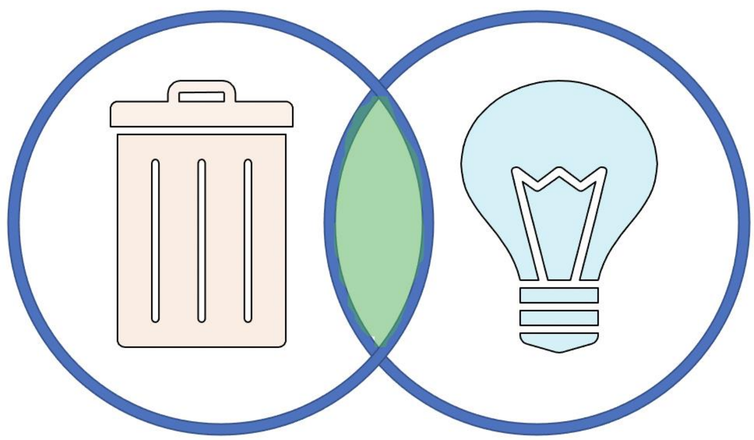
The evolving relationship between clean energy and waste



A discussion paper prepared for the Australian Council of Recycling – March, 2021

Executive Summary

The dual environmental objectives of waste minimization and reducing greenhouse emissions are linked: lower emissions energy can be derived by extracting the energy from the waste stream. These energy sources may be useful as a source of zero emissions fuels, low emissions electricity and as an important complement to running high renewable generation in the electricity grid. This can be achieved while reducing the amount of waste going to landfill and the greenhouse emissions this creates.

Clean energy can be derived from the waste stream in three ways:

1. by the pre-waste collection and industrial composting of organic wastes to produce biomethane and soil improvers;
2. by the management of landfills to harvest a proportion of the methane from the decomposition of organic wastes disposed there; and
3. by the combustion of a blend of remnant organic and other materials left in the post-recovery waste stream to create dispatachable, low emissions electricity or hydrogen which can provide valuable supporting services for high intermittent renewables electricity systems.

Australia produces around 74 million tonnes of waste each year. Around 43 million tonnes is recycled, and 27 million tonnes is landfilled. Around 6.99 million tonnes of organic material is recycled, and 10 million tonnes of organic material in the post-recovery waste stream goes to landfill.

Waste organic material is net greenhouse neutral, meaning its combustion produces zero emissions energy. Recycled organics can be composted to make biomethane. The remaining post-recovery waste organics can also be utilized to make zero emission energy. The purpose of this discussion paper fromthe Australian Council of Recycling (ACOR) is to discuss the potential for improving the way we use and manage these resources in a decarbonizing energy sector.

Waste stream

Australia's waste recycling and recovery performance has been improving for the past three decades. More than 60 per cent of waste is already recycled. The remaining wastes are increasingly difficult to recover because they are highly contaminated and degraded. They are, literally, garbage.

This post-recovery waste stream is still rich in organic material. It is currently landfilled and the anaerobic decomposition of the organic material in landfill produces methane, a potent greenhouse gas. Parts of this waste stream can instead be used for energy recovery. Combusting waste organic matter produces heat which can be converted into electricity or hydrogen. Energy from waste organics is classified as renewable, because the combustion has a net zero emissions profile.

The cost of investing in these energy recovery technologies has been enabled by the rising cost of landfill, driven in part by increasing landfill levies imposed by State Governments. Charging higher levies on waste to landfill is designed to create a commercial incentive to encourage higher value uses for these waste streams and reduce flows to landfill. The materials going to landfill are what is left after recycling. It is the highly degraded, contaminated garbage that is too difficult to separate and recycle. But it can be utilised to make energy.

Different waste streams can be developed using a range of energy extraction technologies:

Organic fuel source	Technology	Energy supplied
Agricultural wastes	Anaerobic digestion	Biofuel
Biomass	Fermentation	Biomethane
Biosolids (from wastewater)	Gasification	Hydrogen
Municipal solid waste	Hydrogenation	Electricity
Commercial wastes	Incineration	Heat
Construction and demolition wastes	Mechanical catalytic conversion	
Wood wastes	Pyrolysis	
	Torrefaction	

Source: ARENA

Markets for waste derived energy

Australia has recently met its Renewable Energy Target of 23.5 per cent of total generation coming from renewable sources. This has been delivered by a combination of (mainly) large scale wind and solar PV generation coupled with small scale rooftop solar systems.

The increasing penetration of these clean but intermittent generation sources is posing new and critical challenges for the safe and reliable operation of the electricity system. This intermittency needs to be supported by a suite of complementary generators and technologies:

- **Firming technologies** like fast responding gas generators, hydro and storage which can enter and exit rapidly to ensure electricity supply matches demand at all times.
- **Balancing technologies** like batteries, pumped hydro, interstate transmission and other controllable loads which can absorb surplus renewable generation at times of over generation and/or low demand and discharge this energy at times of low renewable generation and/or high demand.

- **Ancillary services providers** like batteries, dispatchable generators and synchronous condensers which can provide critical technical services like frequency control, voltage control, inertia and system strength which have hitherto been provided as a by-product of conventional power station generators and which need to be replaced in the emerging high renewable system of the 21st century.

A key physical property of conventional 20th century power stations is that they use large, rotating turbines to create an alternating, industrial scale current which powers the grid. Power stations effectively operate as giant flywheels, and this steady rotating mass is used to stabilize the technical operation of the grid in addition to the provision of electricity.

As conventional generators close, electricity market operators need to find new suppliers of these critical system services. Renewable generators do not replicate this rotating mass. Most generate behind inverters which follow, rather than influence, the quality of the electricity supply. Cost effective, low emissions and reliable provision of these ancillary services will be a critical feature of a reliable renewables-based electricity systems.

Generators powered by post-recovery wastes can be configured to provide some or all of these services, operating at low or near zero emissions. While these generators would be relatively small in the scale of the electricity system, their ability to operate constantly and be able to provide a series of stabilising flywheels could be increasingly valuable when operating as part of high intermittent, asynchronous generation system.

As observed in South Australia last decade, large conventional baseload generators struggle to integrate with very high levels of renewable generation. They are too inflexible to match the large variations in generation. Being forced to remain operating for periods of low or negative prices made them commercially unsustainable.

The advantage of smaller waste fueled energy generators could be that they derive most of their revenue from avoided landfill costs, and so should be able to operate commercially even when wholesale electricity prices are negative. Their smaller size may be advantageous in being able to locate in parts of the grid that would benefit the most from the operation of a small conventional generator.

Opportunities and challenges

The 21st century focus on minimizing packaging waste has tended to undervalue the organic fraction of the waste stream. Organics can be used to make valuable composts and soil enhancers, clean methane, hydrogen and electricity. The high environmental and economic value of these products and its net zero emissions properties can be better exploited.

This has been recognized by the Australian Renewable Energy Agency (ARENA), which has been funding demonstration and deployment energy from waste projects to help build industry capacity and public acceptance. To date it has invested nearly $100 million across 25 projects.

It is critical that the net impact of any new waste and energy technology ensures unambiguous improvement in environmental outcomes. That means any greenhouse emissions from waste derived energy need to be below a prescribed net greenhouse threshold. At the very least this should be lower than the landfill emissions and energy these generators would displace. The broader environmental value of providing ancillary services needs to be factored into the setting of this threshold.

Energy derived from waste can avoid landfill costs and sell both low emissions electricity and potentially some ancillary services. These service markets are evolving with new technologies being developed. Waste fueled generators face similar technology risks as other participants in this market. They should also factor in the impact of a future price on emissions on the commercial viability of their operations.

Stakeholders

Energy from waste is still perceived by many stakeholders as a primitive technology solution to a 21st century problems. To address this, proponents will need to actively demonstrate the net environmental benefits of their approach.

This requires addressing both the waste hierarchy *and* the net emissions balance of their activities. It is a dual test. What this means is proponents will need to demonstrate the principles of the waste hierarchy are preserved, and that all materials that can be recycled are excluded from the post-recovery waste stream, and actively monitor and report the physical condition of the material being considered as an energy source.

They will also need to actively demonstrate an unambiguous net greenhouse emissions reduction as a result of their activity. In order to create large-scale generation certificates (LGCs) under the Renewable Energy Target the feedstock for a waste-fueled generator would need to be regularly audited. It is critical that these generators can demonstrate they are operating at high renewable/low emissions ratio to earn stakeholder acceptance. This, added to accounting for the avoid landfill emissions and other greenhouse costs and benefit, should demonstrate the technology is making unambiguous and significant emissions reductions.

Introduction

The minimisation of waste and the mitigation of greenhouse gases have historically been seen as two discrete environmental policy objectives. This may change with the development of technologies that can harness the energy in key parts of the waste stream to provide low or even zero emissions energy. This Discussion Paper fromthe Australian Council of Recycling (ACOR) will outline the evolution and development of this potential convergence between waste minimisation and decarbonisation of energy.

State of Play

In the 2018-19 financial year Australia produced around 74 million tonnes of waste. About 12.5 million tonnes of this was ash waste from coal fired power stations. Nearly 60 per cent of the total waste stream is already recycled. The residual waste is increasingly more contaminated and more difficult to recover.

The National Electricity Market consumes around 200,000 gigawatt hours of electricity each year. Around 181,000GWH is dispatched from power stations, and the rest is supplied from rooftop solar panels. Renewables now supply around 21 per cent of all electricity.

Waste and energy data snapshot

Waste	Waste (2018-19)	Electricity	GWh (2019)
Total waste generated in Australia per annum (Mt)	74	Total electricity dispatched in Australia per annum (GWh)	181,000
Recycled (Mt)	43 (60%)	Renewables (GWh)	55,481 (21%)
Fly ash from coal (Mt)	12.5	Energy from waste (Mt)	1.6
Municipal solid waste (Mt)	12.6	Household consumption (GWh)*	56,000 (31%)
Commercial and industrial (Mt)	21.9	Small to medium enterprises (GWh)	77,000 (43%)
Construction and demolition	27.0	Large Industrial loads (GWh) (estimate)	37,000 (20%)

*Does not include rooftop solar PV, distribution losses.

Waste minimisation

Minimising waste through improved product design, reuse and recycling has become an important environmental objective in developed economies where waste generation has been increasing. A suite of government initiatives like municipal recycling and packaging reforms have encouraged development of a suite of new waste minimisation technologies. The cost of these strategies are ultimately borne by ratepayers, taxpayers or consumers. Both the environment and cost matters.

More organized waste reduction initiatives in Australia evolved in the 1980s with the evolution of local government recycling services for some material in municipal solid waste (MSW) and increasingly coordinated efforts to reduce waste across all parts of the waste stream: commercial and industrial wastes and from construction and demolition. Each sector of the waste stream has its own opportunities and challenges in reducing waste generated and recovering materials that can be reused in some way.

Waste minimisation has significantly evolved over the past three decades in Australia. Currently around 43Mt of waste, more than 60 per cent of the total waste stream, is recycled each year in Australia.

Waste by material type, Australia, 2018-19

Material	**Total waste 2018-19 (Mt)**
Masonry materials	22.9
Fly ash	12.5
Organics	*14.3*
Hazardous	7.8
Paper and cardboard	5.9
Metals	5.6
Plastics	2.5
Glass	1.1
Other	1.4
Total	**74.0**

Source: National Waste Report 2020

The biggest material type in the Australian waste stream by mass are building wastes (masonry materials), fly ash from coal fired power stations and organic material. Organic material (14.3 Mt) accounts for 20 per cent of total waste from all sectors in Australia. This organic stream (food scraps, garden wastes, timbers and woods, organic sludges, other putrescible) can be converted to energy in a number of ways including combustion to produce heat which can be converted into clean electricity or composted in a bioreactor to produce biomethane.

The energy derived from organic waste is zero emissions because it involves a closed loop carbon system. Organics are primarily found in MSW and C&I waste streams. Around 51 per cent of organic material is currently recycled, while around 1 per cent is already used to make energy.

Landfill levies

The first waste/landfill levy was introduced in NSW in 1971 at $0.56 per tonne charged in addition to the cost of disposal. Levies have since been applied in all states and have been increased by successive governments with the dual, but conflicted, objectives of revenue raising and encouraging waste reduction.

Landfill levies 2020, Australia by state

Jurisdiction	MSW waste levy maximum per tonne
NSW	$143.60
Queensland	$80
Victoria	$65.90
South Australia	$143
Western Australia	$70
Tasmania	$60 progressively – announced 2021
ACT	-

Source: NWRIC White Paper

Waste levies have increased to nearly $150 a tonne in some states. The levies in NSW and South Australia and now higher than the physical cost of disposal, which ranges from $40 to $105 per tonne in Australia[1].The environmental justification for high-cost levies is ambiguous. The full environmental cost of waste to landfill depends heavily on the valuation placed on each tonne

[1] BDA Group, The Full Cost of Landfill Disposal in Australia, 2009

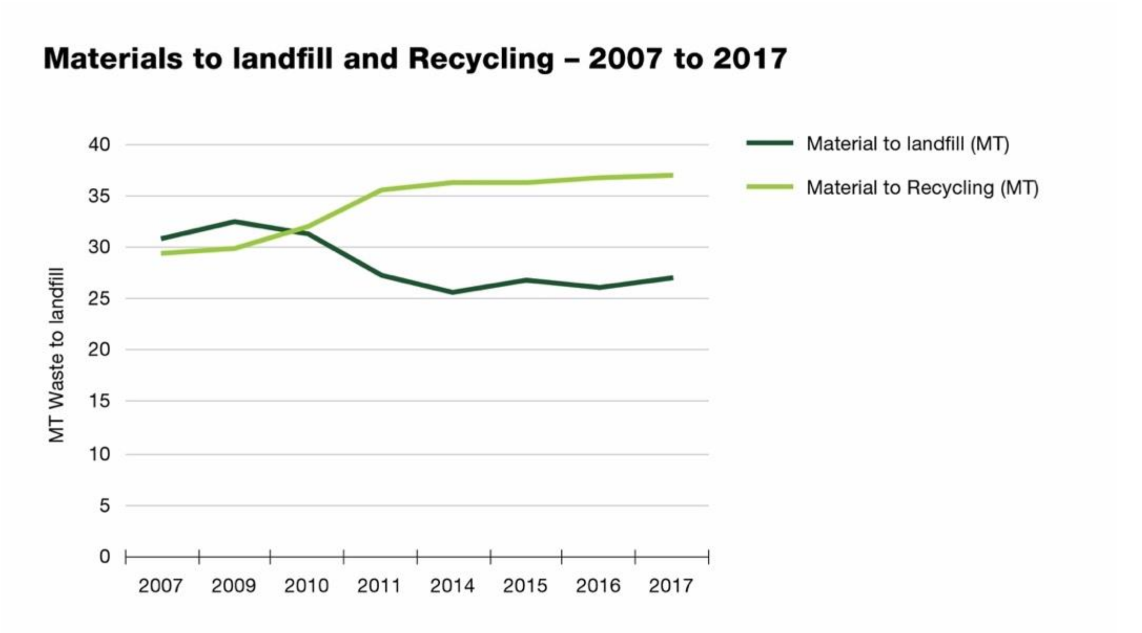
of CO2 equivalent emissions, accounting for the environmental cost of fugitive methane emissions released by decomposing organic matter in landfill.

These emissions are significant. In 2017 emissions from solid waste disposal and wastewater were 11.8 million tonnes CO2 equivalent or 2.3 per cent of national emissions[2]. Around 70 per cent of these are from methane emissions from landfill.

While there is no real scarcity of landfill sites in Australia, in jurisdictions like NSW the cost of proximate landfill sites and resulting transport costs coupled with waste levies have increased the cost of physical disposal. Coupled with landfill levies, this has created a growing commercial incentive to minimize the amount of material going to landfill.

Recycling

Reducing waste to landfill by recovering and recycling parts of the waste stream has steadily increased over the past three decades. Around 60 per cent of Australia's total waste stream (excluding fly ash) is now recycled. This performance has plateaued over the past decade.



[2] https://www.industry.gov.au/data-and-publications/national-greenhouse-gas-inventory-report-2018

In 2019 Australia's waste streams consisted of 43 million tonnes recycled, two million tonnes converted to energy and 27 million tonnes remaining in the post-recovery waste stream sent to landfill.

The highest recovery rates are in construction waste and metals, where it is possible to convert the waste flows into a relatively homogeneous resource. By contract recycling rates are lower for materials types like plastics and textiles, which tend to be less homogeneous and more contaminated.

Materials flows in the waste stream, Australia 2016-17

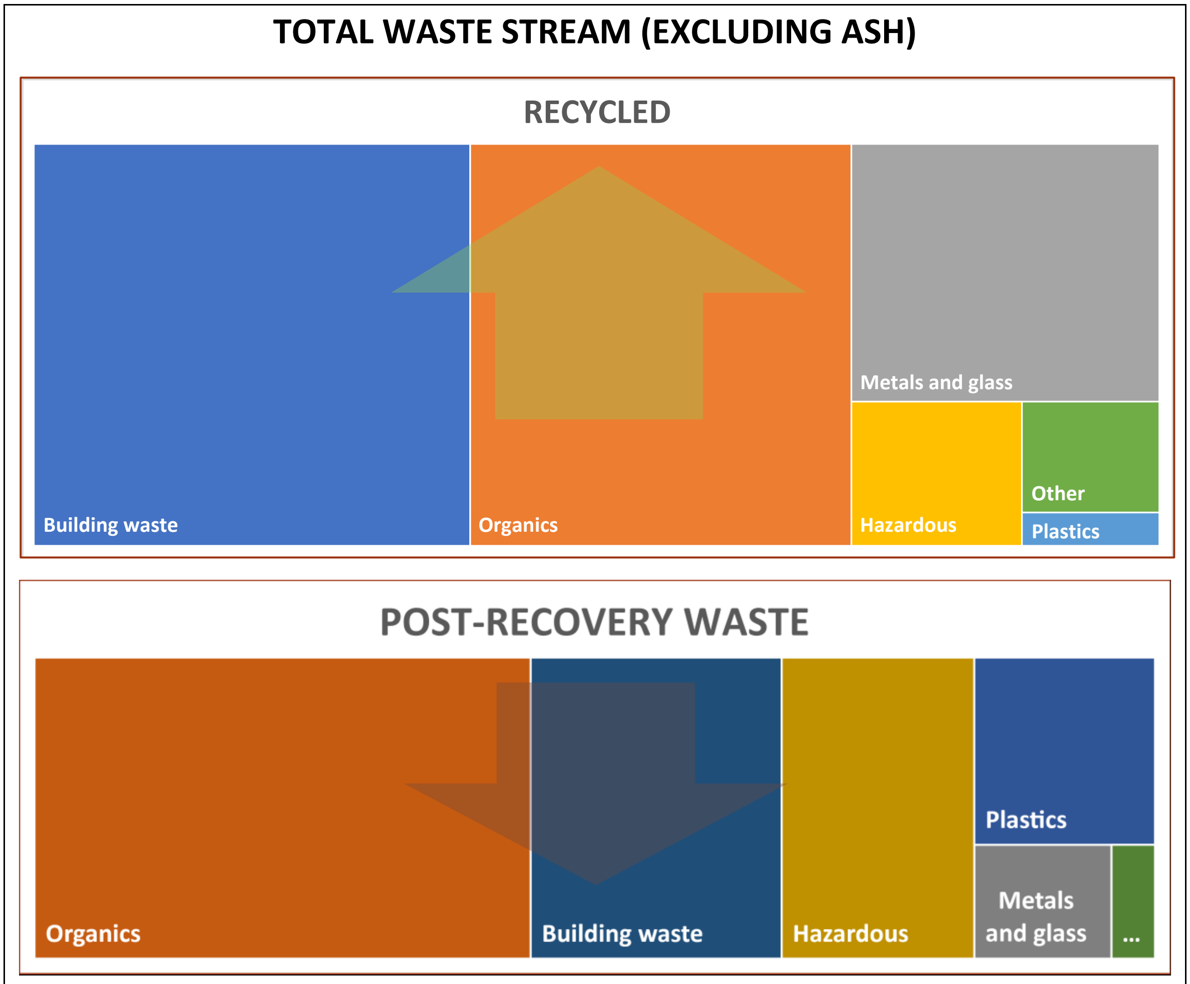
Material	Total waste	Recycling	Other disposal	Landfill	Treatment	Energy recovery
Masonry materials	17.1	12.3		4.9		
Fly ash	12.3	5.3	7.0			
Organics	*14.2*	7.3		6.7		0.2
Hazardous	6.3	1.7	0.024	3.7	0.8	
Paper and cardboard	5.6	3.4		2.2		0.03
Metals	5.5	5.0		0.5		
Plastics	2.5	0.3		2.2		
Textiles etc	0.78	0.09		0.7		0.01
Glass	1.1	0.6		0.5		
Other	1.4	1.1		0.3		
Total	**66.8**	**37.0**	**7.0**	**21.7**	**0.8**	**0.2**

Source: National Waste Audit 2018

The plateauing of this recycling performance reflects the rising marginal cost of each additional tonne of materials recovery. Each tonne of waste becomes progressively more difficult to recover as the condition of materials becomes less defined and more contaminated. There are physical limits to recycling as a method of resource recovery.

The broader organic fraction (including food scraps, garden waste, wood, paper and carboard and other organic materials that is left in the post recycling waste stream represents around 44 per cent of total landfilled wastes. This organic waste has other resource recovery opportunities through energy recovery.

Composition of total waste stream, Australia 2018



Source: National Waste Report 2018

Energy from waste

There are a range of different technologies that have been developed to derive energy from various waste streams. The primary source of this energy from the waste stream is the organic fraction: timber, food and garden wastes, sludges, contaminated paper and cardboard and other organic materials that cannot be recovered from the waste stream.

Different waste streams can be developed using a range of energy extraction technologies:

Organic fuel source	Technology	Energy supplied
Agricultural wastes Biomass Biosolids (from wastewater) Municipal solid waste Commercial wastes Construction and demolition wastes Wood wastes	Anaerobic digestion Fermentation Gasification Hydrogenation Incineration Mechanical catalytic conversion Pyrolysis Torrefaction	Biofuel Biomethane Hydrogen Electricity Heat

Source: ARENA

To synthesize these systems into groups, there are broadly three different ways to convert the energy contained in parts of the waste stream into commercial energy supplies. These vectors are (1) heat which can be converted into electricity (2) the production of syngas, biomethane or hydrogen which are energy products which can be substituted for natural gas in a range of commercial applications and (3) the generation of electricity from landfill gas. All of these sources of energy can be low or zero emissions sources.

1. Waste to heat to electricity

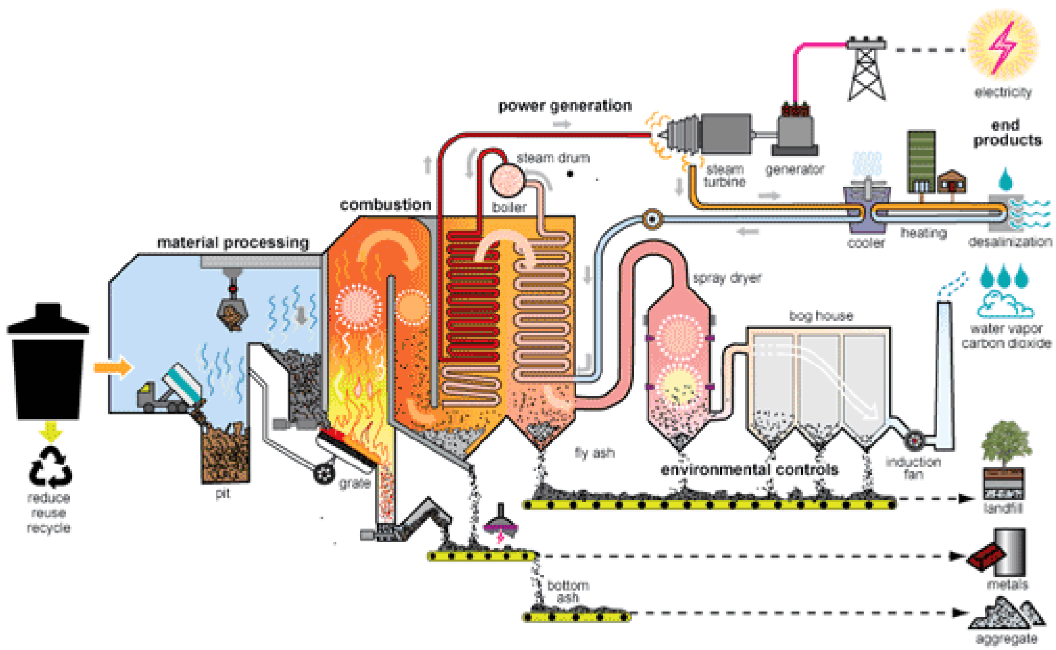
Municipal wastes have been incinerated since the late 19th century in the US and Germany as a way of reducing the volume of these waste streams. Large scale incineration was used where landfill was scarce and disposal costs were high.

The adaption to using the heat from these waste streams to produce electricity evolved in the 20th century as a result of climate change. Combustion of organic (biogenic) material in waste streams is carbon neutral because the carbon dioxide emissions do not increase atmospheric levels. The carbon neutrality of waste combustion depends on the ratio of biogenic material in the feedstock.

Wastes can be used as a fuel for conventional steam turbines which operate in much the same way as a coal fired generator, but at a smaller scale and with a lower emissions fuel. The East Rockingham Waste to energy project in Perth will process up to 330,000 tonnes of residual waste per annum to run a 29MW generator, which will produce around 254,000 MWH per annum. The exact volume of waste needed to deliver different capacities of generation will vary depending on the composition of the wastes used.

The heat from the waste combustion is used to create high pressure steam which turns turbines to make electricity. It is a "baseload" process in that, once fired, it is more efficient and more durable if the unit is kept operating 24/7. This means that these types of electricity generators would need to operate regardless of the supply-demand balance in the electricity market.

MSW waste to energy process



Source: EIA

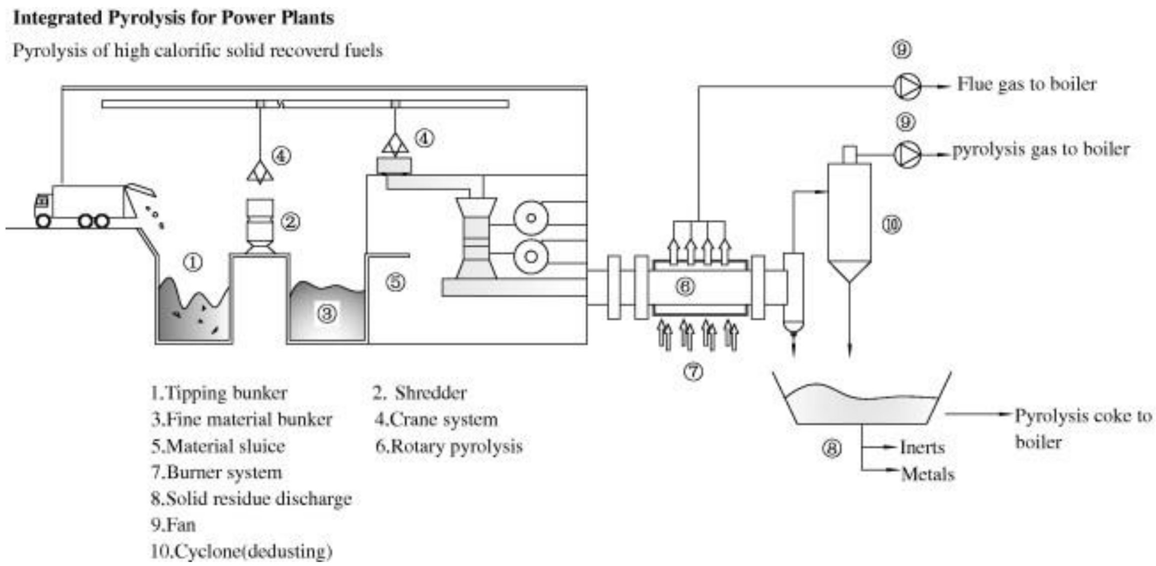
In some conditions some waste types can also be used to co-fire high temperature industrial processes like cement kilns.

2. Waste to gas

The alternative way to extract energy from waste streams is to convert it into gas products: syngas which is a combination of hydrogen and other impurities or biomethane which is a zero emissions substitute for natural gas.

Pyrolysis uses high temperature combustion of waste streams in the absence of oxygen to produce syngas – a combination of hydrogen, carbon monoxide and some carbon dioxide. This method was used to combust coal to make "town gas" for urban gas reticulation before the supply of natural gas in the 1970s.

Pyrolysis process

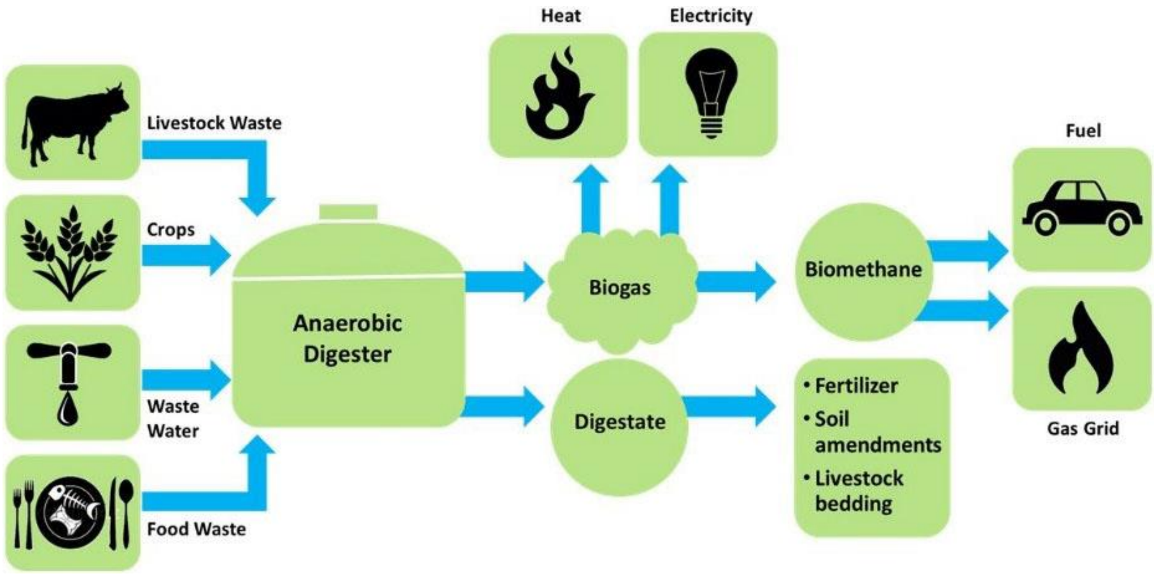


Source: Chen et al

Organic wastes can also be separated and broken down in an anaerobic digester (an industrial compost) which produces biogas (biomethane mixed with carbon dioxide), compost and other soil additives. The process of anaerobic digestion of organic wastes requires higher costs in organizing and maintaining the organic waste stream required, but can produce high value products if managed successfully. The volume of materials going into and out from this process depends heavily on factors like water content and proportion of cellulose[3].

[3] Calise, F et al, Modelling of the anaerobic digention of organic wastes: integration of heat transfer and biochemical aspects, University of Naples, 2020

Anaerobic digestion process

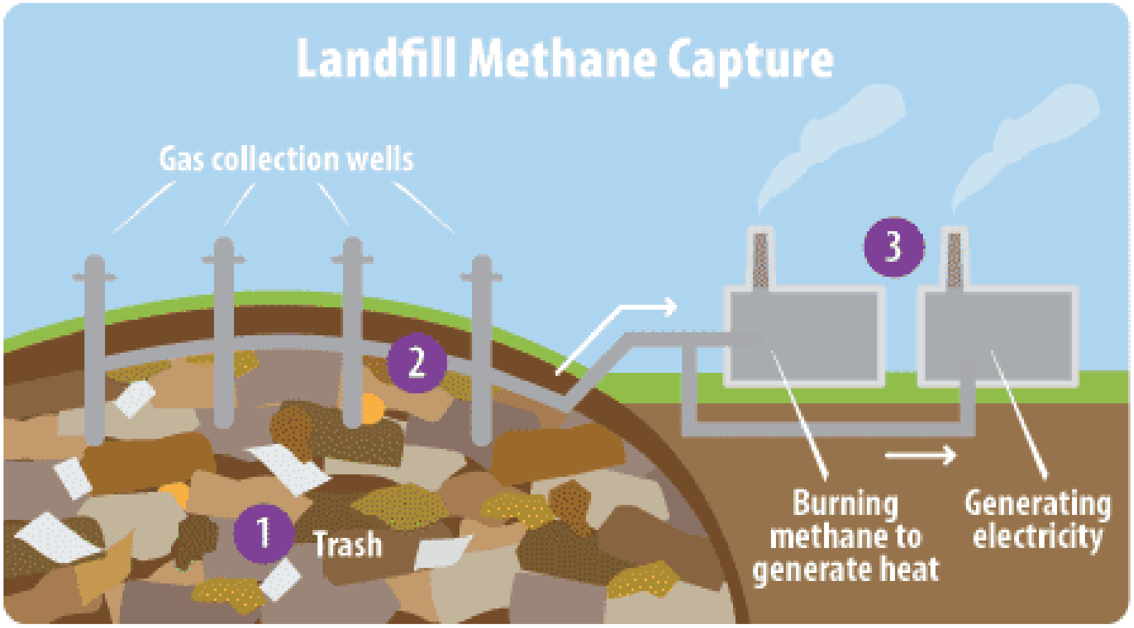


Source: EESI

3. Landfill gas generators

One of the first ways of extracting energy from waste was by capturing some of the fugitive methane created inside decomposing landfills and using it to generate electricity. This method was first identified by the NSW Greenhouse Gas Reduction Scheme (GGAS) in 2002 and became one of the first abatement technologies developed in Australia. It was included in the eligible technologies under the Renewable Energy Target (LRET). It is renewable in the same way that other organic waste to energy technologies are carbon neutral.

Landfill methane capture



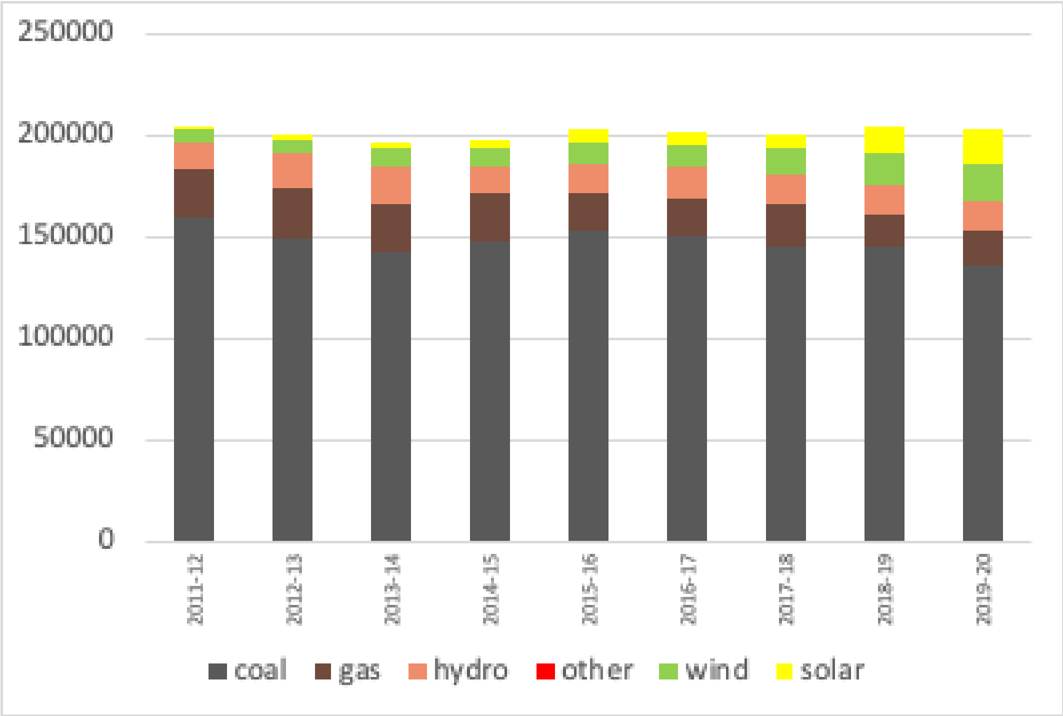
In essence a well lined, formed and capped landfill becomes a bioreactor for the organic matter that is decomposing inside. The anaerobic conditions produce methane which percolates to the top of the landfill and can be captured and converted into electricity. The problem with this approach is that a landfill, no matter how well managed, is a poorly designed bioreactor. Inevitably some of the methane escapes, and methane released into the atmosphere is a highly potent greenhouse gas.

Electricity and energy markets

Climate scientists have been warning about the impact of accelerated release of greenhouse gases on global temperatures since the late 1980s. The Renewable Energy Target (RET) introduced in 2001 took the first tangible steps towards reducing the greenhouse emissions from electricity supply. This process has accelerated somewhat since then.

The most significant change in energy markets over the past decade has been the falling cost and increasing supply of intermittent renewable generation technologies, principally wind and solar PV. They now supply around 23 per cent of electricity supply in Australia. A critical challenge for the electricity market in Australia is to manage the safe and reliable integration of increasing levels of these generation types into the grid. This is revealing new technical challenges and demand for new technical services and markets which did not exist under the "conventional" thermal electricity system of the 20th century.

National Electricity Market: generation by fuel type 2010-20 (TWh)



Source: OpenNEM

Other energy markets like gas are also disrupted: Gas is both a useful complement to help manage the intermittency of renewables, but its combustion produces greenhouse gases and methane, the commodity, is a major greenhouse gas.

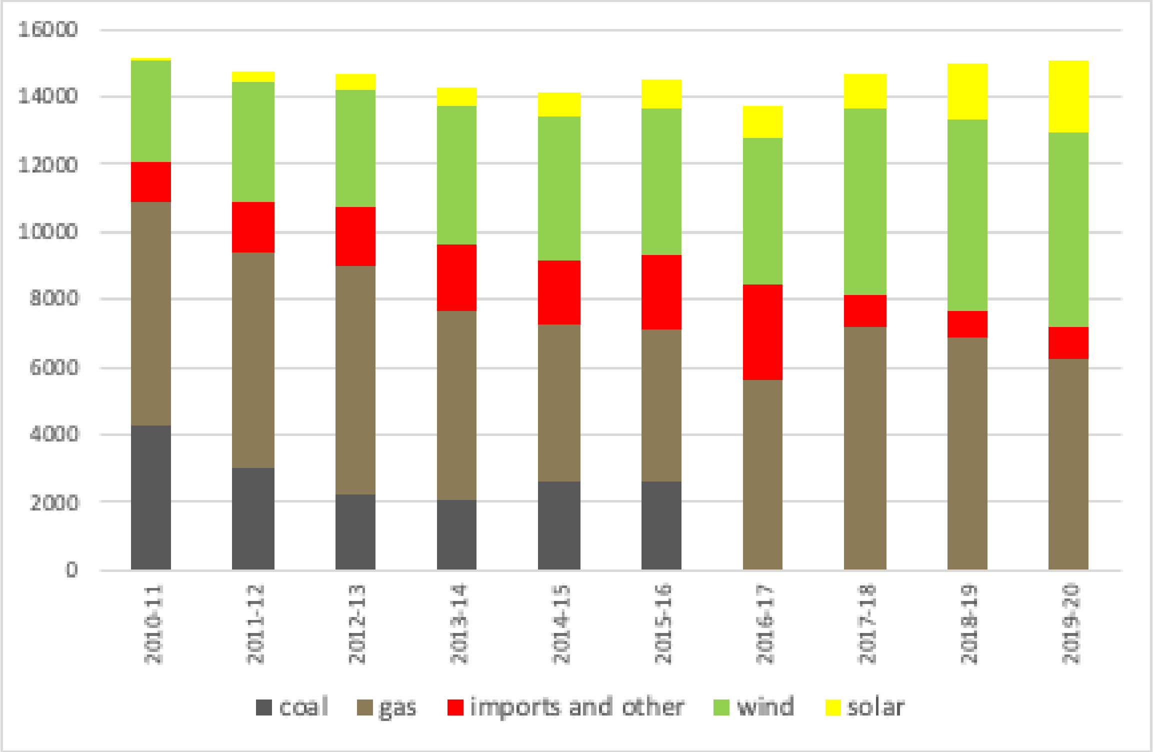
It is into these rapidly evolving energy markets that the waste industry is looking to sell its energy products derived from wastes.

An increasingly renewable electricity system

The cost of wind and solar generation has fallen significantly over the past decade. This has combined with government policy mandating installation of large-scale generation (the Renewable Energy Target) and a separate mechanism subsidizing small-scale rooftop solar to deliver sustained growth in intermittent renewable generation.

New coal fired generation is now effectively no longer an option as banks will not finance it due to the carbon risk over its 50-year operating life and state governments appear unlikely to approve them. This means renewable generation will need to be firmed by gas and storage technologies like pumped hydro and batteries. This is a relatively radical change for the operation and design of electricity systems in Australia.

South Australian electricity generation by fuel type: 2010-20 (TWh)



Source: OpenNEM

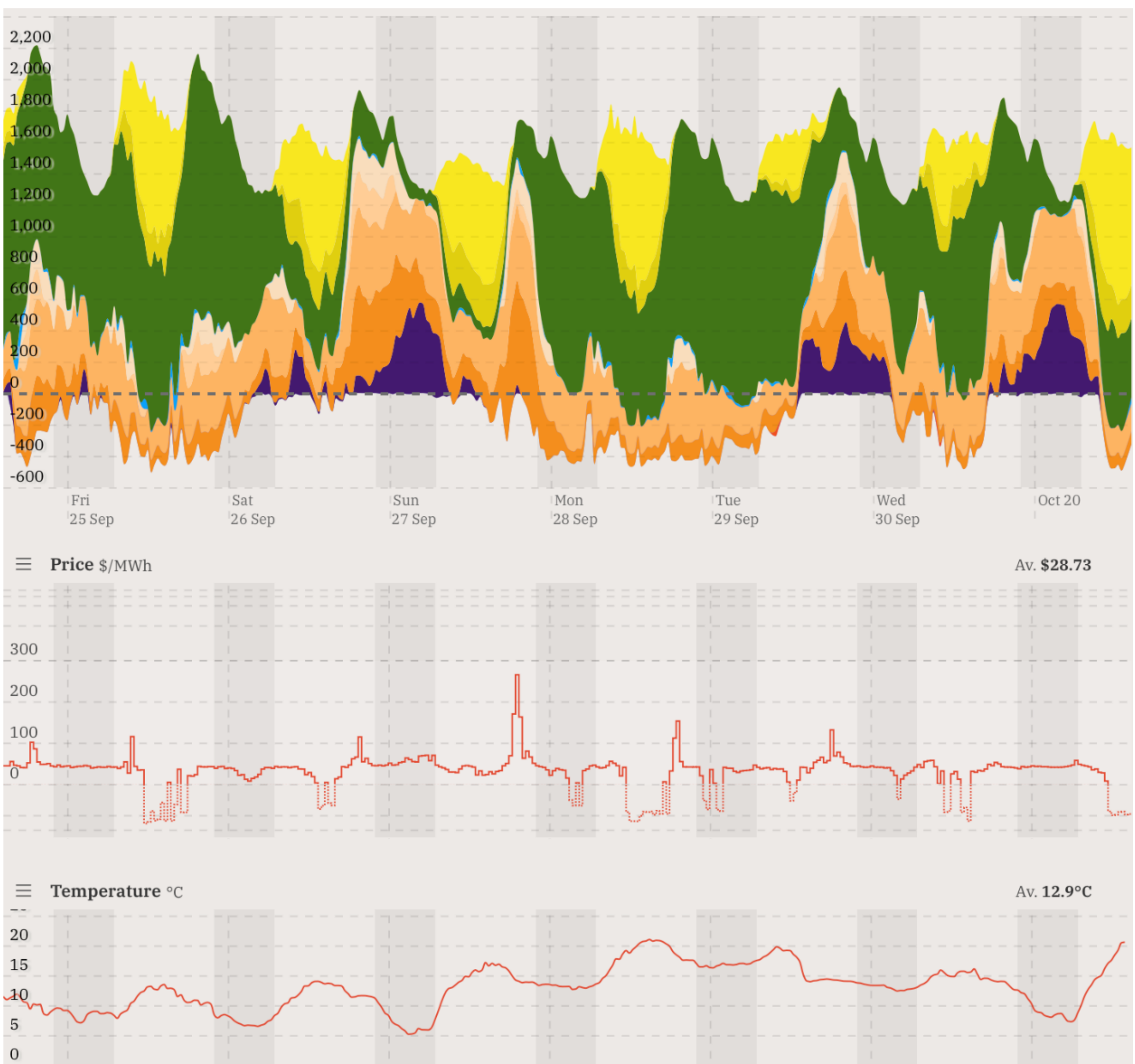
The best way to explain the future challenges and opportunities faced by investors in the electricity grid is to examine the grid in the state of South Australia. As a result of specific market conditions it has attracted around 40 per cent of Australia renewable investment. The South

Australian grid now operates with around 50 per cent wind and solar PV generation on an annual basis. Renewables capacity has been increasing steadily for the past decade.

This renewable generation supply is highly volatile. There are times when it regularly provides all of South Australia's electricity demands, and other times when it is not generating at all. This system requires available generation to be imported from other states via transmission lines and enough flexible, fast start and stop firm generators (principally gas peakers) to jump in and supply enough electricity to meet the state's demand when wind and solar are inadequate.

A snapshot of the last week of September 2020 provides a useful idea of how volatile this grid has become.

South Australian electricity system: September 25 to October 1 2020



The green (wind) and two shades of yellow (utility and rooftop solar PV) show the renewable generation ebbing and flowing with the wind and the sun. There are periods of time when renewables on their own are supplying enough electricity for the entire state. Then there are times when there is almost no renewable generation, meaning this electricity must be sourced from interstate combined with the state's remaining gas generators to meet the state's demand. Note the size of the contribution of batteries in light blue is so small that it is barely visible.

Big renewables and big baseload don't mix

During periods of high renewable generation the wholesale price generally turns negative: that means generators have to *pay* the market to generate. This is a deliberate incentive for generators to stop generating as there is too much electricity. Large baseload generators (typically coal fired) were designed to switch on and stay on, operating inside a range of outputs. They were not designed to switch repeatedly off and on.

These market conditions were what caused the eventual closure of the Northern brown coal power station in South Australia in 2016. It was too inflexible to switch off and on to respond to the market conditions created by large scale renewable generation. every few hours. Eventually it became commercially impossible for Northern to operate under these conditions. The power station closed in 2016.

If baseload-styled generators are going to operate successfully in a high renewables electricity system, they need to be commercially viable noting that for periods of operation the wholesale price is likely to very low or negative. This may be possible for waste fueled generators because most of their revenue comes from avoided landfill costs rather than the value of the electricity they sell into electricity markets.

Increasing importance of power quality

A modern electricity grid operates every second of the day, every day of the year. Maintaining electricity supply is a continuous process built around two basic requirements: balancing supply with demand and maintaining power quality. Balancing supply with demand, or having enough electricity, is called *system reliability*. Ensuring power quality, that the electricity system is operated within safe operational requirements, is called *system security*.

Power quality consists of four basic elements: frequency, voltage, inertia and system strength. These are all simple to manage when electricity systems are powered by large thermal power stations with large rotating turbines. They become more challenging when this is replaced by intermittent generators operating without the constant spinning mass of a power station turbine.

Frequency is a wave form that runs constantly through the grid, like a musical note. It is created in an alternating current system by generators spinning at 3000 RPM, which creates a frequency wave of 50 hertz[4]. Large power stations (and batteries) provide frequency control services, which constantly monitor the level of frequency and adjust their rotation or power output to keep it right at 50 hertz. If the grid deviates too far from this then it becomes unsafe and it trips off. It was a sudden deviation in frequency that caused the system black in 2016.

Voltage is like the pressure in the electricity system. The NEM operates at a voltage of around 230 volts, although it can operate in a much wider safe range than frequency: from around 220 volts to 256 volts. High density of rooftop solar PV systems can cause local problems with high voltages (high pressure) by pushing lots of electricity into a street power line when there aren't enough people at home to use it (like in the middle of a sunny day)[5].

Inertia is a related to frequency. Inertia is the stabilizing effect on the frequency wave of having large rotating turbines and engines in the electricity system. If something disrupts the frequency, then the effect of big heavy power stations and large electrical motors is to slow this rate of change. Inertia is something that wasn't really valued in electricity systems until it wasn't there. In a high renewables grid inertia will need to be replicated and possibly contracted.

System strength relates to how much voltage or pressure there is across more remote parts of the grid, measured by how much voltage changes when there is some sort of fault[6]. Large thermal power stations push electricity into the grid supporting voltage/pressure where they operate. Their removal creates weaker system strength in parts of the grid.

All four of these power quality issues may be commercially relevant to electricity generation derived from waste because their increasing demand could provide additional sources of revenue for those types of generators.

How are these being addressed? When the transmission line between South Australia and Victoria was being upgraded and there was increased risk of South Australia being cut off or islanded, the Australian Energy Market Operator (AEMO) required that 35MW of FCAS be supplied from within South Australia at high risk times. This ruling was later overturned when it was discovered to be causing a spike in FCAS prices. Instead at times of high renewable generation AEMO directed gas generators to stay on to maintain power quality in the state. It is directing these generators more than 100 times a year[7].

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[4] https://aemo.com.au/en/newsroom/energy-live/energy-explained-frequency-control

[5] https://aemo.com.au/en/newsroom/energy-live/energy-explained-voltage

[6] AEMO, System Strength in the NEM explained, March 2020 https://aemo.com.au/-/media/files/electricity/nem/system-strength-explained.pdf

[7] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2018/2018-South-Australian-Electricity-Report.pdf

In 2019 the transmission business ElectraNet was granted approval by the Australian Energy Regulator to install four synchronous condensers in South Australia. These are basically giant flywheels designed to replicate the properties of a large thermal power station, but powered by electricity rather than powering the grid[8]. Four of these are currently being installed in the SA grid.

[8] https://www.electranet.com.au/what-we-do/projects/power-system-strength/

Energy from waste

Using residual waste to make energy

To understand the economics of waste fueled generation it needs to be examined in context of the market this type of generation is selling into.

Initial market opportunities – contracting supply

Waste fueled electricity generators are small compared to the size of the electricity market. Relatively large facilities looking at processing more than 200,000 tonnes of waste per annum have a generation capacity of around 30MW of electricity, which translates to around 0.25 TWh of electricity each year. This is a tiny fraction of the electricity consumed in each state. The National Electricity Market requires around 200 TWh per annum. So these generators will be operating at the margins of the system, and will be taking whatever price is set by the market.

In practical terms at this small scale it is likely that most waste fueled electricity generators would simply contract their electricity at a fixed price to an industrial customer or retailer looking to cover their operational load. The low emissions properties of this supply may be beneficial to the contracting party.

If waste fueled generators elected to operate in the electricity spot market, like other generators they would be subject to the price volatility in the jurisdiction they were operating in. This would be less volatile in states like NSW and more volatile in SA. As “baseload” generators they would be reluctant to turn off, for operational reasons, even if prices fell very low or negative.

However this type of generation may be more immune to low/negative prices and higher in the merit order of electricity generators than even wind or solar PV. That is because only around 30 per cent of the revenue from the[9] generators comes from the sale of electricity. The rest comes from avoided landfill costs. Under these commercial conditions waste fueled generators would possibly continue to be net profitable even at low negative wholesale electricity prices.

Further opportunities – ancillary services

In the near future there may be additional value in being able to supply synchronous or conventional rotating mass generation in high intermittent generation grids. Generators fueled by waste could provide a range of technical services: frequency services, inertia and system strength. This is already critical at times of minimum demand in jurisdictions like South Australia and Western Australia.

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[9] https://www.aemo.com.au/-/media/Files/PDF/Guide-to-Ancillary-Services-in-the-National-Electricity-Market.pdf

There is already a market for frequency services called the Frequency Control Ancillary Services (FCAS) market. Suppliers of FCAS services are conventional power stations with regulators fitted to their turbines and utility scale batteries. There is also a Voltage Control Ancillary Services (VCAS) where generators or synchronous condensers absorb or generate reactive power in their part of the grid. The problem here is not the provision of VCAS, but parts of the grid where there are insufficient VCAS providers.

In September 2020 the Energy Security Board (ESB) released a consultation paper on its Post-2025 Market Design project[10]. The purpose of this work is to identify and implement electricity market reforms arising from the shift from conventional to renewable generation. A key plank of the consultation paper is considering how to design markets and other mechanisms to procure these essential system services. This is an active market reform that needs to be resolved in some form in the immediate future.

[10]http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/P2025%20Market%20Design%20Consultation%20paper.Final_.pdf

The emerging challenge of minimum demand

Minimum demand has been identified by AEMO as a key technical challenge which is fast approaching, particularly in states like South Australia and Western Australia. Minimum operational demand describes the minimum threshold of conventional generation needed to keep the grid operating in a safe manner[11]. Continued growing levels of household rooftop solar PV has the effect of reducing demand (because it's generated behind the consumption meter it shows up as non-consumption and its generation is estimated). At times of bright sunlight and mild weather distributed rooftop solar PV can already be one of the main sources of generation in the grid.

This poses two technical challenges. First, rooftop solar PV operates like an invisible power station that cannot be controlled or turned off or on. Second, solar PV does not provide the technical services needed to keep the grid operating safely. For this reason AEMO ha identified minimum thresholds of operational demand needed to ensure there is enough dispatchable generation operating to provide these services. These thresholds are already being reached on mild sunny weekends in SA and WA[12].

The advantage generation from waste may have over conventional gas generators is that it can operate commercially at a lower spot price than gas generators, and it operates at a lower greenhouse emissions intensity. The installation of synchronous condensers in South Australia will enable power thresholds of operational demand, but not eliminate them.

Generation fueled by waste may have the advantage of being able to locate to provide system strength in key parts of the grid, provide inertia and may be able to be configured to provide frequency control services[13].

[11] https://aemo.com.au/en/newsroom/energy-live/energy-explained-minimum-operational-demand

[12] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2020/Minimum-Operational-Demand-Thresholds-in-South-Australia-Review

[13] https://aemo.com.au/-/media/files/pdf/guide-to-ancillary-services-in-the-national-electricity-market.pdf

21st century electricity grid technologies

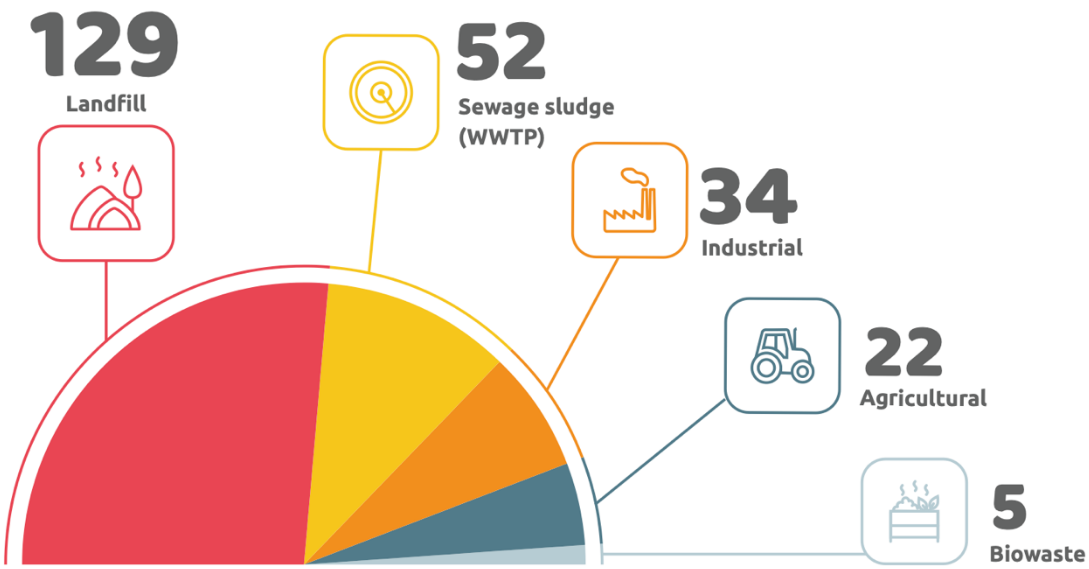
Technology	Advantages	Disadvantages
Coal	Low cost, reliable, provides power quality services at near zero cost	Very high emissions, high capital cost and long term carbon risk, inflexible baseload generation profile
Gas	Lower emissions than coal, able to provide power quality services, around half the emissions of coal, more flexible than coal, lower capital cost reduces carbon risk	Higher cost generation than coal, still produce greenhouse emissions, requires fuel contracting
Wind	Low cost generation, scalable, zero emissions, can be configured to provide some ancillary services when operating	Intermittent, generation does not match demand
Solar PV	Low cost generation, scalable, zero emissions	Intermittent, generation only partially matches demand, no ancillary services
Energy from waste	Small baseload able to operate commercially at low/negative wholesale prices, able to provide some/all ancillary services	Some emissions from non-organic wastes in feedstock, public perception, may be made redundant in long-term by technologies like hydrogen
Batteries	Very dynamic response, class leading frequency services provider, able to balance intermittency of renewables	Small scale, still relatively high cost
Pumped hydro	Large scale storage able to balance intermittency of renewables, can provide some ancillary services when operating	Very high capital cost for very long payback, geographically constrained, low returns on capital
Nuclear	Zero emissions generation, variable output to match demand.	Illegal, very high cost generation, inflexible baseload generation profile

The gas market

Natural gas is an energy source used as a fuel for electricity generation, to provide heat for key manufacturing sectors and as a major export. Natural gas is methane formed in underground gas fields as is a major greenhouse gas and releases carbon dioxide on combustion. The development of clean substitutes like biomethane and hydrogen are important to decarbonize this energy supply and to create more sustainable industrial processes. Gas infrastructure asset owners as well as gas customers are actively looking to blend zero emissions substitutes to demonstrate lower emissions gas has a place in a decarbonized economy.

The challenge with both biogas/biomethane production and town gas produced from pyrolysis is the levels of carbon dioxide in the output. The ability for these gases to provide a credible low emissions substitute for conventional methane will depend on their ability to reduce or manage these greenhouse emissions.

There are currently around 240 biogas plants operating in Australia producing around 4.3PJ of gas. More than half of these operate in the landfill gas capture and generation sector. The commercial value case for many of these projects is in avoiding methane emissions. The electricity generated from biogas earns LGC certificates under the Renewable Energy Target.

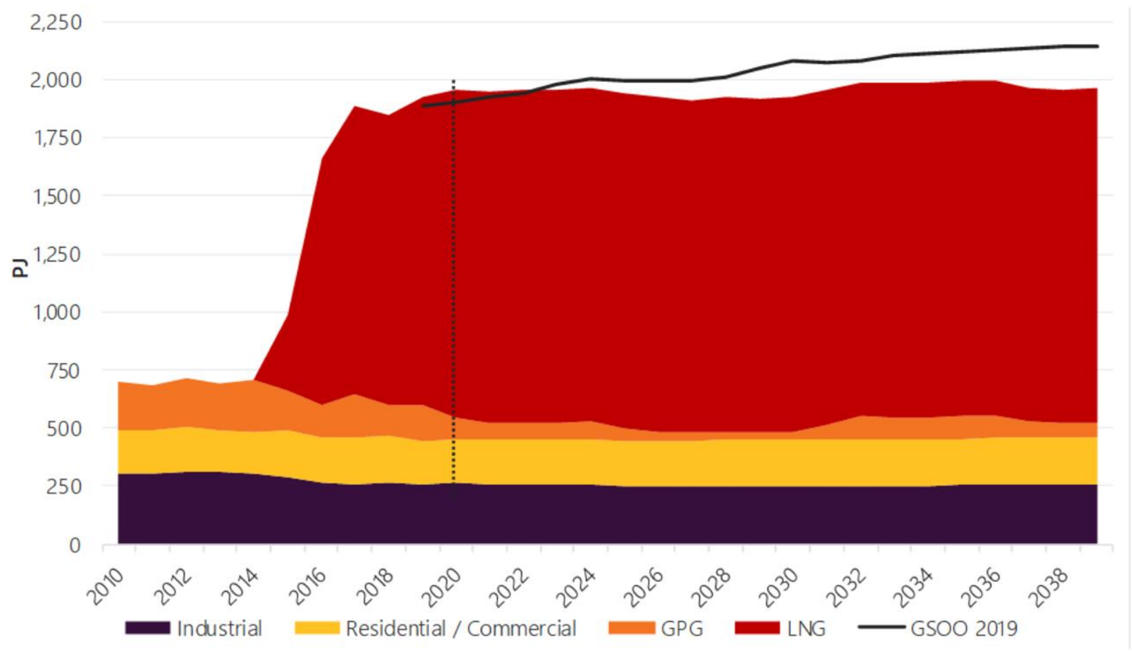


Source: ENEA

The total estimated biogas potential of Australia in 371PJ[14], while domestic consumption is around 600PJ, although exports are double this. In short there is far greater demand for biogas (at a competitive price) than the maximum supply available.

[14] https://www.ieabioenergy.com/wp-content/uploads/2019/07/ENEA-Biogas-Opportunities-for-Australia-March-2019_WebVersion-FINAL.pdf

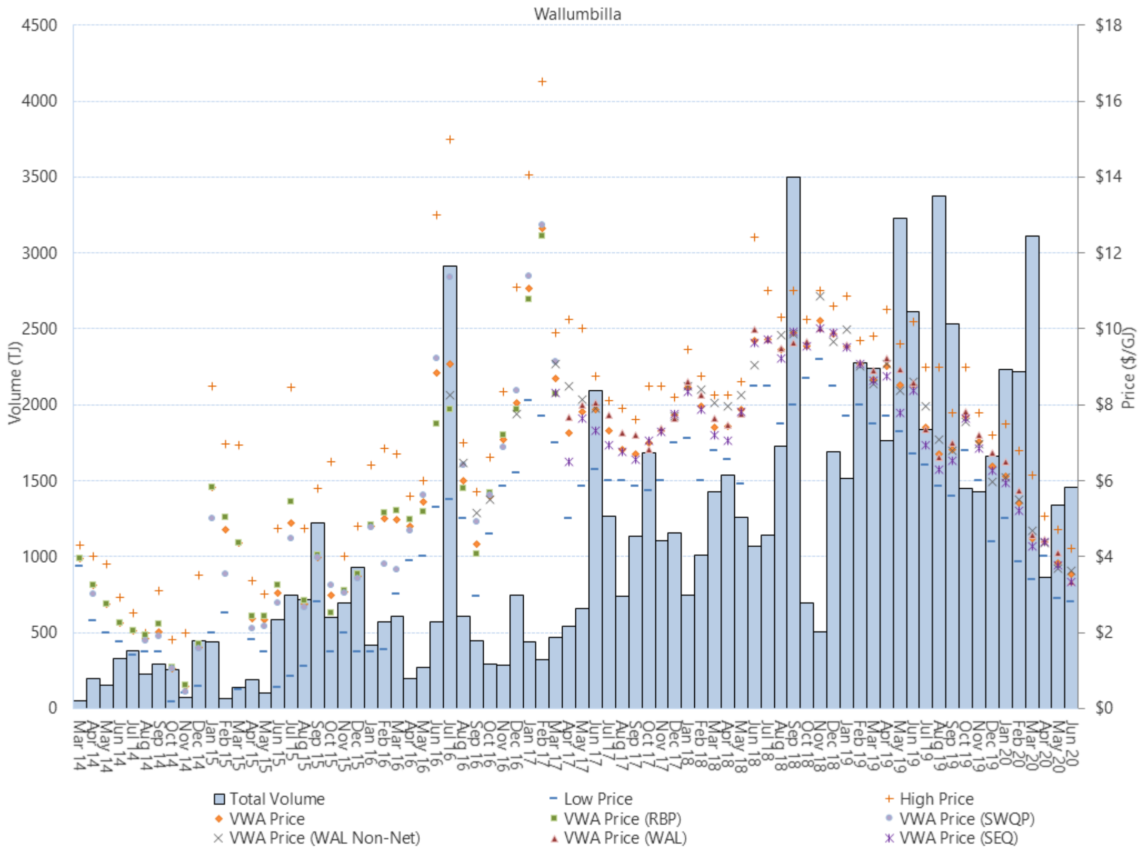
Gas consumption and forecast 2010-39



Source: AEMO GSOO 2020

The cost of producing and injecting biomethane into the gas network is between AUD$7-$51/GJ. Waste is one of the cheapest sources of biogas. The current market price paid for gas in the eastern gas market is below $7.25 in eastern Australia, although recent process are lower as a result of the oil price crash in March 2020. Most biogas production will require some type of commercial recognition of its reduced emissions to compete with conventional natural gas.

Wallumbilla Gas supply hub – price and volume 2014-20



Source: AEMO; AER, Last updated: 9 Jul 2020 - 3:20 pm

It is technically possible to inject small amounts (up to 10 per cent) of hydrogen into the gas distribution network[15]. There is significant interest in development of increased supply of hydrogen including development of a National hydrogen Strategy[16]. Major challenges for hydrogen include cost effective movement and storage.

[15]http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/nhs-hydrogen-in-the-gas-distribution-networks-report-2019_0.pdf

[16] https://www.industry.gov.au/sites/default/files/2019-11/australias-national-hydrogen-strategy.pdf

Current policy

The Victorian Government introduced Energy from waste guidelines in 2017[17]. It applies to all technologies that recover energy or fuel from waste streams. The Victorian EPA assesses energy from waste proposals based on the 11 principles of environmental protection which include the principle of wastes hierarchy, the principle of integration of economic, social and environmental considerations, the principle of improved valuation, pricing and incentive mechanisms, the principle of product stewardship and the principle of integrated environmental management.

The Victorian guidelines encourages energy from waste options where this provides the best practicable environmental outcome based on economic, social and environmental considerations, and where the generation of waste cannot be avoided or the waste cannot be recovered for productive purposes through reuse and recycling.

The NSW Government has an Energy from Waste policy statement[18]. Its energy recovery framework identifies a schedule of eligible waste fuels which includes biomass from agriculture, forestry and sawmilling residues, uncontaminated wood wastes, recovered waste oil, paper pulp residues, source separated green wastes and tyres. Proposals to treat any other waste materials must meet the requirements of an energy recovery facility which include operational requirements on temperature limits, thermal efficiency and limits on the ratio of material that can be sourced from residual wastes.

In April 2020 the South Australian Government released its position statement on waste to energy[19]. This includes specific criteria on the location, operation and approval of prospective facilities. This allows the use of wastes that are not part of the recycling stream for energy recovery, and also allows the use of non-recoverable waste arising from a materials recovery facility or similar.

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[17] https://www.epa.vic.gov.au/about-epa/publications/1559-1

[18] https://www.epa.nsw.gov.au/your-environment/waste/waste-facilities/energy-recovery

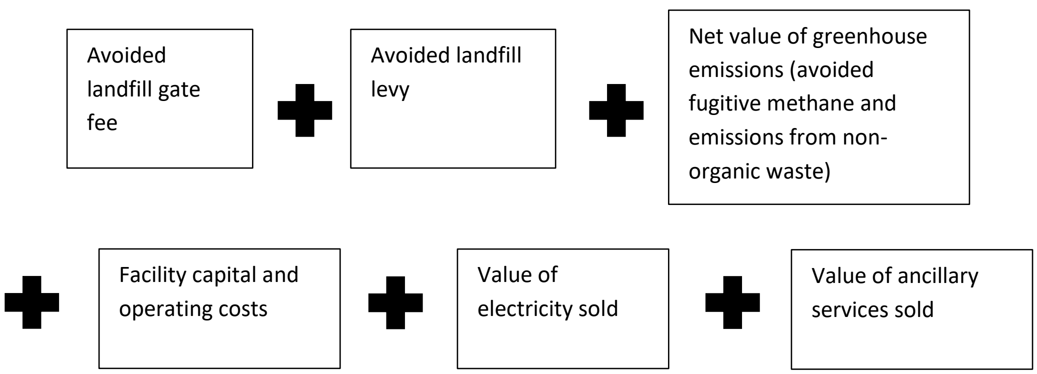
[19] https://www.epa.sa.gov.au/files/14545_efw_position_statement.pdf

Review of challenges and opportunities

Converting parts of the waste stream into clean energy represents the intersection of two environmental issues: waste minimisation and greenhouse emissions reduction. The challenge is how to manage the evolving interrelationship between these different environmental objectives to ensure continuous improvement in the management of both systems. The industries involved in these activities will be guided by the pricing and policy signals governments send them. It's an important and timely discussion.

The 21stcentury focus on minimizing packaging waste has tended to undervalue the organic fraction of the waste stream. Organics can be used to make valuable composts and soil enhancers, clean methane, hydrogen and electricity. The high environmental and economic value of these products and its net zero emissions properties can be better exploited.

The commercial viability of energy from waste will be determined by at least six factors:



The value of these factors is likely to vary over time. Currently energy from waste proposals are being driven by the high cost of landfill and waste levies in some jurisdictions, which, when avoided, account for around 70 per cent of the "value" of the project.

Energy from waste also reduces fugitive methane emissions from landfills, although this is not currently valued. This means any non-organic part of the waste fuel stream is also not valued by current policy settings (i.e. a carbon price).

Electricity generation fueled by waste could play an important technical role in a low emissions grid. These provide the technologies to make a genuine contribution to the decarbonized grid, which may help modernize perceptions about the technology.

Energy from waste developers are likely to contract their electricity supply. They may also want to further explore the potential value of the ancillary services (frequency, voltage, inertia, system strength) they can provide to electricity markets. The value of these services is still evolving as part of ongoing electricity market reforms reflecting the major changes occurring with increased use of renewable generation. It is possible these may become as, or more, lucrative in some cases than the value of the energy sold as MWh into the market.

Stakeholder attitudes towards waste to energy are likely to reflect weak engagement with the technology and the changing needs of energy markets. The perception of energy from waste as a dirty and old-fashioned technology will need to be actively addressed.

This will require active demonstration that any new waste and energy technology delivers unambiguous improvement in environmental outcomes. That means net greenhouse emissions from waste derived energy need to be, at the very least, lower than business as usual, and probably below a prescribed net greenhouse threshold. The broader environmental value of providing ancillary services needs to be factored into the setting of this threshold.

Energy from waste proponents need to demonstrate the waste hierarchy will be preserved. This is already largely reflected in state government policy.

The investment/commercial case for energy from waste is still heavily dependent on government policy, and in particular the setting and holding of (expensive) waste levies. This is always a risk if these settings change for political or other reasons.

Proponents would want to know what the impact of any future carbon price might be on the commercial viability of their operations.

Some services like system strength would require generation to be located in more remote parts of the electricity system. How flexible is locating these types of generation? To what extent can these technologies be used to drive investment and employment in regional Australia?