + The policy recognises that a clear lack of policy direction in the past has been a barrier to investment in advanced resource recovery facilities, in particular for technologies that can produce energy and fuels from waste. Clear policy direction from the Victorian Government is aimed at promoting investor confidence + The policy welcomes investments in waste to energy and other alternative reuse technology that can convert waste into useful products. + Government will expect project proponents to demonstrate that investment will deliver strong environmental, public health and economic outcomes
Queensland	Waste Reduction and Recycling Strategy 2010-2020 + Targets include reducing landfill gas emissions, increasing recovery and recycling of resources across all waste streams.
Western Australia	Waste Avoidance and Resource Recovery Act 2007 Waste Strategy for Western Australia 2010 + Strategy includes W2E as a resource recovery option. Strategic Waste Infrastructure Planning Programme – to initiate and maintain long-term planning for waste and recycling processing In 2012, announced a comprehensive review of international W2E facilities to provide the state government with the most up to date information.

State	Key programs and strategies impacting on W2E
Tasmania	Tasmania Waste and Resource Management Strategy 2009 + Includes strategic actions to develop policies, services and programs to promote resource recovery; + Includes strategic action to develop infrastructure.
Australian Capital Territory	Waste Management Strategy 2011-2025 + Includes strategies to continue methane capture from landfill, minimise organic waste to landfill, and investigate W2E options.
Northern Territory	Territory 2030 is a long-term plan with clear targets that provide a framework for the government's strategic plans and policy initiatives. Waste management is addressed in some key areas of the plan, but there is no specific waste strategy. The plan is due to be reviewed in 2015.

12.2 SA Government Policy and Strategies

The South Australia's Strategic Plan (SASP) was first developed in 2004, and has an overarching aim to grow prosperity, improve well-being and attain sustainability in the state. The 2011 update of the plan sets out 100 targets across areas such as economic development, community, health, education and environment.

12.2.1 South Australian Government Targets Relating to W2E

Under the banner of environment, there are three specific targets to which W2E is relevant, and which the implementation of W2E could contribute to the achievement of these targets:

+ **SASP Target 59: Greenhouse gas emission reductions**
    - Achieve the Kyoto target by limiting the state's greenhouse gas emissions to 108% of 1990 levels during 2008-2012, as a first step towards reducing emissions by 60% (to 40% of 1990 levels) by 2050.
+ **SASP Target 64: Renewable Energy**
    - Support the development of renewable energy so that it comprises 33% of the state's electricity production by 2020, with a milestone target of 20% by 2014.
+ **SASP Target 67: Zero Waste**
    - Reduce waste to landfill by 35% by 2020, with a milestone target of 25% by 2014.

SASP Target 59: Greenhouse Gas Emissions

The waste industry can deliver a range of different solutions and technologies that can contribute to reductions in GHG emissions. In Europe, GHG emissions have been reduced as a result of policies and regulations founded on the principles of the waste hierarchy. Specific targets such as the diversion of biodegradable municipal waste from landfill have led to the development of anaerobic digestion facilities, therefore reducing landfill emissions. In the US, emissions of methane from landfill have reduced as a result of a range of economic incentives, regulations and policies. Both thermal waste technologies such as incineration and the use of biogas from anaerobic digestion facilities can contribute to the reduction in fossil fuel use and GHG emissions.

Table 12—2 summarises the opportunities to reduced GHG emissions by different W2E technologies.

Table 12—2: Contribution to GHG emissions reduction by W2E technologies[37]

Technology	Sources of GHG emissions	GHG emissions reduction
Anaerobic Digestion	CO_2 from electricity consumption during plant operation	Capture and conversion of methane (CH_4) into energy by production of biogas Substitution of energy produced by fossil fuels Substitution of chemical fertilisers through applying the digestate to productive land Enhance soil carbon by applying digest to land
Thermal technologies	CO_2 from electricity consumption during plant operation CO_2 from combustion of inorganic waste	Substitution of energy produced by fossil fuels Substitution of virgin raw materials by recovery of metals from bottom ash
MBT	CO_2 from electricity consumption during plant operation CO_2 from combustion of waste (RDF) CH_4 and N_2O emissions from biological treatment of organic waste, if composting or biodrying as part of the MBT process	Increased diversion of biodegradable waste from landfill Substitution of fossil fuels by utilisation of RDF

SASP Target 64: Renewable Energy targets
The Renewable Energy Plan for SA was released in October 2011 and sets the agenda for the future growth of the renewable energy sector across the state. The plan outlines the key strategies to achieve the Strategic Plan target of 33% of the state's electricity production by 2020 to be from renewable sources. It was announced in a Ministerial Statement in June 2011 that the 2014 milestone target of 20% has already been met, three years ahead of schedule.

W2E can clearly contribute towards the achievement of future renewable energy targets, as many of the sources of waste derived fuels that can be used for energy recovery are considered renewable. Anaerobic digestion of biodegradable wastes such as household food waste, food processing waste, agricultural residues and slurries can produce biogas, which can be used to power gas engines or steam turbines to generate renewable electricity.

Conversion of waste into energy in thermal processes can also contribute to renewable energy targets, although only the non-fossil-derived fraction of the waste stream will be classified as renewable. Table 12—3 includes the fraction of different waste feedstocks considered to be renewable.

[37] Adapted from Waste and Climate Change ISWA White Paper, 2009

Table 12—3: Renewable energy content of W2E feedstocks and technologies[38]

Technology	Source of Waste	Form of energy	% of energy considered renewable
Incineration with energy recovery	Mixed residual waste	Steam – electricity and heat	47-80
Landfill gas	MSW or mixed residual waste	Biogas – electricity and heat	100
Solid Recovered Fuel	Sorted fraction of MSW or C&I waste	Solid fossil fuel substitute or used in combustion/ATT	30-55
Anaerobic Digestion	Source separated biomass fraction or sorted bio-fraction of MSW	Biogas – electricity and heat	100
Biomass Energy Plants	Waste wood, other agricultural wastes	Steam – electricity and heat	95-100

SASP Target 67: Zero Waste

The first state's waste strategy was published in 2005, and the delivery of the strategy between 2005 and 2010 was successful in reducing the amount of waste disposed of in landfill in the state.

The SA Waste Strategy 2011-2015 relates directly to Target 67: Zero Waste in the SASP, and will also contribute to other targets in the areas of prosperity, environment and ideas. The strategy has two main objectives in to which W2E can fit:

+ To maximise the useful life of materials through reuse and recycling; and
+ To avoid and reduce waste.

Technologies such as MBT and AD can contribute to the first objective by facilitating the recovery of recyclable materials, and by extending the useful life of organic wastes by conversion to energy. Whilst not contributing to waste avoidance, both thermal and biological W2E solutions can play a significant role to help meet the waste diversion targets set out in the waste strategy.

Fundamentally, W2E can contribute towards driving waste further up the waste management hierarchy, in which energy recovery is a more preferable option than disposal.

12.2.2 South Australia's Waste Strategy 2011-15

The South Australia's Zero *Waste SA Act 2004* establishes a statutory authority, Zero Waste SA to reform waste management in the State. The Act requires Zero Waste SA to develop a State-wide waste strategy and three-year business plans. The Business Plan supports the strategy by setting out Zero Waste SA's major projects, goals, priorities and budget.

The current South Australia's Waste Strategy 2011-15 aims to build upon the success of the State's first Waste Strategy and sets further targets for waste diversion from landfill. The Strategy's long term objectives are to avoid and reduce waste, and to maximise the useful life of materials through re-use and recycling.

[38] The renewable energy contribution from waste across Europe, CEWEP 2009

The development of the Strategy is underpinned by the waste management hierarchy framework (see Figure 12-1), which stresses the need to operate at the highest possible level of the hierarchy, considering social, environmental and economic practicalities.

Figure 12-1: Waste Management Hierarchy

South Australia's Waste Strategy 2011-15 recognises a role for energy recovery enterprises where these are consistent with the waste management hierarchy. The intention to develop a W2E policy foreshadowed in ZWSA's Business Plan is well aligned with the National Waste policy stance on W2E, which outlines high level strategies to enhance biodegradable resource recovery and diversion from landfill and reduce GHG emissions. Increasing AWTs, W2E plants and bio-digesters are highlighted as potential means of doing so.

12.2.3 South Australian Environment Protection Act 1993

Energy from waste (using incineration) is currently licensed under Schedule 1, Part A '3 – Waste Treatment and Disposal' of the *Environmental Protection Act 1993 (SA).*

It is noted that the 'primary purpose' of this section is waste destruction; any energy recovery is a secondary purpose. The same applies for biogas from anaerobic digestion or from a wastewater treatment facility.

A facility undertaking the prescribed activity of environmental significance (3(3) Waste or Recycling Depot) may be subject to the payment of the waste levy. For a facility not to be classed as a waste depot, noting the exceptions in the Schedule, it must be receiving a product.

There is also a 'Fuel Burning' category (Schedule 1, Part A, '8 – Other (2) Fuel Burning –, and includes facilities involving the use of fuel burning equipment alone or in aggregate is capable of burning combustible matter at a rate of heat release exceeding 5MW.

The term of resource recovery as defined in the *Environmental Protection Regulation 2009 (SA)* includes the recovery of energy.

The Legislation and Policy Unit of the SA Environment Protection Authority are currently reviewing the legislation, in particular Schedule 1 of the *Environment Protection Act 1993 (SA)* to look at the addition of new waste technologies.

12.2.4 South Australian Environment Protection (Waste to Resources) Policy 2010 (the W2R EPP)

The SA W2R EPP supports the SA Strategic Plan, and provides the regulatory underpinning for SA's Waste Strategy. Key elements of the W2R EPP impacting on W2E development include:

- the phased introduction of landfill bans for certain types of waste; and
- the treatment of waste prior to landfill – since September 2012, waste from metropolitan Adelaide must now undergo a resource recovery process before being disposed of in landfill; and
- when waste constitutes a product

Impact on W2E:

Landfill bans

Landfill bans were introduced in SA in September 2010. Many materials to be banned from landfill under SA W2R EPP do not lend themselves to energy recovery, for example hazardous waste, batteries, vehicles and computer monitors and television. The banning from landfill of these materials is more likely to act as a driver for increased recycling and recovery technologies. Similarly, the banning of landfill of aggregated recyclable materials such as cardboard and paper, metals and glass packaging will also drive recycling infrastructure development.

Of most significance to W2E are the banning of whole tyres (from September 2010), as W2E can provide an alternative to landfill for tyres, as discussed in 3.1.5. The banning of liquid wastes from landfill could also create a potential feedstock for anaerobic digestion plants, depending on the type of waste. However it is more likely that most liquid wastes are already destined for effluent treatment or other means of disposal, as opposed to habitually being landfilled.

Landfill bans – do they work?

The forthcoming banning of biodegradable municipal waste from landfill in Scotland (by January 2021) has been responsible for an upsurge in the construction of Anaerobic Digestion facilities. The ban has been supported by making the provision of food waste collections to households a mandatory requirement for local authorities, plus legislation requiring medium to large food businesses (those producing over 50kg of food waste per week) to segregate food waste is being introduced.

From 1 January 2014, businesses in Scotland will also have to present metal, plastic, glass, paper and cardboard for separate collection, and these separately collected recyclable materials will also be prohibited from landfill. This increased supply of segregated recyclables will no doubt act as a driver for the development of increased recycling infrastructure, but not necessarily as a driver for W2E.

Therefore landfill bans can act as a driver for both W2E and recycling, depending on the target waste material.

The over-riding driver behind the Scottish landfill bans is to reduce the amount of biodegradable waste disposed of in landfill, hence reducing greenhouse gas emissions. The Waste (Scotland) Regulations 2011 under which the landfill bans are being introduced, does not go as far as specifying the end treatment of these materials, leaving it up to the market to respond.

The EU Landfill Directive requires all Member States to implement some form of ban or restriction on landfill of certain wastes, for example tyres, liquid wastes and wastes which have not been pre-treated. Some countries such as Austria, Denmark, Finland and Sweden have introduced further landfill bans for biodegradable and combustible waste streams.

Landfill bans can be introduced for different reasons. In some cases, the ban is intended to drive waste up the hierarchy and to increase recycling. In many cases in Europe, the intent is to divert biodegradable waste from landfill in accordance with the EU Landfill Directive targets, as is the case in Austria, Finland, Germany, Italy and Norway. In the case of Denmark and Sweden, the aim was to divert waste from landfill to W2E, as both countries have introduced bans for combustible waste to landfill. Additionally, the Flanders region of Belgium has banned the landfill of the combustible residual fraction from the sorting of waste, and other wastes suitable for incineration. European countries who have implemented such landfill bans, also tend to have the lowest percentage of MSW sent to landfill.

Defra began a consultation exercise on wood waste landfill restrictions in England in July 2012.[39] The aim of such a ban would be to reduce greenhouse gas emissions produced by waste wood in landfill. It is understood that the majority of wood disposed of in landfill is in mixed waste streams, and therefore currently difficult to recycle. Restricting the landfilling of waste wood would increase the quantity recovered for re-use and recycling, and help meet the increasing demand of wood as a source of biomass energy generation in the UK.

When waste constitutes a product

The SA *Environment Protection Act 1993* and the *Environment Protection Regulations 2009* require all SA EPA licensed waste depots to pay the waste levy per tonne of waste received for disposal. The levy may act as a disincentive to W2E development, as they would have to set a gate-fee that incorporates the obligation to pay the waste levy. The waste levy is not applicable when the SA EPA deems that a waste stream is a product and no longer a waste.

[39] http://www.defra.gov.uk/consult/files/consult-wood-waste-document-20120808.pdf

There are currently only three standards developed by the SA EPA which provide the information and processes required to support the beneficial use of a waste stream as a product. These standards include:

+ Waste derived fill (i.e. clay, concrete, rock, soils and other inert materials);
+ Waste derived soil enhancers (i.e. an organic waste such as manure); and
+ Refuse derived fuel.

Waste derived fill and waste derived soil enhancers are unlikely to become feedstocks for W2E. However, the classification of Refuse Derived Fuel (RDF) as a non-waste could act as an incentive both for a W2E developer and also for a manufacturer of RDF. The EPA Standard defines RDF as:

+ being produced from specific wastes otherwise destined for landfill;
+ having sufficient net calorific value to supplement of replace a standard fuel in an industrial process; and
+ meeting an approved, consistent and fit for purpose specification.

The standard for RDF also requires that there is an immediate market available, that the RDF meets the requirements of the standard, and that the use of the RDF does not reduce the efficiency or overall performance at the industrial facility at which it is used.

Avoiding having to pay the waste levy also provides an incentive to industrial facilities to consider using RDF as a fossil fuel substitute. In addition to its use in cement kilns (see Section 3.1.2), RDF can be used as a solid fossil fuel replacement in applications such as power stations, steel works and paper and pulp processing facilities. This may be particularly attractive to industrial facilities that do not receive or treat waste as part of their core activities.

There is still an element of risk to a W2E developer, as each new use of RDF must gain EPA approval. This process involves first designing the RDF and demonstrating its potential benefits, before undertaking sampling and assessment. A full Recovered Product Plan (RPP) must be prepared before the EPA can give approval for a trial. Subject to trial results, planning approval and a licence may then be awarded.

Potential manufactures and users would therefore need some degree of confidence that they would be able to meet the standard prior to committing the required investment.

12.3 International W2E Strategies and Policy Developments

In considering what policies might help SA promote appropriate and effective W2E technologies and their uptake, it is important to gain a better understanding of the international policy developments. This section provides a brief review of policies in Europe, including Scotland in particular, and North America.

12.3.1 EU Policy Frameworks

12.3.1.1 Waste Framework Directive

The revised EU Waste Framework Directive 2008/98/EC is the overarching legislative framework that dictates how waste is managed in Europe. The directive was brought into law in the UK in December 2010. The revised Waste Framework Directive sets out a revised waste hierarchy, which prioritises energy recovery from waste above disposal or incineration without energy recovery.

12.3.1.2 Renewable Energy Directive

The EU has committed itself to sourcing 20% of its energy needs from renewable sources by 2020, and this has been set in law in the Renewable Energy Directive 2009/28/EC. Each EU Member State has an individual target. The UK renewable energy target is 15% by 2020. Member States have flexibility to decide on how this target should be achieved across electricity, heating fuel and transport fuels. The UK has opted to put incentives in place that will deliver in each sector but not to set specific targets. It did, however, set out a “lead scenario” in the 2009 UK Renewable Energy Strategy, which showed 12% of heating coming from renewable sources by 2020.

12.3.1.3 Waste Incineration Directive (WID)

In the UK, combustion of waste materials is subject to the Environmental Permitting (England and Wales) Regulations, 2012 (EPR). The EPR implements European Directives 2008/1/EC on Integrated Pollution Prevention Control (IPPC) and 2000/76/EC Incineration of Waste, which currently regulate waste combustion installations.

WID sets minimum criteria for waste incineration and co-incineration activities and has no lower threshold for plant/installation size. IPPC covers incineration and co-incineration for plant capacities exceeding 3 tonnes per hour. In addition, EPR sets criteria for installations with a capacity smaller than IPPC and the treatment of wastes that are excluded from the provisions of the WID.

The 'thermal treatment' (which includes combustion, gasification and pyrolysis) of solids or liquids that can be defined as waste ('which the holder discards or intends or is required to discard') is governed by the WID.

12.3.1.4 EU Landfill Directive

The European Landfill Directive (99/31/EC) aims to prevent or reduce adverse effects in the environment which may be caused by the landfill of waste.

In the UK, in order to meet greenhouse gas reduction targets, the Landfill Directive sets challenging targets for the reduction of biodegradable municipal waste (BMW) sent to landfill. The Waste and Emissions Trading Act provides the framework for landfill allowance trading schemes, designed to implement Article 5(2) of the landfill directive.

The EU Landfill Directive of 1999 also ‘sets challenging targets for the reduction of biodegradable municipal waste (BMW) sent to landfill’. The targets for the UK are (1995 baseline):

+ By 2010, to reduce the amount of BMW going to landfill by 25%;
+ By 2013 to reduce the amount of BMW going to landfill by 50%; and
+ By 2020 to reduce the amount of BMW going to landfill by 65%.

In response to these targets, the UK introduced the Landfill Allowance Trading Scheme (LATS) in 2005, in order to give local authorities more flexibility in meeting these targets. Each UK waste disposal authority (WDA) was allocated a landfill allowance, i.e. a cap on the amount of biodegradable municipal waste (BMW) they were permitted to landfill each year. The allowances were allocated in order to meet the targets for the total amount of BMW landfilled in the Landfill Directive target years of 2010, 2013 and 2020. Local authorities were able to trade allowances with each other, so they could sell allowances if they have diverted more waste from landfill (e.g. by increasing recycling or energy recovery) or buy more if they were likely to exceed their own allocation.

For every tonne that is landfilled over the allowance, a fine of £150 is incurred. The scheme was successful in ensuring that the UK met its first Landfill Directive targets in 2010 and avoided non-compliance fines estimated at up to £0.5 million per day. However, following the Government Review of Waste Policy in England in 2011, the decision was made to end the LATS as analysis showed that it was no longer the main driver in diverting waste from landfill. Due to the landfill tax escalator (which adds £8/tonne per year to landfill tax, currently at £64/tonne), landfill tax is now considered to be the main incentive for local authorities to reduce waste to landfill.

Waste Management Policy in Germany

The principal act for managing waste treatment and disposal in Germany is the 'Closed Substance Cycle and Waste Management Act' which regulates all aspects of waste management, including provisions concerning the end of waste status of a material. This act was initially released in 1994 and was updated in February 2012 to take into account a revised waste hierarchy. It defines a new five-step hierarchy for waste management:

- avoidance,
- pre-treatment for recycling,
- recycling,
- other – in particular energy recovery;
- disposal.

Germany is one of the few exceptions in Europe as it does not use landfill tax as an instrument. In 1993, waste policy in Germany dictated that the disposal of untreated organic waste would be banned within 12 years. This policy eventually led the way for the development of the EU Landfill Directive. Initially, this policy had no legal power, and therefore progress on meeting the ban was slow. The landfill ban was eventually introduced in 2005, which now restricts material to landfill based on biodegradability and other criteria.

The low landfill rates, and lack of landfill tax, suggests that the landfill ban itself has resulted in diverting waste from landfill. Since the ban was introduced in 2005, landfilled municipal waste has decreased significantly. Landfill has been replaced by increases in recycling, MBT and W2E.

Germany also banned the landfilling of untreated waste, i.e. waste which has not undergone any form of processing or treatment, which became a strong driver for the development of W2E. Energy demand is also a very strong driver for W2E in Germany, as energy security is a priority issue for an industrial country such as Germany which still has to import a significant share of its energy demand.

This energy demand has increased the capacity of W2E facilities, and in particular increased the use of Solid Recovered Fuels (SRF) which complies with the European CEN standards. The use of SRF in Germany began in the 1980's and 1990's, driven by industry demand for a cheaper fuel in times of increasing energy costs. SRF in Germany is mainly produced at MBT facilities, and predominantly from commercial and light industrial waste streams. SRF is still classed as a waste in Germany, and falls under the waste management regime.

Germany has continued to increase its W2E capacity, rising from 56 conventional combustion facilities in 2000, to 60 operational facilities in 2010. W2E continues to be driven by industry demand for cheaper energy, and the biogenic content of waste being able to contribute to greenhouse gas emissions targets.

12.3.2 Scotland

Scotland published their Zero Waste Plan in 2010, which sets out high level targets and messages aimed at achieving their zero waste goals. In order to help achieve this, Scotland has also published a new set of regulatory policies, which are known collectively as the Waste (Scotland) Regulations 2011. Some of the mandatory requirements of this regulation include:

+ Application of the waste hierarchy;
    - The European revised Waste Framework Directive has embedded the waste hierarchy as a statutory consideration when determining appropriate waste management treatments & is now transposed into Scottish law.
+ A requirement to sort and collect;
    - A requirement on waste producer to sort key materials.
    - Waste management companies to ensure that waste producers comply with their duty to segregate.
    - Minimum recycling & food waste collection services to householders.
+ Food waste segregation;
    - Separate collection of food waste for medium to large food businesses (i.e. produce over 50kg of food waste / week) ~120litre bin to present food waste for separate collection from 1st January 2014.
    - Small food businesses which produce over 5kg of food waste / week from 1st January 2016
    - Rural areas are exempt (& businesses that produce less than 5kg / week – de minimis threshold)
+ Mixing, landfill and incineration bans.
    - A ban on subsequently mixing any of the key materials with other wastes.
    - A ban on any of the key materials collected separately for recycling from going to incineration or landfill from 2014.
    - All new incinerators must ensure that metals and dense plastics have been removed from residual municipal waste prior to incineration.
    - A ban on biodegradable municipal waste going to landfill by the end of 2020.

In anticipation of increasing quantities of food waste being available for treatment, the Scottish waste and utilities industry has responded to this, with significant investment being made available to develop new facilities.

It is also anticipated that the future ban on biodegradable waste to landfill will be successful in driving residual waste management up the hierarchy, and that there will be further development of residual waste treatment technologies such as MBT and advanced thermal treatment.

12.3.3 United States Policy Experience

Relative to the EU, a limited number of incentives or programs have been created and/or used to support the development of W2E projects in the US, with most federal and state funding being focused on more traditional renewable energy technologies such as wind and solar. In addition, there is no feed-in-tariff and few tax incentives for the promotion of W2E. The primary exception is the inclusion of landfill gas and W2E from MSW as covered in Table 12—4.

12.3.3.1 States with Renewable Standards

There are currently 33 states in the US that have renewable portfolio standards (RPS), of which 5 have voluntary standards instead of binding targets. There are also currently 25 states that legally define W2E as a renewable resource, of which, 21 have RPS standards. These 21 states offer potential for increased W2E project expansion, though few specifically include W2E technologies.

12.3.3.2 Carbon Trading

In December 2010, California passed an extensive carbon-trading plan aimed at cutting greenhouse emissions. If the plan is implemented, California will have the second largest carbon trading market behind Europe and may thus be attractive for W2E developers. On 20 September 2012, the California Air Resources Board temporarily exempted W2E facilities in the state from the obligation to purchase CO2 emission allowances through Resolution 12-33[40].

12.3.3.3 Carbon taxes

Other locations in the US have introduced carbon taxes on emissions from electricity, such as Boulder, Colorado; San Francisco, California; and Montgomery County, Maryland. This may also present more opportunities for limited W2E development but broader adoption will be limited.

12.3.3.4 Federal and State Drivers

While few direct federal incentives or policies currently exist for W2E, there are some limited federal opportunities that benefit businesses and local governments. The following provides a snapshot of the available W2E incentives on an on-going basis (but does not include federal funding opportunities for research & development, demonstration projects, outreach or inter-governmental programs).

The Renewable Electricity Production Tax Credit (PTC), is a tax incentive program offered periodically for the production of electricity from renewable sources, and includes landfill gas and waste incineration, which qualify for a tax credit of $0.9 cents per kilowatt hour.

The Renewable Energy Production Incentive (REPI) was created by the Energy Policy Act of 1992. It provides incentive payments for electricity generated and sold by new qualifying renewable energy facilities including landfill gas, livestock methane and biomass but MSW is specifically excluded. Qualifying facilities are eligible for annual incentive payments of 1.5 cents/kWh, for the first ten years of operation.

The US Department of Energy's *Energy Policy Act of 2005* requires the federal government to purchase 7.5% of its electricity from renewable sources by 2013, which includes W2E generation.

Clean Renewable Energy Bonds (CREB) may be used by certain entities, primarily in the public sector, to finance renewable energy projects. The list of qualifying technologies is generally the same as that used for the federal renewable energy production tax credit (PTC). CREBs may be issued by electric cooperatives, government entities (states, cities, counties, territories, Indian tribal governments or any political subdivision thereof), and by certain lenders.

In 2009, the United States Department of Energy (USDOE) selected 19 integrated biorefinery projects to receive grants up to US$564 million from the American Recovery and Reinvestment Act to accelerate the construction and operation of pilot, demonstration, and commercial scale facilities. Of this amount, US$231.5 million is being used to support the development of four waste conversion technology demonstration projects. These projects are:

- Production of succunic acid from sorghum to produce a biofuel (BioEnergy International);
- Gasification of woody biomass and biomass fraction of MSW to produce ethanol (Enerkem Corporation);
- Production of ethanol and electricity via the gasification and fermentation of wood and C&D wastes (INEOS New Planet BioEnergy); and
- Cultivation of algae into green fuels (Sapphire Energy Inc.).

[40] http://swana.org/Portals/Advocacy/CARB-Resolution-12-33.pdf

As part of the US EPA's effort to promote flexible and innovative ways to convert W2E, EPA finalised an exclusion to the Resource Conservation and Recovery Act (RCRA) regulation for oil-bearing hazardous waste generated at a petroleum refinery in January 2008. This exclusion ensures that the gasification of these materials will have the same regulatory status (i.e., excluded) as other oil-bearing hazardous waste reinserted into the petroleum refining process.

12.3.3.5 State Incentives

Table 12—4 presents a summary of the various incentives and funding programs available for the waste sector, primarily focused on Landfill Gas, W2E or MSW. Most state incentives are principally geared toward other waste or organic streams (e.g. biomass or farm-level manure anaerobic digestion).

Table 12—4: Examples of relevant US state incentives and funding programmes for Municipal Solid Waste[41]

State	Type of Incentive
Alabama	The **Biomass Energy Program** assists businesses in installing biomass energy systems. Program participants receive up to $75,000 in interest subsidy payments. With an initial emphasis on biomass in the form of wood waste, the program now also focuses on MSW. Industrial, commercial and institutional facilities, agricultural property owners, and city, county, and state government entities are eligible.
California	**Supplemental Energy Payments** are awarded to eligible renewable energy facilities to cover the above market costs of renewable resources selected by retail sellers to fulfill their obligations (i.e., California's three largest investor-owned utilities). These payments are required by law, with funding of approximately $69.5 million. Eligible technologies include LFG, MSW and anaerobic digestion.
Connecticut	**New Energy Technology (NET) Program** offers up to $10,000 to Connecticut residents or businesses with more than 30 employees who develop innovative energy efficiency and renewable energy technologies to save energy, improve air quality, and help invigorate Connecticut's economy by creating employment opportunities. Applicable technologies include MSW and anaerobic digestion.
Hawaii	Offers a five year, 100 percent tax credit of up to $2 million dollars on an equity investment in a qualified high tech business (QHTB). A QHTB is defined as "a business that conducts more than fifty percent of its activities in qualified research which includes non-fossil fuel energy-related technology," which includes energy produced by and including LFG, W2E, MSW, and biofuels.
Illinois	The **Renewable Energy Resources Program** (RERP) is a state grant program offering rebates for small systems and grants for large systems, including MSW. Funding varies by technology but averages around $300,000.
Indiana	Businesses, non-profit institutions and units of local government are eligible to apply for grants of $30,000 or 30 percent of projected costs. Eligible projects include W2E technologies.
Massachusetts	Offers a 100 percent tax deduction for any corporate and personal income received from the sale of or royalty income from a patent that is deemed beneficial for energy conservation or alternative energy development. This deduction is unique among incentives in that it targets patents and not simply real property.

[41] http://www.epa.gov/osw/hazard/wastemin/minimize/energyrec/rpsinc.htm

13 Drivers and barriers for W2E projects

This section seeks to identify typical drivers and barriers impacting on W2E, whilst highlighting specific and local factors to the development of W2E in SA. This section also contains the key issues raised by stakeholders whilst developing this report.

Implications for W2E in South Australia

- There are some well-known drivers and barriers impacting the development of W2E projects worldwide;
- Drivers and barriers will be specific to each situation, but some common factors that always need careful consideration are finance, proven nature of the technology and feedstock security and supply;
- The economies of local landfill will always dictate the financial viability of W2E projects. When landfill remains at a low cost, it will always be difficult for W2E projects to compete;
- Landfill bans have been a key driver in Europe for diverting waste from landfill into W2E projects;
- Climate Change and greenhouse gas emissions targets can be an additional driver, but only if backed up by mandatory regulation or financial incentives;
- Energy security is becoming an increasingly important driver, but W2E has to compete with other renewable energy technologies for support and funding; and
- Uncertainty in carbon pricing and current political priorities is seen as a barrier to investment by stakeholders.

13.1 Overview of drivers and barriers

Table 13—1 provides an overview of the issues that may drive or act as a barrier in the adoption and expansion of W2E technologies based on global experiences.

Table 13—1: Example Drivers and Barriers for W2E Projects

Factor		Impact
Drivers	+ Increasing landfill prices	Landfills compete with W2E technologies for waste. It follows that, as landfill becomes more expensive, W2E projects become more viable. Landfills are also becoming more expensive to operate, due to tighter environmental controls being required by permitting agencies. In South Australia, the cost of landfill has also increased through the introduction of the waste levy which has resulted in more waste being diverted from landfill. However, this has been more apparent in the Construction and Demolition sector where the price signal has had greater influence.
Drivers	+ Decreasing or unavailability of landfill capacity	In some European countries, landfill capacity is estimated to be less than 4-5 years, and so this acts as a strong driver to the development of alternative technologies and infrastructure. Gaining planning permission for new landfill sites is also being made more difficult by policy and regulations. Japan has historically been land-scarce, and therefore has relied predominantly on the thermal treatment of waste. Japan has developed a high number of gasification plants for a wide range of waste streams.
Drivers	+ Increasing energy demand	Residual waste to landfill represents a wasted resource, and countries for which energy security is an issue are increasingly looking to waste and biomass as part of the solution to meeting energy demand.
Drivers	+ Increasing electricity/fuel prices	Another means to make W2E more attractive is to increase the value of its outputs. Of these, electricity is the most obvious, noting that increasing fossil fuel and transport fuel prices can make W2E more attractive to investors.
Drivers	+ Increasing value of recyclable materials	Similarly, increasing the value of any material outputs from W2E operation – such as IBAA, digestate or metals – will also promote W2E technologies.
Drivers	+ Greenhouse gas reductions	Usually linked to policy and regulatory drivers, greenhouse gas reductions can help drive W2E, particularly for organic waste streams.
Drivers	+ Policies, strategies and regulatory drivers	By judicious use of policy and regulations, governments have ample opportunity to influence technology decision. This is discussed further in Section 12.
Barriers	+ Ample Landfill Space	The availability of landfill space also can act as a barrier to the development of alternative technologies. For example, in Japan, where land is limited, there have been historically few landfills, and incineration and advanced thermal treatment of waste is well advanced. In contrast, in most parts of the US, landfills are plentiful and cheap. Only more densely populated states, such as those on the East coast, have seen significant W2E developments. While South Australia has ample space for new landfills, the South Australian Waste Strategy 2011-2015 includes a government commitment not to establish new landfill facilities in metropolitan Adelaide.
Barriers	+ Inexpensive landfill disposal	In many countries, the cost of landfill disposal remains comparatively low, particularly for those without landfill taxes or levies.
Barriers	+ Lack of funding options	Experience from the UK in particular has highlighted that in recent years, with the global economic recession, securing financing for a range of W2E projects can be difficult. This is most notable for ATT and other forms of advanced technologies which have limited reference sites and operational hours to provide as evidence to potential funders. Helping showcase successful technology types to funders can help alleviate this – a Government sponsored demonstrator programme in the UK is attempting to address this issue head on. There remains significant barriers to raising private finance – lenders perceive waste projects as exhibiting significant technology risks and waste

Factor		Impact
		infrastructure is not necessarily viewed as a safe and reliable long term investment by venture capitalists, pension funds, banks or private equity firms. Financiers require long term contracts with guaranteed levels of payment to ensure sufficient income for the life of the project.
	+ **Unable to demonstrate proven technology**	If the UK market is anything to go by, Australian investors will prefer to see operational examples in Australia of the proposed W2E facility in which they are being asked to invest. This creates a tough "chicken and egg" scenario for the first movers. Developers are often unable to secure municipal waste contracts without a facility at least in the planning or construction stage. In this case, sometimes developers need to be prepared to take a risk and develop a merchant facility without any feedstock contracts secured in order to develop their first reference facility
	+ **Management of MSW organics**	Some AD technologies are able to receive mixed residual waste, by adopting more advanced mechanical treatment up front. However, more rely on a feedstock of source separated organic waste. If this is not available, the technology is not viable in that location.
	+ **Technical**	Certain W2E technologies – most obviously ATT – remain subject to technical concerns about their robustness. For example, there are limited commercial examples of the application of gasification or pyrolysis on mixed residual waste streams, Operators are predictably upbeat about their technologies, but, where technical doubt remains, developing a project becomes much harder.
	+ **Feedstock supply and security**	Some sources of waste derived fuels can be seasonal, such as bagasse, normally produced in the sugar cane harvesting period between May and November. Other biomass fuels can be produced as by-products of agricultural or manufacturing processes, and can also depend on economic or seasonal factors. Investors would need to be able to demonstrate availability and consistency of suitable feedstocks when seeking funding.
	+ **Planning and public perception**	Although two separate concerns, obtaining planning permission can be a significant barrier to developing W2E facilities, and public opinion, often fuelled by misconceptions, can (and, arguably, should) play a role in the decision process.

13.2 Drivers and Barriers specific to South Australia

A range of stakeholders were consulted with during the development of this background paper, as to what they considered to be the key drivers and barriers to W2E in South Australia. This exercise established some common themes, in areas such as planning, technology, fuel feedstocks, regulation, policies and financing. Some specific issues in these key areas are discussed below.

13.2.1 Technical

Australia has seen a number of W2E facilities fail in recent times, due to inappropriate application, lack of technical understanding, poor scalability, lack of due diligence and a lack of understanding by the regulators. Australia can benefit from the experience and lessons learned by W2E projects across the globe, but the current lack of penetration of certain W2E technologies within Australia may be perceived as a barrier by some investors. Whilst in Europe both thermal and biological W2E facilities are well established, in Australia there is limited deployment of these technologies to the full remit of MSW and C&I waste streams. AD in Australia is largely confined to the treatment of wastewater, whereas the digestion of source segregated food waste from households and businesses present a different set of challenges. Similarly, W2E facilities in Australia have been focussed on clean biomass from agricultural sources, as opposed to mixed residual wastes.

Much research has been undertaken in Europe and the US to overcome particular barriers, including the development of Advanced Thermal Treatment, see the boxed text below.

There are also barriers in terms of connecting W2E facilities to the electricity grid. This was highlighted by a number of stakeholders. There are interconnection issues, and variations in installation costs, and the interaction between a W2E developer and electricity distributor. One stakeholder identified significant problems with connecting a proposed plant to the electricity grid, with the network provider stipulating that a review be undertaken to determine all of the impacts of the facility on the grid. This represented a significant cost at an early stage of a feasibility study. Additionally, the cost of grid connections must be fully borne by the W2E developer, meaning that some smaller-scale facilities may not be viable for grid connection.

However, there are over 30 grid-connected facilities in Queensland (mainly sugar mills and other agricultural applications, but also landfill gas and wastewater biogas applications), demonstrating that grid connection from W2E plants are viable if they are effectively scaled.

Overcoming barriers to Advanced Thermal Treatment technologies

A landscape review of advanced thermal treatment technologies undertaken by AEA on behalf of the Energy Technologies Institute showed that the successful development of a process that can make use of biomass or waste derived material is relatively rare and difficult to achieve.

Advanced Thermal Treatment projects that have been successful have tended to develop schemes that have focussed on designing processes to be tolerant of variation in feedstock parameters, which has often been the most significant issue facing the processes.

In contrast, many factors have caused the failure of projects, and some are seen to be repeated on a number of occasions.

- Project development costs tend to be far more than expected. This places pressure on technical objectives and drives companies toward premature commercialisation to attract private equity;
- Gas turbines and reciprocating engines are very sensitive to the presence of contaminants in the syngas. The seemingly simple process engineering task of removing these has proved intractable and as a result there are very few examples of successful implementation, and many of failure. Successful projects have sidestepped this issue by using direct combustion in a boiler and steam cycle electricity generation; and
- Understanding gas cleaning and developing commercially successful solutions are by far the most important research challenges in this area.

There are some technical themes that reoccur in successful projects:

- Gasification only succeeds when the feedstock is consistent. This can be achieved in waste installations by:
    - a preliminary pyrolysis step that presents char to a gasification step; or
    - extensive fuel preparation;
- The pyrolysis route has worked at small and large scales; extensive fuel preparation is probably more appropriate to larger installations only; and
- Large fluidised bed gasifiers (several MW) have proved successful and reliable if the feedstock is controlled.

In summary, there are currently limited commercially operational ATT processes, despite a wealth of investment and R&D input. There are far more examples of problems and failures than fully operational facilities. This is a reflection of the problems explained above and concerns about feedstock quality, consistency and the resources required to make these processes success when using waste as a feedstock.

More progress is now being made in the gasification of clean biomass with several installations now operating successfully. Biomass gasifiers have now achieved many tens of thousands of hours of operational experience, most notably in Austria and Denmark.

13.2.2 Feedstocks

The availability, quality and security of supply of waste fuels are always key criteria in the development of a W2E facility. As previously mentioned, some agricultural waste streams are seasonal. This was seen as a barrier by some stakeholders as W2E facilities are continuous operations. The distribution and availability of feedstocks, and future forecasts of feedstocks availability and suitability need to be fully understood prior to any W2E facility development.

Many waste feedstocks are eligible for RETs, however, generators must be able to demonstrate how much of their feedstock is renewable based on published guidelines to determine the renewable components in the waste arriving on site.

As outlined in the review of different technologies, not all W2E technologies are compatible with all waste streams, and this needs to be fully understood by developers from the outset.

The way in which wastes are currently collected can also be a barrier in SA. For example, if household food waste is not currently separated for recycling, there is little incentive for an AD technology developer to build a facility unless they were able to secure sufficient sources of commercial and industrial food waste.

13.2.3 Regulation and Policy

A common concern of stakeholders was the lack of political certainty in the area of W2E. The focus of current strategy and policy in South Australia is on source separation and increasing recycling. Whilst this is important and in line with the waste hierarchy, the role that W2E has to play as part of a sustainable waste management solution is perhaps not yet being fully recognised. Anaerobic Digestion facilities are licenced under wastewater treatment regulations, even those that are exporting energy to the grid, which creates some additional confusion for proposed new facilities that want to deal with waste streams that are not traditionally engaged with wastewater regulators.

There is a general lack of specific W2E regulation, which in itself causes uncertainty and presents a barrier to development. Stakeholders believe that Industry needs a stable and transparent licencing regime in order to invest in W2E, and that without this, the risks for investment are too high. In SA, W2E (using incineration) is currently licenced under Schedule 1, Part A '3 – Waste Treatment and Disposal' [Environmental Protection Act 1993], but the 'primary purpose' of this section relates to waste destruction. Any energy recovery is considered a secondary purpose. The same applies to biogas from anaerobic digestion or from a waste water treatment facility. The SA EPA is currently reviewing this legislation, in particular Schedule 1 to look at the addition of new waste technologies including W2E.

One stakeholder opinion is that there needs to be flexibility in how the waste hierarchy is applied, and that technical, environmental and economic factors also need to be considered.

The position regarding W2E policies by some trade associations was mixed. Some recognised that the waste sector can contribute to greenhouse gas emissions by generating electricity from wastes that have no higher resource value. Others go further in their support for W2E as part of an integrated waste strategy.

Finally, many were concerned about both political and public resistance to thermal W2E technologies in particular.

13.2.4 Carbon Price Mechanism

The Carbon Price Mechanism (CPM) is Australia's emissions trading scheme which commenced on 1 July 2012. The scheme was implemented as part of a package of Clean Energy Acts[42]. The scheme is regulated by the Clean Energy Regulator and overseen by the Climate Change Authority.

Four of the six greenhouse gases under the Kyoto Protocol are included under the scheme: carbon dioxide, methane, nitrous oxide and, for aluminium smelting only, perfluorocarbons (PFCs). Liable organisations are required to purchase one carbon permit for each tonne of CO_2 equivalent emitted by its operations annually. Sites and facilities that emit over 25,000 tCO_2 equivalent/year will be liable under the CPM. Note that emissions attributable to the combustion of biomass, biofuel or biogas are not included under the scheme. The detailed methodologies for determining the level of liability are set out in the National Greenhouse and Energy Reporting (Measurement) Determination 2008[43].

During the first stage of the CPM, the price of carbon permits will be fixed at $23, increasing by 2.5% each year. During this period, liable organisations will be able to purchase permits at the fixed price or purchase credits under the Carbon Farming Initiative[44].

The second stage of the CPM will start in July 2015 and will move from a fixed price system to a 'cap and trade' scheme whereby a fixed number of permits will be issued to each sector by auction and liable organisations will be able to trade permits.

The CPM and the Waste Management Sector

Operators of landfills emitting over 25,000 tCO_2-e/year are liable under the CPM. This equates to landfills accepting about more than 30,000 tonnes of municipal waste per year. The number of landfills impacted by the CPM in South Australia is estimated to be less than 20. Note that there is also a provision in the Clean Energy legislation which allows for landfills that emit more than 10,000 tCO_2-e/year and are located within a certain distance of a liable landfill to be covered by the scheme. This provision has not yet been activated but is intended to ensure that waste destined for liable landfills is not diverted to smaller landfills nearby in order to avoid the liability.

The liability applies to waste landfilled from 1 July 2012 and applies to each year that the waste generates emissions, which in some cases could extend up to 40-50 years. Waste which was landfilled prior to July 2012 (legacy waste) is not covered by the scheme. Emissions from the recovery of landfill gas do not incur a liability under the scheme. There are three methods for determining landfill emissions under the National Greenhouse and Energy Reporting Scheme (NGERS), each resulting in varying calculations of landfill emissions (and hence liability).

Incineration facilities generating over 25,000 tCO_2-e/year are also liable under the scheme. This equates to a W2E facility of the order of 50,000 tonnes capacity per year. Note that the liability only applies to the W2E emissions generated by the fossil derived fraction waste (i.e. biogenic wastes do not incur a liability under CPM). Therefore the composition of waste accepted by W2E facilities will impact on how much of their emissions will be liable.

Emissions from anaerobic digestion of waste are not liable under the scheme.

[42] http://www.climatechange.gov.au/government/clean-energy-future/legislation.aspx
[43] http://www.comlaw.gov.au/Details/F2012C00472
[44] http://www.climatechange.gov.au/cfi

The implications for W2E

The CPM provides an incentive for the up-take of waste to energy schemes. Pricing the carbon emissions associated with both landfill emissions and fossil-fuel based energy generation is expected to provide a clear signal for alternative energy generation technologies, including those based on waste feedstocks. In summary:

1. Landfill operators will need to include the cost of current and future carbon permits in current gate fees. Clearly, due to the market-based nature of the scheme there will be uncertainty around the post-2015 price of these permits so operators will also need to include some form of risk premium in the gate fee. The overall effect is an increase in landfill costs, incentivising waste reduction and the development of alternative forms of waste treatment, including W2E.

2. W2E technologies could have a price advantage over fossil-fuel based energy generation technologies, depending on how the price of permits develops over time. Whist some W2E operators may need to acquire carbon permits for the fossil derived component of their feedstock, the CPM should favour the full range of W2E technologies including conventional incineration, advanced thermal technologies, anaerobic digestion and landfill gas capture. Furthermore, anaerobic digestion and other small scale W2E applications (i.e. those that generate less than 25,000 tCO_2-e/year) will fall outside of the CPM and thus will have a greater price advantage. This is likely to be relevant for advanced thermal technologies which are typically operated at scales below the 25,000 tCO_2-e/year threshold. As discussed above, this threshold corresponds to a facility with a capacity of the order of 50,000 tonnes of waste per year.

3. The CPM provides an incentive to reduce the proportion of biodegradable matter disposed of via landfill so as to reduce the emissions and liability associated with the degradation of organic matter in the landfill. This has the potential to act as stimulus for the separate collection and treatment of organic wastes via anaerobic digestion. In addition, for landfill operators who are close to the 25,000 tCO_2-e/year threshold, there is additional incentive for them to reduce the proportion of biodegradable matter entering landfill in order to reduce their emissions and avoid being captured by the CPM.

4. There may be opportunities for landfill operators to reduce their CPM liability by developing W2E landfill gas recovery schemes under the Carbon Farming Initiative (CFI). Unlike other sectors affected by CPM, landfill operators can use CFI credits to off-set up to 100% of their CPM liability. In addition, for those landfill operators who are close to the 25,000 tCO_2-e/year threshold, there is an incentive to undertake biogas based (and other emission reduction) projects, for the purposes of keeping under the threshold and saving the cost of compliance for the entirety of the facility's emissions.
5. As part of the Clean Energy package, the federal government has made $10 billion of finance available for clean technologies. This could potentially provide support for W2E projects.

Overall, the CPM forms part of a range of Clean Energy measures aimed at supporting and incentivising non-fossil fuel based energy generation and has the potential to provide a significant incentive for incineration, advanced thermal technologies, anaerobic digestion and landfill gas capture.

Despite the incentive that the CPM can provide, as outlined above, it is not currently considered a driver by some stakeholders due to the uncertainty around the carbon price.

13.2.5 Renewable Energy Target Scheme and Renewable Energy Targets

A main driver is the Australian Government Renewable Energy Target Scheme (RET) which governs the payments of Renewable Energy Certificates (RECs). The RET is legislated under the Renewable Energy (Electricity) Act 2000.

There are recognised limitations with this legislative approach, most notably the omission of various waste streams from classification as acceptable renewable energy sources. There are some renewable components that are currently omitted such as leather, cooking oil and other putrescibles which constitute up to 3% of the typical waste mass of MSW.

Whilst it is possible to send other appropriate waste streams outside this list for thermal treatment with energy recovery, they will not attract RECs. Additionally only power sent to the grid is eligible for RECs. The fact that RECs are only applicable to electricity and not to heat, is seen as a barrier by some stakeholders, and does not incentivise on-site heat recovery.

The RET and renewable energy targets have resulted in a marginal increase in renewable energy, with nine small projects being developed in the last two years. A report to the Clean Energy Council on the 'Benefits of the Renewable Energy Target to Australia's Energy Markets and Economy' in August 2012 details how the RET has delivered significant investment in renewable energy, and also achieved lower energy prices for consumers, with a decrease in wholesale energy prices as much as $10/MWh. A further result of this is that Australia has met its Kyoto emission reductions targets. The RET is also expected to deliver further investment. Whilst the RET has been effective in increasing investment in wind, PV, solar water, and hydro technologies, it has not driven energy recovery from municipal waste. Wind power is one of the cheapest forms of renewable energy, and it is in wind power that SA has seen huge advances in the past few years. However, biomass can also be a cheap form of energy, including biomass derived from waste materials such as agricultural and saw mill waste.

Nevertheless, the RET has also supported energy recovery from landfill and sewage gas, and agricultural residues such as bagasse, see the boxed text below.
Future projections do not forecast renewable energy from sources such as MSW and waste wood as increasing their market share between now and 2020[45]. Uncertainties with regards to electricity prices and a historically low REC value may present a perceived barrier to potential investment projects. Prices have also been depressed as a result of legacy issues with some small scale technologies which were previously part of the scheme. This resulted in an over-supply of Large-scale Generation Certificates (LGC's). This combined with the price uncertainty has meant that retailers have not been currently in the market to buy. However the market is expected to recover by 2013-14 as retailers will still need to meet their obligations under the target.

SA currently has a policy target of reaching 33% of its energy from renewable sources by 2020. This should act as driver for the development of W2E, and in particular organic waste recovery.

[45] Benefit of the Renewable Energy Target to Australia's Energy Markets and Economy, Report to the Clean Energy Council, August 2012.

Renewable Energy Certificates Case Study: Mackay Sugar Co-operative

Mackay Sugar produces approximately 20% of Australia's raw sugar and is a collaborator in Australia's largest sugar mill (Racecourse) located at Mackay. In addition to Racecourse, Mackay sugar owns two further mills (Marian and Farleigh), all with cogeneration facility.

During 2008, Mackay Sugar Co-operative committed to a new construction of a large-scale co-generation plant at a cost of AU$120 million over a construction timeframe which is expected to be between 18-24 months. The project received $9million from the Queensland Renewable Energy Fund to establish renewable energy production in the form of co-generation and also ethanol production (Office of Clean Energy, 2009) as well as on-going support through the RET scheme. The co-generation plant currently supplies approximately 27MW of electricity to the grid all year round whilst the ethanol plant produces around 60ML of ethanol. The new co-generation plant is 36MW, which will provide up to 30% of the Mackay district's growing power needs.

"Mackay Sugar Limited has developed a $100+ million cogeneration expansion project, to be constructed over three years. The project will deliver 167 direct and 109 indirect jobs, and generate enough additional power to supply one-third of Mackay. In additional to attracting $9million of Queensland Government support, the company has completed project specifications, including detailed design, engineering and contract specifications and has progressed project funding conditional upon a viable Power Purchase Agreement (PPA). Without RET legislation, it is not possible to secure a viable PPA. There is significant cost and capacity investment required to align all aspects of this project" (ASMC, 2009).

"*Our records show that construction costs have increased on average by 7% per annum for each of the last 20 years, and have doubled in real terms over that period. With a skilled labour shortage in Queensland, it is becoming increasingly difficult to compete with large coal and gas projects for materials and skilled personnel, and this is adding unbearable costs to non-resource projects…..for sugar mill renewable projects, there has been a distinct lack of technical and management skills in integrating new generation projects on brownfield sites*" (Mackay Sugar Limited, 2010)

13.2.6 Carbon Farming Initiative

The Carbon Farming Initiative (CFI) is a voluntary Australian Government carbon offsets scheme to help farmers and land managers earn additional income from reducing emissions such as nitrous oxide and methane and sequestering carbon in vegetation and soils through changes to agricultural and land management practices.

Approved methodologies for CFI currently include capture and combustion of landfill gas, destroying methane from piggery manure, environmental plantings and reducing savannah burning. However, further methodologies under consideration include destroying methane from dairies, native forest protection, reforestation and culling camels.

For an activity to be eligible under the CFI, it must:

+ be within the scope of the CFI;
+ be covered by an approved CFI methodology;
+ be on the 'positive' list; and
+ not be on the 'negative' list.

To be eligible, a project also needs to pass an additionality test, i.e., a project must not be required by law and activity must not be a commonly adopted practice. For example, would the activity have occurred, holding all else constant, if the activity were not implemented as an offset project? Or more simply: Would the project have happened anyway? If the answer to that question is yes, the project is not additional. For example, where the EPA has instructed or mandated under licence conditions the collection of landfill gas, then the project cannot be considered.

Recognising the additionality test may often cause problems for project developers, the Carbon Farming Initiative (CFI) design has been streamlined to avoid these risks. As such the Commonwealth Government has approved four landfill gas projects under CFI that can generate 170,000 offset credits per annum.

Project based additionality testing evaluates each individual project on a case by case basis.

Table 13—2: Additionality tests and criteria

Additionality test	Criteria
Legal and Regulatory Additionality Test (Regulatory Surplus)	The CFI includes a two-part additionality test to ensure credits are only issued for additional abatement. First, projects must not be required by law. Activities that are required by law must take place and therefore are not additional. For example, some native forests and native vegetation are protected already.
Common Practice Test	The second part of the additionality test looks at common practice. Activities that are already common practice or in widespread use are not additional. Activities that are identified as going beyond common practice will be listed on the CFI positive list, which is established in regulations

Which test is best suited to validate additionality depends on the type of project. An additionality test appropriate for one type of project (e.g., a simple regulatory test for methane flaring, where there is no reason to do the project if not required by law) might not be sufficient for other kinds of projects (e.g. energy efficiency, where there could be plenty of reasons for doing a project besides complying with regulations).

The main issue with project-based additionality testing is that the determination of whether a project is additional can be quite subjective. A developer can claim that their project's IRR was too low without a carbon revenue stream, and that the carbon revenues therefore made the project viable. But who can really determine what level of IRR is acceptable to a given company, and thus whether the additionality demonstration is valid? Such additionality claims can only be tested with access to internal company information relating to the financing of the project, yet this information is in most cases confidential.

With regards to landfill gas, it should be noted that only avoided emissions from 'legacy' waste, i.e. waste accepted by the facility before 1 July 2012, are eligible to earn CFI credits.

Some CFI activities are not included in greenhouse accounts under the Kyoto Protocol and do not count towards Australia's national target. These include soil carbon, feral animal management, improved forest management and non-forest revegetation. Through the CFI, these activities can earn non-Kyoto Australian Carbon Credit Units (ACCUs). Activities that count towards Australia's national target include reforestation, avoided deforestation, and reducing emissions from livestock, manure, fertiliser and waste deposited in landfills before 1 July 2012. These activities can earn Kyoto ACCUs. After the Kyoto Protocol commitment period ends in 2012, these activities will continue to receive ACCUs that can be used to meet liabilities under Australia's carbon price mechanism. After 2012 these ACCUs are referred to as compliance ACCUs

There is also much concern over the CFI credit value. During the fixed price period (i.e. 1 July 2012 to 30 June 2015), the value of CFI credits eligible to be used under the CPM (i.e. Kyoto compliant carbon credit units) may trade around the fixed price for carbon credits for the relevant financial year. However, it is widely expected that CFI credits sold into voluntary markets to trade at a discount[46]. Buyers for CFI credits will include businesses who are seeking to meet their CPM compliance requirements or to organisations who have adopted voluntary climate change targets.

In May 2012, the Australian Government announced $72.5 million in grants for 117 research and on-farm projects, including many in South Australia. Many of the research projects underway in SA will be used by the government to inform the best methods for the on-farm store of carbon. The research is being used to inform 'approved methodologies' or what changes in on-farm practices the government will recognise contribute to reducing carbon emissions and will reward with carbon credits.

[46] In November 2012, the Australian Government released the Non-Kyoto Carbon Fund Discussion Paper for public comment. This proposed fund of $250 million over 5 years, will provide financial support non-Kyoto CFI credits.

Table 13—3: Example of approved research and on-farm projects in South Australia

Project funding	Project aims
Improved nitrogen efficiency across biophysical regions of the Eyre Peninsula – Eyre Peninsula National Resource Management Board Funding up to: $322,295 ex GST	The project is trialling rotational cropping practices, including the use of legumes and strategic management of nitrous fertilisers to reduce nitrous oxide emissions across from cropping/pasture systems on the Eyre Peninsula, South Australia.
Livestock and pasture case studies to demonstrate greenhouse gas abatement – Department of Primary Industries and Regions Funding up to: $215,486 ex GST	The project will trial and demonstrate practices to reduce methane and nitrous oxide emissions associated with livestock production systems in South Australia.
Farmers leading and learning about the soil carbon frontier – Crop Facts Pty Ltd Funding up to: $550,000 ex GST	The project will trial and demonstrate practices to increase soil carbon sequestration for cropping and grazing farm systems in the wheat/sheep zones of South Australia, Tasmania, Victoria and New South Wales.
Perennial pasture management systems for soil carbon stocks in cereal zones – Upper North Farming Systems Funding up to: $549,682 ex GST	The project will trial and demonstrate practices to increase sequestration of soil carbon through use of perennial pastures and strategic grazing of pastures across the mid northern and eastern Eyre Peninsula cereal zones in South Australia.
Antimethogenic stockfeed via Eremophila pellets – South Australian No–Till Farmers Association Incorporated Funding up to: $390,909 ex GST	The project will trial and demonstrate Eremophila as a forage/feed supplement to reduce methane emissions from livestock in South Australia.
Rapid post–weaning growth of steers to reduce greenhouse gas emissions – The University of Adelaide Funding up to: $231,818 ex GST	The project is trialling and demonstrating practices to reduce livestock methane emissions by rapid post weaning of steers in feedlots in Meningie, South Australia.
Greenhouse gas abatement in viticulture – The Australian Wine Research Institute Funding up to: $548,046 ex GST	The project is trialling and demonstrating different vineyard floor management practices to reduce nitrous oxide emissions and increase sequestration of soil carbon in five wine grape growing regions across Australia covering a range of soil types and climatic conditions.

Impact on W2E:
W2E projects which involve capturing and combusting landfill gas from ‘legacy’ waste will be eligible to earn CFI credits. There are other potential impacts on W2E associated with the CFI such as using digest from AD as a fertiliser (i.e. offsetting NO_2 emissions from fossil fuel fertilisers) or applying compost to land. ATT biochar by-product may also generate CFI credits if used to sequester carbon in soils. While there are no methodologies, these may be developed in the future.

The value of a CFI credit is uncertain, but $23/t could be considered the likely maximum price that a business seeking to meet CPM compliance requirements would be willing to pay. However, CFI credits that include other social and environmental benefits may be more competitive in the market.

The prices of carbon credits have historically varied, with several factors contributing to this variability, including the credibility of the offsets program, the integrity of offset credits and whether the project provided other social or environmental co-benefits.

13.2.7 Landfill Bans

Whilst there are landfill bans in operation in SA through the W2R EPP, many waste materials that these bans will divert from landfill are not suitable as a feedstock for W2E, and these landfill bans do not act a main driver for energy recovery. As discussed previously, introducing a ban on food waste to landfill has stimulated the development of Anaerobic Digestion facilities. Similarly in Europe, countries introducing landfill bans for organic and combustible wastes have also developed well-established W2E infrastructure.

13.3 Financial

13.3.1 Funding options for waste infrastructure

The underlying nature of waste infrastructure projects results in several key differences from the financing of other infrastructure projects, and as such will impact on the funding options available. Waste infrastructure will involve far higher and long term management, operational and maintenance costs, which can sometimes account for the majority of a waste contract. In the case of waste infrastructure being built to meet the needs of a council, the council will be purchasing a service where payments may typically be spread over a 25 year contract term. The developer however, will require investment to fund the infrastructure upfront and the income received throughout the contract term may be variable. This complexity has led to the development of a wide range of financing options.

Public Private Partnerships (PPP) are commonly used to finance waste infrastructure projects. Public Finance Initiatives (PFI) credits are also used to finance waste infrastructure in many countries, although to a lesser extent as they may only contribute a relatively small proportion of overall project costs. Where PFI credits are available, there is often also the need to secure additional funding to make up the shortfall. Additionally, PFI credits are used to fund the use of the facility over the contract period, and do not include the finance needed for capital costs. There are three main options to secure further finance:

+ Public sector – prudential borrowing. Prudential borrowing loans tend to be based on a council basis, and are not secured against a specific project. This tends to make them simpler and cheaper than other funding options, but more suitable for low risk assets and smaller projects.
+ Private sector – corporate balance sheet. Private sector funding refers to projects financed by the private sector developer, using their own capital or balance sheet to secure bank financing. Again, loans can be secured on the corporate borrower, as opposed to specifically on one waste infrastructure project. This type of funding may be the only option for new and alternative technologies which may be considered too risky by other lenders.
+ Project finance – third party financers. This refers to third party funding secured specifically against a particular waste infrastructure project. This type of finance is often secured after construction has commenced or the project is operational.

In a recent edie[47] webinar poll, more than 40% of respondents indicated that investor confidence is the biggest barrier to the successful delivery of future waste infrastructure. In the recent global economy, investors are inevitably more cautious. Traditionally, banks and private equity firms will be more confident in financing conventional combustion facilities

[47] http://www.edie.net/news/5/Bankability-top-stumbling-block-for-waste-sector/22400/ (130 Listeners)

using proven technologies. Additionally, finance will be easier to secure facilities supported by long term council contracts.

A UK Government report[48] presents a range of finance options to improve the deliverability of waste infrastructure projects, in an attempt to move away from traditional project finance. These options aim to provide the waste industry with cheaper forms of capital through greater links with the real estate sector, to allow the deleveraging of senior debt and to encourage greater equity investment. The current weakened position of funders has resulted in the requirement for greater levels of equity investment in projects. This means that there is an additional drain on scarce corporate funds needed to foster the greater delivery of waste infrastructure, leading to a reduction in the number of proposed waste schemes.

Greater equity requirements can be off-putting for family owned and operated waste management companies, where the release of significant equity may be synonymous with the release of control. In addition, pension funds (which are key investors in sectors like housing) are reluctant to invest in infrastructure as they do not want to take on any construction risk. If a way could be found to pass back this risk to the construction manager, a core group of pension funds could be willing to consider investing in infrastructure projects, both public and private sector, potentially including waste management infrastructure.

Some see “crowd-funding” as a new approach to support the financing of small scale facilities. Crowd funding is a model where projects or businesses are financed by small contributions from large numbers of people. NESTA have recently released a report[49] on the benefits of crowd-funding.

13.3.2 Financial barriers in SA

Currently, for many waste streams, disposal in landfill remains a cheap option. As the SA Waste Levy would be applicable to W2E facilities as well as landfills, there is no cost advantage to W2E developers despite resource recovery taking place. Even with the waste levy, landfill gate fees would have to increase significantly for W2E to be able to take economic advantage.

Whilst there are financial instruments which are applicable to W2E, these have not been a significant incentive to W2E, and in particular for solid MSW and C&I waste streams. One particular barrier identified by stakeholders was that RECs are only paid on electricity supplied to the grid, and therefore this would not be a financial incentive for W2E development for on-site energy use. The historic low price of RECs and expected future variability do not offer security to investors of this future income. Support and incentives have tended to focus on other renewable technologies, and agricultural residues and biomass rather than W2E.Capital costs for W2E are high, and the lack of confidence in their performance and reliability will mean obtaining financial backing is a challenge. The continual perceived political uncertainty with regards to policies and incentives will also add to this problem.

There is also much variety in capital costs and therefore it is difficult to compare projects in Australia. There is no rule of thumb in $/tonne or $/kWh and capital costs will vary according to location, access to electricity grid, emissions control, fuel storage and feed systems and the link between any existing facilities, i.e. for cogeneration.

One stakeholder was of the view that the comparative capital and operating costs, and the difference in associated gate fees between landfill and W2E technologies has been too great to stimulate long-term investment.

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[48] ‘*Rubbish to Resource: Financing New Waste Infrastructure*’, Associate Parliamentary Sustainable Resource Group, 2011
[49] http://www.nesta.org.uk/publications/assets/features/the_venture_crowd

Other than RECs, there is little other financial support for W2E. One source of potential funding is the Australian Renewable Energy Agency (ARENA) Investment Plan. This fund commenced in July 2012, and includes a $126.6m ‘Emerging Renewables’ program to support the development of creative solutions. The program provides funding in two categories: grants for the development of renewable energy technologies along the technology innovation chain, and grants for renewable energy capacity building and development activities. Whilst the majority of funded projects to date have been focussed on wave, solar and other technologies, there are also examples of innovative projects using waste or biomass, including the of transport fuels from mallee bio-mass by pyrolysis, the conversion of sugar cane bagasse into fuel and feed using yeast strains and advanced biomass gasification technology.

A summary of the key themes concerning drivers and barriers to W2E is summarised in Figure 13-1.

Figure 13-1: Summary of key themes identified in stakeholder engagement

Planning	Technology	Feedstocks	Regulation and Policy	Financing
+ Site Preferences/ + Identification + Environmental Impact Statements (EIS) + No Specific Licence Categories (EP Act)– overlap to Development Act 1993 + Easements + Identification as a Major Development (s46 Development Act 1993) + Zoning – metropolitan plan versus rural	+ Proven, Scalable + Patents + Efficiency of Technology (specifically where no grid connected) + Markets for Residues + Provides Base-Load Energy + Needs Life Cycle Thinking + Synergies to Other Activities (i.e. landfill)	+ Fuel Management Issues + Fuel Supply Issues (seasonality of agricultural feedstocks) + Waste Acceptance Criteria + Competing Markets for feedstocks + Future of Asian Markets for Recyclate + Opportunity for Off-Setting Fossil-Fuel + Utilisation of Waste Streams with no other Utilisation/ Market	+ Regulation Not Up-to-Date With Technology + No Specific Licence Categories + Site Identification – Planning + Grid Connection Agreement + Position of EfW in Waste Hierarchy + Unknown Political Environment – Creates Uncertainty and Risk + Lack of Regulator/ Government Consistency (RDF versus LFG)	+ Capital Costs + Infrastructure Costs (Grid Connection) + Limited Funding Opportunities + Funding Limited to RECs + Due Diligence Process + Competing with Landfill (Gate Fees) + Waste in SA subject to a Levy

14 A Strategic Approach to Waste to Energy in South Australia

14.1 Introduction

This section provides a discussion of the key policy options available to South Australian Government and identifies the potential elements that could form part of a strategic approach to developing W2E as part the State's broader zero waste policy. W2E has a potentially important role to play in South Australia's move towards Zero Waste and supporting the State's renewable energy objectives.

As identified in Section 12, W2E can contribute to the achievement of a number of key national and state level policy initiatives including:

1. South Australia's Strategic Plan 2004 (updated 2011) which sets out specific targets on greenhouse gas emissions reduction, deployment of renewable energy and landfill waste diversion for South Australia;

2. Zero Waste SA Act 2004, which resulted in the formation of ZWSA.

3. South Australian Environment Protection (Waste and Resources) Policy, which is used to bring in phased landfill bans and the requirement for the pre-treatment requirement for landfilled waste; and

4. South Australia's Waste Strategy 2011-15, which sets targets for waste reduction and landfill diversion, including*:* 70% diversion of household waste by 2015; 75% diversion of commercial and industrial waste by 2015; and 90% diversion of construction and demolition waste by 2015.

Given this context, it is essential that the approach taken by ZWSA continues to support and complement existing policies and strategies.

14.2 The role of Government in addressing market failure

South Australia has made significant progress in diverting waste from landfill for resource recovery and recycling. Significant progress has also been made in the deployment of renewable energy in South Australia. Interventions such as the waste levy, landfill bans, planning processes and various government programs have played an important role in South Australia's strong performance in resource recovery and renewable energy.

However, further intervention may be needed to address the market failures currently impacting on W2E development in the state. The Government's role will be to provide both the regulatory framework and information needed to address market failures and perceived barriers to development.

It is important that the maximum value is extracted from society's wasted resources. Markets for some materials will drive recycling and recovery to a degree, but landfill remains the norm for the residual streams, reflecting its availability and price differential. Markets themselves (without environmental costs being fully factored in, i.e. environmental externality) will not ensure that wastes are treated in line with the waste hierarchy, with the end result being continued disposal to landfill without any form of resource recovery.

Market failures are often seen in terms of imperfect information, uncertainty, imperfect competition, prohibitive planning costs and lack of project funding. Lack of information and uncertainty will result in market failure, and developers and stakeholders can make better decisions if provided with the right information.

Government interventions into market failures and barriers will not work in isolation. For example, using an intervention such as landfill tax will increase the cost of sending waste to landfill but does not necessarily consider the relative scale of environmental impacts of other treatment methods further up the hierarchy.

Newer technologies in particular will require additional intervention to overcome market failures and government intervention will be needed to address technical uncertainties in some W2E technologies. SA's renewable energy plan identified lack of quality information to support investment as a market failure, particularly in relation to specific local factors resulting in market failure. This was said to be true of the bio-energy sector, due to bio-energy projects requiring commitments from multiple sources of feedstocks. To address this, the SA government has provided support to generate high quality information. Recipients of this support include 3 bio-energy projects:

+ Syngas Ltd – Yorke Peninsular Alkaline Soils Group – biomass collection field trials;
+ RuralAus – feasibility of a 10MW W2E for forest residues on Kangaroo Island; and
+ Clean Carbon Capture – biomass pyrolysis plant.

The government has pledged to continue to work to bring together developers, suppliers and investors to make progress on projects that may be economically viable, and can contribute to the state's renewable energy targets.

Experience elsewhere has demonstrated that consistent and clear interventions are needed to give industry the confidence to invest in new technologies and infrastructure. Without a clear, long term commitment from government and regulatory bodies, the business community and other stakeholders are unlikely to have the confidence to support, develop and invest in waste to energy projects which generally requires large upfront capital input.

Overall, a complementary portfolio of regulatory requirements, economic incentives and support mechanism is likely to be needed in order to ensure goals are met.

14.3 Types of Support and Intervention

There are three broad types of policy options (regulatory, economic and support mechanisms) and are outlined in the following sections.

Table 14—1: Types of policy option

Support Mechanisms	Regulatory	Economic Incentives
+ Partnerships + Demonstrator programmes + Guidance and Information + Stakeholder Engagement + Education and Training	+ Regulatory standards and requirements + Infrastructure planning + Effective regulation + Voluntary standards + Landfill limits or bans	+ Landfill taxes or levies + Grants and loans + Landfill allowance trading schemes

14.3.1 Regulatory Standards

In this context, regulatory options consist of setting mandatory requirements for the development and operation of W2E infrastructure and related systems. In addition to serving as a mechanism for ensuring the protection of human health and the environment, regulatory standards can be used to set performance or system requirements, or prohibit specific activities, and thus support the development of W2E. Examples include setting levels of thermal efficiency, establishing requirements to collect certain waste materials separately, or banning specific materials from landfill. Standards also provide a level playing field for W2E facilities, providing confidence for project developers and operators.

Table 14—2: Regulatory Standards

Description	Impact
Minimum standards for energy conversion efficiency[50]	+ Ensures W2E meets set standards of power generation efficiency which enhance the generation of renewable power from W2E + Reduces greenhouse gas emissions.
Regulatory standards for RDF and SRF	+ Provides a framework for the production of RDF and SRF for use in W2E + Encourages the development of an effective market in SRF and RDF + Incentivises production of consistent fuel feedstock for W2E, which can be particularly important for ATT facilities.
Regulatory standards for digestate outputs from anaerobic digestion facilities	+ Builds confidence amongst consumers (e.g. farmers) in the quality of AD digestate and encourages the development of an established market + Protects human health and the environment
Regulatory standards for incinerator bottom ash aggregate	+ Builds confidence amongst consumers of IBAA and encourage its use as an aggregate.
Mandatory Requirements for separate collection of organic waste from households	+ Creates a base load of feedstock for biological treatment facilities. + Supports consistency of biological and residual fractions of waste stream and hence consistency of feedstock for W2E.
Landfill limits and bans	+ Limiting the quantity or types of waste that can be landfilled drives the development of alternative infrastructure and outlets, including W2E. + Banning specific materials from landfill will drive the development of alternative treatment infrastructure including W2E. Examples of materials that have been banned from landfill include biodegradable materials, wood and plastics.
Infrastructure planning[51]	+ Provides the framework for developing W2E infrastructure. + Assist in the identification of sites for W2E facilities.

[50] *Can be linked to economic incentives (i.e. a tariff, subsidy or tax credit is contingent upon a W2E facility meeting a defined standard).*

[51] *The 'ecopark' approach, whereby a number of waste management, W2E and resource management businesses are incentivised to develop facilities at a particular site, is a model that has been applied successfully in various parts of the world. See the following Ecoparks for examples:*
http://www.binnecopark.com/
http://www.sitasurrey.co.uk/eco-park/proposals
http://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/eco_front.html

14.3.2 Economic Incentives

Economic incentives are a widely used mechanism for supporting the development of W2E. In South Australia, the landfill levy regime acts as an incentive for the diversion of waste from landfill. The Australian CPM, introduced earlier this year, serves as an economic instrument for diverting waste from landfill through applying a price on carbon emissions associated with the landfill. The table below provides a summary of the key economic incentives that could be applied to support W2E schemes.

Table 14—3: Economic Incentives

Description	Impact
Tariffs and trading schemes to support renewable energy generation	+ Incentivises renewable energy generation
Tariffs or tax credits to support alternative uses for biogas or syngas from W2E	+ Incentivises the use of syngas or biogas for gas-to-grid injection or transport fuels
Tariffs or tax credits to support biochar applications	+ Incentivises the use of pyrolysis outputs as a biochar.
Grant aided support for W2E schemes	+ Encourages W2E schemes that require additional support to reach economic viability. Note that this approach can form part of a demonstrator programme.

14.3.3 Support Mechanisms

Whilst regulatory frameworks and economic incentives provide a formal framework for supporting W2E, a wide range of support mechanisms will also be important to encourage the development of successful W2E schemes.

Regulatory systems rarely operate successfully without an effective and proactive support system of capacity building and information provision. Similarly, economic incentives often operate most successfully when supported by strong partnerships, networks and stakeholder engagement.

Table 14—4 provides a summary of the key support mechanisms that could form part of a strategic approach for W2E.

Table 14—4: Support Mechanisms

Description	Impact
Demonstrator programmes	+ Provides commercial scale demonstration of new technologies and applications. Encourages wider uptake of new technologies.
Guidance and information	+ Builds capacity in the industry for developing successful W2E schemes. + Encourages compliance with regulatory standards.
Education and Training	+ Promotes awareness and disseminates best practice. + Provides key professional skills and expertise to industry + Facilitates transfer of knowledge and skills
Partnerships	+ Strong industry networks and partnerships between the private and public sectors will provide the network for the effective transfer of knowledge and support for W2E schemes.
Stakeholder engagement	+ Empowers local communities in developing its waste infrastructure, including W2E. + Encourages strong private/public/community partnerships. + Encourages community acceptance of W2E.

The UK government established a £30M demonstrator programme to support a similar initiative around advanced waste treatment technologies in the 1990s. It aimed to fund ten projects, but only seven were built, as detailed in Table 14—5.

The success of the programme was uneven, with AD the undoubted winner, and pyrolysis the least successful technology. Orchid, with their mechanical heat treatment facility (likened to a waste tumble drier), and Energos, with their close-coupled gasification technology, would also claim success, though the former has now closed the demonstrator plant and the latter has struggled with performance targets.

Our conclusion from this experience is that such a demonstrator programme is expensive (though perhaps cheaper than building faulty full-scale plants) and can have strong impacts, both positive and negative, on the future development of facilities, depending on the success of the demonstrator plants.

Table 14—5: Outcome of UK Demonstrator Plants

Operator	Technology	Fate	[A]	[B]
Biocycle	AD	Now closed, but arguably pioneered the use of AD to treat household food waste in the UK	✓	✗
Envar	In Vessel Composting	still operational, as ADAS (formerly standing for Agricultural Development Advisory Service) (not fully commercialised)	✓	✓
Energos	Gasification	Has struggled with issues including dioxin emissions, but still operational and now earning ROCs	✓	✓
Orchid	Mechanical Heat Treatment	Huyton demonstrator plant shut in July 2011, but two larger plants in Shotton and Bexley in development	✓	✗
Bioganix	IVC	operated 3 IVCs between 2001-09, but company no longer trading	✗	✗
Premier Waste	IVC	not operational, though company is still in business	✗	✗
Scarborough Power	Pyrolysis	never worked properly; beset by financial problems	✗	✗

[A] Was the project successful? [B] Is the test unit still operational?

A further example of a pilot scale plant being instrumental in the scaling up to commercial level is the Lahti Gasification plant in Finland, see Case Study 1. Here, a pilot scale plant helped determine optimum fuel characteristics, and this project has succeeded where similar projects have failed.

14.1 Choosing the Right Interventions

It is inevitable that there will not be just one strategy or policy that could alone be successfully implemented in order to achieve the objectives of the SA Waste Strategy. Instead, a portfolio of complementary regulations, incentives and support instruments will need to fit together in order to provide appropriate drivers and legislation, and ensure goals are met. EU and UK experience has demonstrated that clear, simple and predictable interventions are needed to give industry the confidence to invest in new technologies and infrastructure. In applying those learnings, SA will need to adopt the policies that are most appropriate to identifying and addressing existing market failures and barriers.

Issues Affecting Waste Infrastructure Development

We recently conducted a comprehensive review, with extensive stakeholder input, of the barriers and solutions to the development and delivery of waste infrastructure and its associated systems in the South East of England. The study concluded that the following points are the priority areas for action. Addressing these areas should have the benefit of unlocking several blocks within the delivery process.

- **Data and Information –** the availability of more accurate data on business waste arising and better sharing of data
- **Networking –** encouraging dialogue between all stakeholders to understand individual needs and approaches
- **Training** – supporting and up skilling the sector, particularly around new technologies, planning and permitting and communications
- **Communication** – raising awareness of the need for infrastructure, the need for businesses to ‘do the right thing’ and the many benefits that waste infrastructure can bring
- **Consistency in policy and messaging –** providing confidence to the sector through consistency across government departments
- **Partnership working –** de-risking delivery through greater partnership working, particularly at the top of the waste hierarchy
- **Resource retention** – investment in technology and processes that will help to protect the loss of materials from our economy

SA will need to draw up a clear policy statement on its ambitions for W2E technologies. Once this is finalised, SA can identify the various regulatory and economic measures as well as support mechanisms that it wishes to adopt to promote that policy. Whilst there is much that can be learned from the experiences, successes and failures of W2E in other countries, any initiatives introduced by ZWSA will need to take into account the local situation including current waste collection, waste composition, quantity, existing infrastructure and economic climate.

This body of measures should be wide ranging and comprehensive, to demonstrate to business, householders and councils how ZWSA plans to support the implementation of W2E as part of the overall sustainable waste management solution for the state. A summary of potential regulatory and support mechanisms is included in Appendix 1.

15 Summary

A detailed review of available W2E technology has established that the use of thermal treatment to recover energy from waste is well established globally, and is commonly applied to a wide range of combustible feedstocks. Conventional combustion technologies can be applied at varying scales, and are flexible in the types of feedstock they can accommodate. However, Advanced Thermal Treatment (ATT) technologies are generally less developed than more conventional systems for the recovery of energy from waste, although progress is being made on overcoming financial and technical barriers.

The biological treatment of organic waste by Anaerobic Digestion (AD) is also a well-established technology, particularly in Europe where it is commonly applied to source separated food waste from households, commerce and industry.

There is a wide range of proven technologies which could be applied in South Australia for the recovery of energy from a range of waste feedstocks. However, financial cost is a critical consideration when deciding which waste treatment technologies to promote. There are many factors impacting on the financial viability of W2E projects, and careful assessments of each project must be undertaken against specific local environmental and economic circumstances.

There are currently few examples of W2E involving solid wastes such as residual MSW or C&I wastes in SA. This results in a lack of local reference facilities and technologies. Australia can take advantage of experiences in other countries, particularly those in Europe, to ensure that any new W2E facilities are designed and developed to deliver safe, modern and efficient energy recovery from waste.

Key drivers and barriers to the development of W2E in SA have been discussed, including project finance, proven nature of the technology, feedstock security and supply, economics of landfill and the impact of policy, regulation and strategy.

This background paper has established that W2E can play an important role in an integrated waste management solution in SA, providing an alternative to landfill for wastes which have no further recovery or recycling value. In addition, W2E can make an important contribution to SA's energy security and renewable energy and greenhouse gas emission reduction targets.

Appendix 1 - Policy Options South Australian Government's Consideration

Regulatory

Strategy	Targeted Sector /Waste Stream	Examples – where has this worked?	Impacts (positive & negative)	Lessons Learned	Relevance to SA
Landfill Ban	Food waste, wood and/or other biodegradable wastes	Landfill bans have been successfully implemented in many European countries (such as Scotland, Germany, Austria, Finland, Italy and Norway), particularly targeting at diverting biodegradable and combustible waste from landfill.	• Can act as a driver for W2E or other recycling • Likely lead to the increased feedstock competition between W2E and existing composting	• Need to keep the measure non-prescriptive of the end treatment of these materials leaving it up to the market to respond. • Requires a long lead time in order to the market to respond • Need to be delivered in conjunction with a policy to implement source separated collections of materials included in the bans, i.e. food waste.	SA W2E EPP has introduced a limited landfill ban on biodegradable wastes, i.e. vegetable matter collected by councils
Mandatory Landfill Diversion Targets	Municipal Solid Waste and/or biodegradable wastes	The European Landfill Directive set mandatory landfill diversion targets for biodegradable municipal waste. These targets were the overriding driver for landfill diversion in Europe, in particularly through the source separation of organic waste for energy recovery.	• Can act as a driver to increase landfill diversion of specific waste streams • Areas with lower performance in recycling and landfill diversion may struggle to catch up	• Requires a long lead time for councils to introduce changes to recycling and/or waste collection schemes • Fines and penalties for not meeting targets must be high enough to incentivise action	SA could use mandatory landfill diversion targets to help achieve the targets set out in 2011-2015 Waste Strategy
Landfill allowances trading	Municipal Solid Waste and/or biodegradable	The UK government introduced a landfill allowance trading scheme	• Rewards high performing councils and penalises those	• Allowances need to be set against a baseline • Landfill allowances meant	Trading could be possible between metropolitan and

Strategy	Targeted Sector /Waste Stream	Examples – where has this worked?	Impacts (positive & negative)	Lessons Learned	Relevance to SA
schemes	wastes	in order to meet these targets. The scheme worked by giving each council an allowance of biodegradable municipal waste which they could landfill, but allowed them to buy more allowance, or sell their allowance if not needed. The scheme was successful in increasing both recycling and energy recovery.	with lower performance • Little incentive for councils that are already meeting landfill allowance to make further improvements	that councils in England were able to be flexible in meeting tough EU landfill directive targets.	non-metropolitan councils, with those high performing areas able to sell allowances to others, and vice versa.
Mandatory source separation of food waste	Food waste from households and/or businesses	Scotland has seen an increase in the development of anaerobic digestion facilities in anticipation of new legislation for all homes and certain businesses to be provided with separate food waste collections.	• Incentivises the market to develop infrastructure to treat food waste • Can be costly for business and councils to implement	• Support is needed to help councils implement food waste collections and to procure treatment facilities or capacity in existing facilities • High level engagement with householders and businesses is needed	Increasing the anaerobic digestion of food waste will contribute to SA Renewable Energy targets, in addition to greenhouse gas emissions targets.
Landfill tax/waste levy escalator	Councils and/or businesses and industry	In addition to the requirements of the EU landfill directive, landfill taxes are also accredited with driving landfill diversion and increased W2E. In the UK, the landfill tax escalator increases landfill tax by £8/tonne	• Proven in increasing recycling and landfill diversion • Extra financial burden on councils • Unpopular with waste management industry, who have to pass on costs to	• The waste levy in SA has contributed to the state having one of the highest recycling rates in the country. Whilst there may be concerns that the waste levy places a financial burden on councils who are already undertaking best practice, it remains an	SA could consider exempting W2E facilities from the waste levy, providing facilities met criteria for energy recovery at high efficiency. This would enable W2E

Strategy	Targeted Sector /Waste Stream	Examples – where has this worked?	Impacts (positive & negative)	Lessons Learned	Relevance to SA
		each year. This fixed yearly increase gives stability and confidence to investors, and shortens the time in which alternative technologies become more cost effective than landfill.	customers	effective tool to drive continuous improvement.	to be able to compete financially with landfill.
Development of waste protocols for W2E residues	W2E developers	The UK waste protocol for anaerobic digestate has enabled AD operators to market digestate as a product, providing they meet the requirements of the protocol. Similarly, in many European countries there are clear regulations on the criteria that IBA needs to meet in order to be used in construction applications.	• Offers security to W2E developers that there will be end markets for residues • Can increase processing costs	• Waste protocols take a long time to develop, and the quality of residues is dependent on the waste input. For example, to meet the AD protocol in the UK, food waste must be source separated.	SA Environmental Protection (Waste to Resources) Policy 2010 already provides the regulatory underpinning for when waste constitutes a product.
Higher rate of intervention for renewable energy from solid waste	W2E developers, biodegradable waste	In the UK, Renewables Obligations Certificates (ROCs) are banded, with more ROCs being awarded per MWh for advanced treatment technologies and AD than for biomass and landfill gas. This effectively makes projects to recover energy from solid waste more financial attractive.	• Helps recognise high investment costs and technical barriers associated with some forms of W2E • Some projects may become financially viable only due to incentives, and are then at risk if these are to change	• Whilst RECs have worked to drive investment in landfill gas energy recovery in SA, there has not been a take up in other W2E technologies. Uncertainty in the future value of RECs or other financial interventions can be seen as a barrier, and so certainty and stability is key for investor confidence.	Using different incentive rates for the recovery of energy from solid waste could allow SA to achieve a greater mix of renewable energy sources, in addition to facilitating increases in landfill diversion.

Support Mechanisms

Strategy	Targeted Sector /Waste Stream	Examples – where has this worked?	Impacts (positive & negative)	Lessons Learned	Relevance to SA
Financial support for capital costs of developing W2E infrastructure	Councils, W2E developers, businesses. All waste streams suitable for W2E	The UK Waste Infrastructure Development Programme (WIDP) was set up to accelerate the building of infrastructure needed to treat residual waste in order to meet obligations under the EU Landfill Directive. Financial support was made available in the form of Public Finance Initiatives (PFI) credits, grants and consultancy. The programme has resulted in the funding of £3.6 billion to 29 local authority waste infrastructure projects. The grants are paid over the 25 year operating life of each project. By 2020, WIDP is estimated to have supported the development of some 8 million tonnes of residual W2E capacity.	• Capital funding can help ensure necessary infrastructure is developed and any gaps in capacity are met • Significant and long term financial investment needed by national or state governments • Conditions of funding and procurement process can be constrictive and time consuming.	• In addition to supplying capital funding, large funding schemes are able to deliver additional benefits such as encouraging partnership working, promoting on-going market development initiatives of treatment capacity for recyclate and product off take markets, and providing practical support.	ZWSA has already delivered a series of grant funding programmes, and currently has grants open for and existing facilities that recover materials for reprocessing or otherwise reduce waste going to landfill. This grant funding could be expanded to include energy recovery, to include capital costs or feasibility studies. As a funder, SA would be able to influence the type of W2E facilities that are developed, in particular for preferred technologies or priority waste streams.
Demonstrator Programmes	Household waste, commercial and industrial waste,	The UK government established a £30M demonstrator programme to support an initiative	• Demonstrator projects can be expensive with high levels of risk • Demonstrator	• The success of the UK programme was uneven, with not all technologies resulting in scaling up to a commercial	The lack of tried and tested W2E technologies within SA has been

	specific waste streams such as wood or plastics	around advanced waste treatment technologies in the 1990s. The programme supported a range of technologies including Anaerobic Digestion, Mechanical Heat Treatment, Gasification and Pyrolysis.	programmes can have a strong impact on the development of W2E facilities by enabling innovation	level. • The experience concluded that whilst demonstrator programmes are expensive, the future development of new types of facilities is dependent on the success of demonstrator or pilot scale plants.	identified as a barrier to further development, and therefore a demonstrator programme could be a means of addressing this.
Procurement support to councils to procure new technologies	Councils, Municipal Solid Waste	In Wales, a Waste Procurement Programme Office (WPPO) has been established to work with local authorities, the Welsh Local Government Association and other stakeholders to coordinate the procurement, provide quality assurance support, and engage with the market. The programme provides local authorities with access to experience waste procurement professionals. There are programmes of support for both food and residual waste. To date, there have been contracts signed to develop two AD facilities and other projects are at preferred bidder stage.	• Councils can benefit from specialist waste procurement expertise • Procurement support can be both technical or financial	• W2E facilities require long contracts for financial stability. Whilst in some cases W2E operators may be willing to take a risk and develop a merchant facility, it is more likely that they would be interested in a long term, council contract. In order to help facilitate this, both financial and technical support could be offered to councils procuring new W2E technologies.	SA has the opportunity to work with its councils to support them in the procurement of W2E infrastructure

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