



Department of
Agriculture and Food



Biomass scoping study

Opportunities for agriculture in Western Australia

Bulletin 4862

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Department of
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Kim Brooksbank, Mitchell Lever, Harriet Paterson, Melissa Weybury

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Copies of this document are available in alternative formats upon request.

3 Baron-Hay Court, South Perth, WA, 6151

Tel: (08) 9368 3333

Email: enquiries@agric.wa.gov.au

Website: agric.wa.gov.au

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Summary

This report aims to provide a summary of national and international activity in the use of agricultural by-products for the production of bioenergy and biofuels. The summary is primarily an internal report for the Department of Agriculture and Food, Western Australia (DAFWA), but will hopefully be of some value to industry proponents that are interested in pursuing the opportunities provided by what are currently low value agricultural waste products. We outline three processes for obtaining energy from these by-products that may be appropriate for the farming sector in Western Australia (WA).

Chapter 2 provides an explanation of the three processes identified as being the most likely prospects for the production of biomass energy in WA: gasification of plant waste, biogas production through anaerobic digestion and ethanol generation from crop residues respectively. These technologies are already operating on commercial scales in other countries and have the potential to be exploited here as an additional income for farmers.

Chapter 3 outlines past and present biomass related projects and attempts to explore why previously mooted projects have often failed to eventuate. This chapter also explores feedstock availability, potential customers for the energy produced and barriers to uptake.

Renewable energy for producing heat, power and liquid fuel is the subject of much interest and activity worldwide. Fossil fuels currently meet most of the world's requirements for energy. However, interest in reducing greenhouse gas emissions, secondary income generation from low value waste products, energy security and promoting regional development have caused a marked increase in community interest in bioenergy. The economic value of renewable fuels is becoming more apparent as the cost of finding and extracting fossil fuels goes up.

Estimates in 2010 suggested that it could be feasible to produce 30 to 70% of Australia's transport fuel from biomass, and potentially produce up to 45GL of ethanol nationally (Parrat & Associates 2010). In 2012 Australia's total transport fuel use was 32GL. Additionally, the use of low value agricultural waste products creates a secondary income for farmers and/or reduces their running costs. However, history has shown that introducing new technologies can be slow, especially when they seek to upset the deeply embedded footing of the incumbent energy providers.

1 Introduction

A recent surge in interest in low value agricultural biomass for the production of biofuels and bioenergy has led to a number of enquiries to DAFWA about the availability of feedstocks and how they might be accessed. DAFWA responded to these enquiries by initiating a cross-directorate working group to explore the opportunities available to farmers and industry to take advantage of potential new markets for what are currently considered low value products such as cereal straw, animal effluent and horticultural wastes. While DAFWA has made some considerable efforts in the past to support the development of biomass based industries, past initiatives have not resulted in the hoped for industry development. The Biofuels Taskforce was a cross-agency initiative to set a strategic direction for the industry, but hindsight suggests the economic settings were not yet suitable for this kind of initiative. However, developments over the past two years in technology and relative prices of fossil fuels are driving a resurgent interest in the feedstocks currently available for this area of endeavour.

Biofuel is any fuel derived from recently living organisms or their by-products. This includes wood and wood waste, animal manure and effluent, agricultural by-products such as straw and bagasse or even dried municipal waste. In this report it will be used to describe bioethanol, syngas and biogas. Syngas is produced through the process of gasification, while biogas pertains to a gas produced through the anaerobic breakdown of organic matter.

By using otherwise low value agricultural waste products to produce biofuels there is the opportunity for producers to augment their income and/or reduce their running costs. This can be achieved by creating and using their own biofuels to produce heat and electricity for their own processes (reducing costs) or selling their by-products to biofuel producers. Some of the processes used to create biofuel also produce secondary products that can be used or sold on (e.g. fertilisers and biochar).

For example, each year India produces more than 200 million tonnes of inedible agricultural waste such as rice and cotton stalks. These are unsuitable for human consumption, animal fodder or bedding but would be suitable for the production of biofuel. Most is burned to speed up the process of crop rotation. Europe produces 900 million tonnes of agricultural, forestry and food waste annually. A 2010 Clean Energy Council study estimated that, nationally, Australia produces 48 million tonnes per year (Mt/y) of non-food biomass. This consisted of 24Mt/y of crop stubble, 8Mt/y of bagasse, 9Mt/y of forestry residues, 6Mt/y of municipal waste and 0.2Mt/y from dedicated energy crops and woody weeds (Parrat & Associates 2010). Putting this to use would bring substantial benefits to industry and the economy: instead of paying to burn or bury biomass waste, farmers or companies can sell it as the starting point for creating valuable gaseous and liquid biofuels such as gasoline, diesel and jet fuels.

In 2007 the Western Australian Biofuels Taskforce reported on the production of ethanol and biodiesel in WA. The report focused on feedstocks, infrastructure, marketing, environmental and health issues and possible opportunities for a biofuel industry. The report detailed 24 recommendations which broadly covered government action, changing legislations, research and development, funding, marketing, increasing education and consumer awareness. This taskforce was unable to pursue the implementation of its findings due mainly to a change in government priorities. While two ethanol plants were proposed to be constructed in

Kwinana, neither was built even though one gained Environmental Protection Authority (EPA) approval.

This document provides a new perspective on the viability of agricultural biomass as a bioenergy feedstock. We have also conducted an analysis of the three main technological areas in use around the world in terms of their suitability for economic and production circumstances in WA.

2 Conversion processes, products and technologies

2.1 Introduction

In order to focus on the processes which are most likely to lead to successful uptake and long-term sustainability in WA, the following selection criteria were used. It was considered that any process promoted should have been demonstrated to:

- be technically viable at the medium to large scale
- use a diversity of widely available feedstocks
- result in a net production of energy
- reduce greenhouse gas emissions and other environmental impacts
- be commercially viable.

With these criteria in mind three conversion processes were identified: gasification, anaerobic digestion and cellulosic ethanol. The processes of combustion and pyrolysis are included under the banner of gasification, since the three terms generally refer to stages of a single overall conversion process. Anaerobic digestion is more commonly referred to in terms of the product (biogas) or equipment (digester or biodigester). Cellulosic ethanol was chosen over traditional sugar or starch ethanol production because it can utilise cereal straw, an abundant agricultural residue in WA, as a feedstock.

Each of these processes produces energy products (syngas, biogas, and ethanol) and residues which can be applied to soil to return essential elements and enhance carbon levels. In cellulosic ethanol, the residue is predominantly lignin which can be burned to provide heat for the conversion process. The three processes are summarised in Table 2.1 and described in more detail in the sections which follow.

Table 2.1 Summary of established processes for the conversion of biomass to energy and other products

Process	Gasification	Cellulose ethanol	Anaerobic digestion
Feedstock	Cellulosic biomass: wheat straw, oat husks, forestry products & waste from energy crops (grasses, canes)	Cellulosic biomass: wheat straw, oat husks, forestry products & waste from energy crops (grasses, canes); waste/surplus grains, fruit & vegetables	Any organics (sewage, manure, municipal waste, waste/surplus grains, fruit & veg) can mix with cellulosic wastes & abattoir waste
Energy products	Heat, electricity	Ethanol, heat, electricity	Biogas, heat, electricity
Other products	Biochar, ash	Ash, compost, liquid fertiliser	Liquid & solid fertiliser
Technology	Gasification boiler (heat), cogeneration (heat + electricity)	Steam explosion, enzymatic saccharification, fermentation, distillation, cogeneration (heat + electricity)	Biogas digester, gasholder biogas boiler (heat), cogeneration (heat + electricity); engine or turbine, generator (heat exchangers)

2.2 Combustion, gasification and pyrolysis

2.2.1 Processes

Combustion, gasification and pyrolysis are all processes which occur when relatively dry biomass, such as woodchips, straw, rice or oat husks are heated. Biomass with moisture content below 60% can be used but generally only feeds with moisture content below 50% are employed. Generally it is better to dry them down to 20% moisture content prior to use to avoid the energy losses associated with evaporating the additional moisture.

The three processes differ in the amount of oxygen, or other oxidising agent, added during heating.

Combustion refers to burning biomass in the presence of sufficient oxygen to enable complete oxidation to occur. It is employed in modern biomass boilers to produce hot water or steam for domestic or industrial processes. Combustion steam can also be used to drive a turbine for electricity generation.

Pyrolysis occurs when biomass is heated with no oxygen or other oxidising agent. First the moisture is driven off, and then the volatile compounds (mainly hydrocarbons) in the biomass are vaporised. The smaller molecules in the vapours will remain in the gaseous state when cooled (e.g. carbon monoxide, carbon dioxide, light hydrocarbons) whereas the larger ones will condense to form a liquid, referred to as tar, bio-oil or pyrolysis liquids. The solids remaining after the volatile compounds have been driven off are referred to as char or biochar.

Generally, the liquids produced cannot be used directly as a fuel, but must undergo further processing to convert them to a useful fuel. However, some more sophisticated processes can finely tune the composition of the vapours so they condense to form liquid fuels suitable for direct use in modern diesel or petrol engines. The most common process of this nature is the Fischer-Tropsch process. It has been proven in a number of demonstration and pilot plants around the world, but is not yet employed widely as a commercial process.

Gasification is intermediate between combustion and pyrolysis, in that limited oxygen is provided to the process. Practical gasifiers typically have zones of combustion (to generate heat), pyrolysis (to drive off the volatile compounds) and reduction (to reform the gas into a higher quality fuel). Where the focus of pyrolysis is generally on the quality of the char or oil produced, the focus of gasification is on the quality of the gas produced, which is referred to as syngas or producer gas.

Syngas is a useful fuel which can be burned in a boiler to produce heat, or in an engine or turbine connected to a generator to produce electricity. For use in an engine syngas must be cleaned to remove tars and other undesirable compounds which can cause damage to mechanical parts.

Table 2.2 Typical concentrations of syngas from gasification with air as oxidising agent

Component	Composition (%)
CO (carbon monoxide)	15–20
H ₂ (hydrogen gas)	15–20
CH ₄ (methane)	0.5–2
CO ₂ (carbon dioxide)	10–15
N ₂ (nitrogen gas)	40–60
O ₂ (oxygen), C _x H _y (hydrocarbon)	5–10

With steam or oxygen as oxidising agent the composition of carbon monoxide and hydrogen gas (and therefore the energy content) is significantly higher due to the absence of nitrogen, but more energy is required to drive the process.

The biomass used in combustion, gasification, or pyrolysis must first be physically treated to make the size of the particles small enough for the device used. Feedstock can include small logs, woodchips, waste wood offcuts or purpose made wood pellets. The feedstock can be manually or automatically fed to the burner.

Feedstocks with too much sand or gravel can be problematic because they block up boilers leading to the need for frequent cleaning. This needs to be taken into account when collecting and stockpiling the biomass feedstock (e.g. stockpiles can be put on concrete pads).

2.2.2 Conversion technologies

Many types of equipment have been developed for converting wood, straw and other dry forms of biomass into useful energy. Probably the most well-known example in Australia is the use of pot belly stoves for space heating. Some Australian homes have a 'wet back' arrangement with hot water pipes in the back so water can also be heated when the stove is running. Woodchip or wood pellet hot water boilers are widely used in colder climates in Europe to provide hot water and central heating.

For industrial process heating a biomass-fired steam boiler or gasifier can be utilised (Figures 2.1.1, 2.1.2). When electricity is desired a steam boiler can drive a steam turbine, or a gasifier can supply syngas to an engine generator. The conversion efficiency of wood fuel to electricity is typically in the range of 25 to 40%. Efficiencies from 80 to 90% can be obtained when electricity and heat from an engine or turbine are both used. This is referred to as 'cogeneration' or combined heat and power (CHP).

Industrial biomass plants are usually automatically fed. Trucks or loaders fill a hopper with chips or pellets. Screw conveyors typically take the feed from the hopper to the boiler or gasifier. The speed of the conveyors is automatically varied according to the demand for heat or electricity.



Figure 2.1.1 Phil Beresford showing the viewing port to the combustion chamber on the gasification boiler at Macco Feeds, Williams, WA. About 3500 to 4000 tonnes per year (t/y) of mallee woodchips are used to generate up to 1.7MW of thermal power to produce steam for direct injection to soften the stockfeed product



Figure 2.1.2 Infeed system to boiler: a screw conveyor automatically feeds woodchips from the hopper to the boiler at a speed controlled to match steam demand

2.2.3 Environmental impacts

In an ideal situation, if biomass is burned completely in the presence of oxygen, the only end products will be carbon dioxide and water vapour. In practice, however, a range of pollutants may be present in the exhaust gases. Incomplete combustion due to insufficient air, mixing or low combustion temperatures can leave a range of unburnt pollutants including carbon monoxide, hydrocarbons, tar and ammonia. Complete combustion can lead to the production of nitrogen oxides due to the nitrogen content of the fuel. Combustion in excess air may produce additional nitrogen oxides. Other contaminants can include sulphur dioxide, hydrochloric acid, heavy metals and ash particles. The specific nature of the contaminants depends not only on the combustion process but also the composition of the fuel.

With proper emissions control measures, biomass combustion can be carried out with lower emissions than those associated with burning coal. One measure to reduce the emission of pollutants is to ensure good mixing of the air and gases so complete combustion can be obtained without using excessive air. This is achieved in modern biomass devices by two-stage combustion. Primary air is injected into the fuel bed and secondary air is injected at multiple points in the combustion chamber, which ensures good mixing with the combustible gases formed. Large combustion chambers resulting in longer flames and longer residence times also minimise the presence of unburnt pollutants. Good insulation of the combustion chamber allows higher temperatures to be reached which also improves the degree of combustion.

By adjusting the mixing of fuel and air, temperature and residence time, emissions can be minimised. Beyond this, additional emission reduction measures can be carried out. In general, biomass combustion is considered carbon neutral from a life cycle perspective because the carbon released as carbon dioxide during combustion is sequestered during plant growth (although greenhouse gas emissions caused during production, harvest and transport need to be considered). In reality this depends on the feedstock being sourced from sustainably managed forestry or agricultural practices. Small amounts of methane or nitrous oxide (N₂O) in the exhaust gases can have a negative impact on the greenhouse audit since these gases have much higher global warming potentials than carbon dioxide.

With complete combustion, such as is required in biomass boilers, the char formed by pyrolysis is burned and the solid residue is a fine ash. With pyrolysis and gasification some unburnt char remains (referred to as charcoal or biochar depending on the application). The properties and benefits of ash or char depend on many factors including the feedstock used, the temperatures employed in the process, soil type and climate. In any situation, testing of gasification products and soils, as well as field trials, should be carried out before the products are applied on a broad scale.



Figure 2.2.1 Rainbow Bee Eater Pty Ltd (RBE) has developed a pyrolysis based system that converts large square bales of straw into clean syngas and biochar. The syngas is a clean gas suitable for gas engines and boilers. Independent research indicates that biochar may reduce fertiliser consumption and increase crop health and yield on some soil types. Biochar is also a form of long-term carbon storage. The prototype plant was commissioned on a large wheat farm at Kalannie, WA, in 2013. RBE is continuing technology development aimed at providing reliable and automated biomass to energy systems for commercial applications in the near future

2.2.4 Financial viability

In Australia the cost of woodchips, straw or other dry biomass (excluding transport) is typically one-quarter to one-fifth the cost of LPG (bottled gas) or natural gas for the same energy content, if purchased from a commercial supplier. In some cases the biomass cost can be zero, or even negative where the feedstock is available onsite or is costing money to dispose of.

On the other hand, the capital cost of biomass combustion or gasification equipment can be higher than gas or electricity based equipment. This is because solids handling is more complex than gas or electricity, and additional land and buildings are required to maintain stockpiles and fuel delivery equipment. Additional operating costs apply compared to gas handling because of the extra labour needed to manage stockpiles, load hoppers, remove ash and clean boiler tubes which may foul more frequently.

When all these factors are taken into account, for a business with a high demand for process heat, typical payback periods can be in the range of two to four years.

Where electricity generation is also employed, payback periods will be higher due to the additional costs of generating equipment. A key factor in determining the financial viability of a gasification process is how many hours per day the plant is operating. Equipment which is running for longer periods will take less time to offset the capital

cost with energy savings. There is no minimum or maximum scale for potentially viable projects because appropriate technologies have been developed at most scales. Suitable situations arise where there is a significant demand for heat or electricity combined with the availability of low cost feedstock.

As an example, Table 2.3 shows a simple financial analysis of the typical case for switching from a 5MW gas fired boiler to one fired by biomass. The simple payback period for 16 hours per day (h/d) operation is under two years. If the hours of operation are reduced to eight, the payback period increases to three and a half years. If they are increased to 24 the payback period reduces to around one year. Appendix A provides more detailed analysis of this comparison.

Table 2.3 Comparison of costs of gas and wood-fired heat production

Item	LPG boiler	Biomass boiler
Capital expenditure	\$0	\$3 000 000
Operating time	16h/d	16h/d
Unit fuel cost	\$0.80/L	\$0.09/kg
Unit energy cost	\$0.113/kWh	\$0.023/kWh
Consumption	13400L/d	24 158kg/d
Daily cost	\$10 720	\$2 174
Annual cost	\$2 358 414	\$478 326
Additional operating costs	\$0	\$100 000
Total annual operating cost	\$0	\$578 326
Annual savings	\$0	\$1 780 088
Simple payback period	Not applicable	1.7 years

It is also important to investigate the reliability of fuel supplies. For example, forestry waste may have established supply chains backed by long-term contracts with plantation owners. Wheat straw or oat husks are more seasonal and a number of sources may be needed to ensure feedstocks are available during low harvest or drought years. New enterprises can potentially be developed around providing reliable supply chains for agricultural residues.

Although there are thousands of biomass boilers, steam turbines, gasifiers and syngas engine/generators around the world (in Europe, Asia, Africa and the United States), there are only a handful in operation in WA. Possibly the greatest barrier to wider adoption is simply lack of knowledge. Even under the most promising financial circumstances there may be reluctance to switch to an unfamiliar process.

As the prices of conventional energy sources continue to rise, supplies continue to decline and public awareness of environmental impacts grows, it is likely combustion and gasification technologies will become increasingly attractive in WA. Awareness will improve as more local examples are built.



Figure 2.2.2 Ankur gasification system providing 500kW electrical power to a site in the United States

2.3 Anaerobic digestion

2.3.1 Processes

When moist organic materials such as manure, food or agricultural wastes are placed in a warm, sealed tank with limited air they will be broken down by naturally occurring micro-organisms and a combustible gas will be produced. It is called biogas and typically contains 50 to 70% methane, with the rest being mostly carbon dioxide. Biogas is of value because it can be burned to produce energy for heating, lighting, cooking and transport.

Although the biochemical pathways involved in anaerobic digestion are complex, the process is frequently described in a simplified sequence of four stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Different groups of micro-organisms are involved in each stage.

In the hydrolysis stage long-chain carbohydrate, protein and lipid molecules are broken down by enzymes secreted from naturally occurring bacteria and fungi. The products include sugars, amino acids, long-chain fatty acids and glycerine. In the acidogenesis (acid-forming) stage the products of hydrolysis are converted into short-chain fatty acids, alcohols, carbon dioxide, hydrogen and other compounds.

Specialised micro-organisms take the products of the second stage and convert them into acetate in the acetogenesis stage. Finally, during methanogenesis specialised microbes called 'archaea' convert acetate, hydrogen and C1 carbon compounds into methane. Methane-producing archaea are among the oldest living organisms on the earth, having evolved at a time when oxygen was not present in the atmosphere.

Figure 2.3.1 shows a simplified representation of the overall anaerobic digestion process. Note that in this diagram the term 'fermentation' has been used instead of 'acidogenesis' for the second stage.

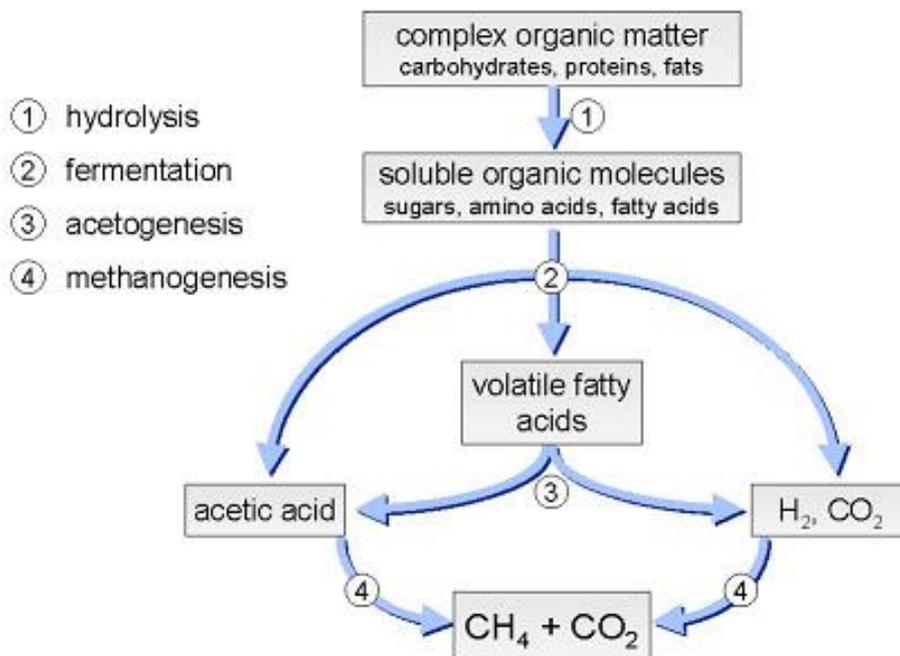


Figure 2.3.1 Anaerobic digestion process

2.3.2 Conversion technologies

The tank used to make biogas is called a biogas digester and these have been developed at scales ranging from household, through farm scale to industrial scale. At the household scale a single tank may be all that is necessary to generate and utilise the gas. As the scale increases more equipment is needed to handle the increasing volumes of feedstock to be supplied to the digester and even greater volumes of liquid and solid by-product to be removed.

In general the following equipment may be needed:

- mixing tank or pit with mixer/macerator to chop up the feedstock and mix it with water into a pumpable slurry
- the digester itself which can be an above ground tank or covered pit or pond; sometimes two tanks are used with conditions in each optimised to different stages of digestion
- mixer/s inside the digester or recirculating pump
- floating cup gasholder (i.e. inverted smaller tank inside a bigger tank), flexible or inflatable membrane to store the gas produced; the gasholder can be integral with or separate from the main digester
- method of heating the digester to operating temperatures which do not use excessive biogas or fossil fuel inputs (e.g. solar hot water or waste heat)

- blower or compressor to deliver the gas at a steady rate to the burner
- burner or boiler suitable for the intended application
- suitable engine or turbine generator if electricity is required (the waste heat can be used to keep the digester warm)
- pipework, pumps, valves to transfer the feed slurry to the digester, remove sludge and liquid effluent, transfer biogas to the end use and flare
- filters or scrubbers to clean the gas or remove carbon dioxide to improve the energy content
- flare to burn biogas when it is being produced but not used for heat or generating electricity.

Suitable situations for anaerobic digestion arise where there is a demand for heat and/or electricity and also an availability of putrescible waste. Silage is sometimes used and digests well because the initial stages of digestion are commenced outside the digester. High carbon dry biomass such as straw digests slowly on its own, but when mixed with high nitrogen putrescibles the digestion of both is improved (as in backyard composting). Biogas digesters can be installed in homes, farms, villages, dairies, piggeries, sewage treatment plants and waste processing facilities.

Millions of small biogas digesters provide energy for cooking in Africa, India, China and other Asian countries. China has an estimated 30 million household biogas digesters; India, 4 million; Nepal, 200 000; and Bangladesh, 60 000. In some European countries biogas is widely used in agricultural regions to supply heat and electricity. The leading country in this respect is Germany which has over 6000 large agricultural biogas digesters. Sweden has a significant portion of its transport sector fuelled by biogas. The biogas comes from sewage treatment facilities, farms and landfill sites.

In Australia the use of biogas digesters is small but growing. On the east coast there are a handful of digesters at sewage treatment facilities, piggeries and one facility in Sydney which uses fruit and vegetable waste to produce electricity for export to the grid. In WA there is a biogas digester at Woodman Point sewage treatment facility which has been producing electricity from waste activated sludge for over a decade.

There are also two biogas plants presently under construction or commissioning in Perth. One at Shenton Park waste facility is processing the organic portion of household waste and producing electricity for onsite use and export to the grid. The other, at Richgro Fertilisers in Jandakot, will use 35 000t/y of organic waste from hotels, supermarkets and markets to produce electricity for onsite use and export to the grid. Waste heat from the generator will be used to heat nurseries and thereby improve yields. The solid residue from the digester will be turned into commercial fertiliser products.

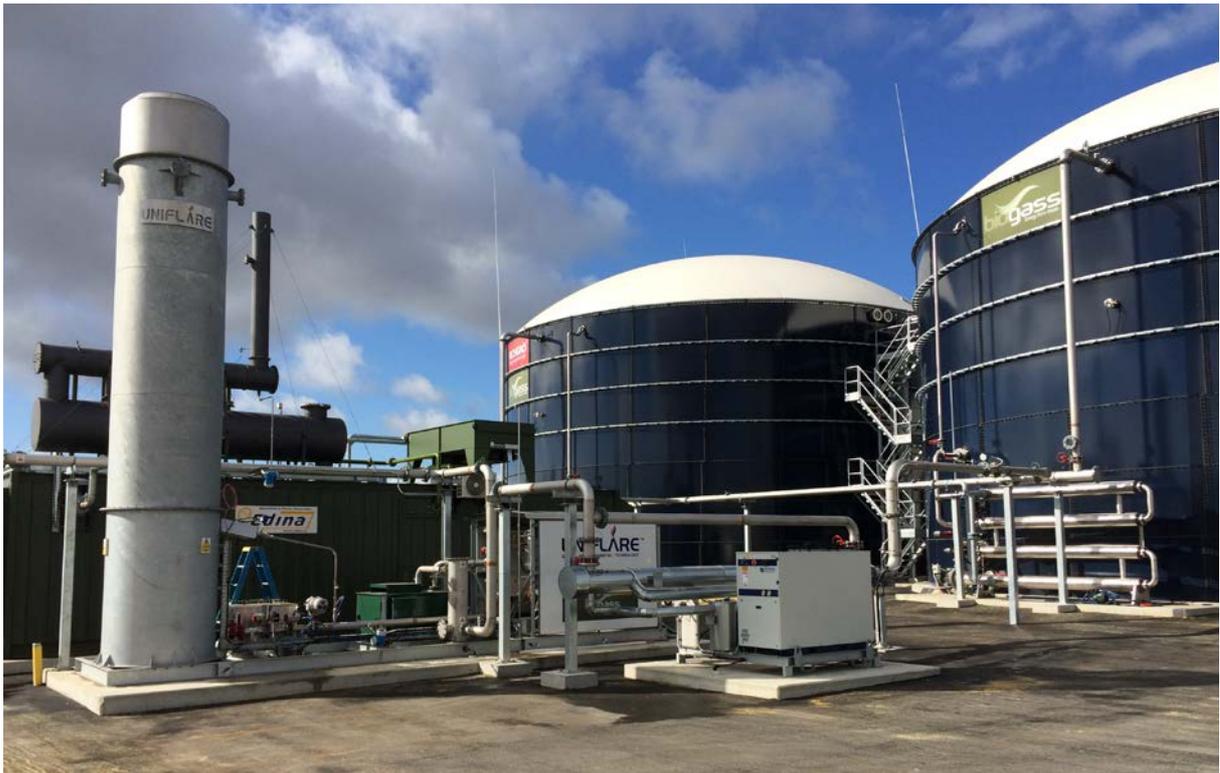


Figure 2.3.2 Richgro biodigester

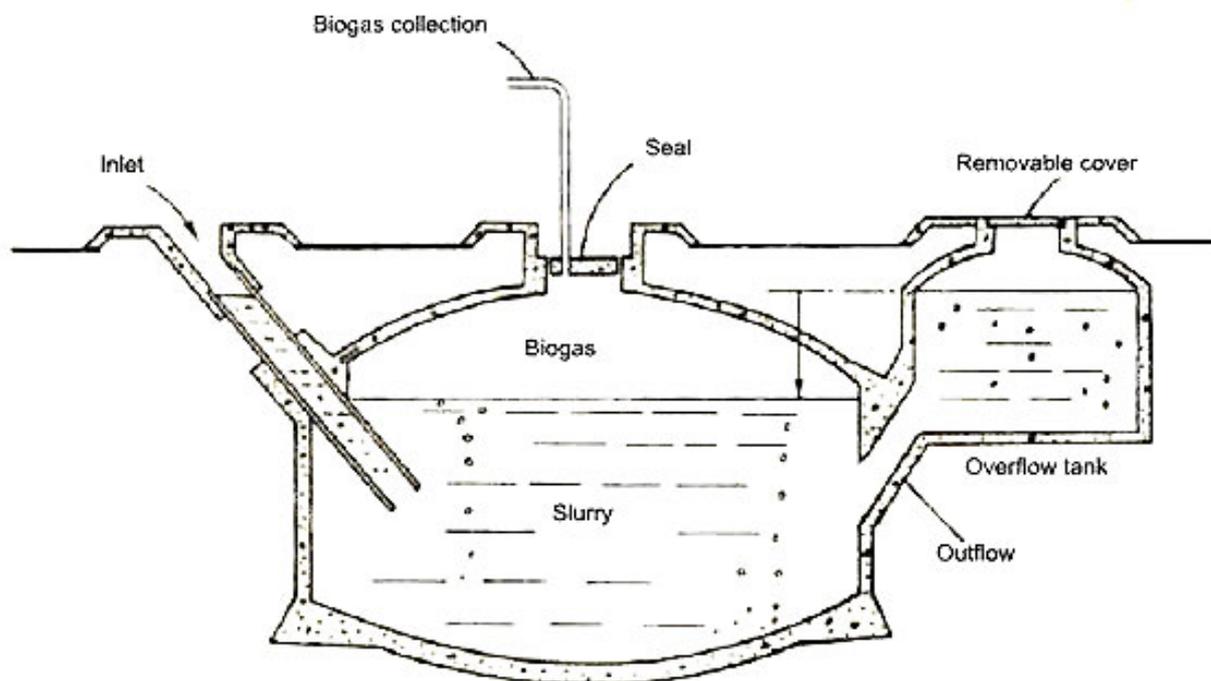


Figure 2.3.3 Underground digester design used by China's 2003–2010 National Rural Biogas Construction Plan to increase biogas use by 11 million to a total of 20 million households and to make one in 10 farmers' households a biogas user. Some digesters are designed to automatically receive both human and pig waste (source: [Institute of Science in Society](#))



Figure 2.3.4 Jühnde, a 'bioenergy village' in Germany, has completely replaced its fossil energy use for heating and electricity with bioenergy from agricultural wastes. The domes are biogas digesters which use local crops and waste to produce electricity and heat for a 5.5km hot water grid. In Germany there are over 6000 large agricultural biogas digesters

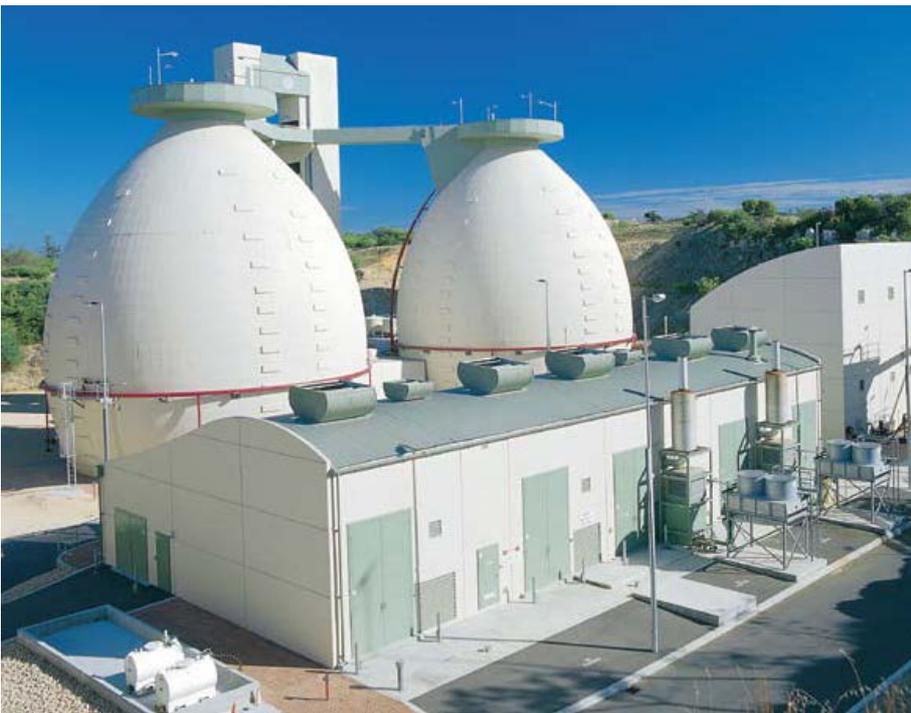


Figure 2.3.5 Egg-shaped biogas tanks at Woodman Point sewage treatment plant, Perth

2.3.3 Environmental impacts

The environmental impacts from biogas include those associated with the discharge of liquid and solid effluent from the digester or covered pond, and those associated with combustion of the biogas itself, although the digestion of the waste also significantly reduces odour issues associated with traditional effluent treatment options.

Since biogas digesters are also a form of effluent treatment, the solid and liquid products produced should be beneficial to the soil and not produce any adverse effects. Nevertheless it is still important to test the effluent and soils, and where necessary obtain environmental approvals, to ensure waterways are not contaminated by nutrient run-off. Health department approval and mandatory pathogen testing may also apply, especially at human sewage facilities.

Gas scrubbers and clean-burning combustion equipment with pollution controls are generally included in modern biogas equipment. From a greenhouse perspective biogas digesters have positive impact because they convert methane, with a global warming potential (GWP) of about 23, to carbon dioxide (GWP of 1). If the biogas is used to generate heat and/or electricity then the reduction in greenhouse gases is improved further because the use of an equivalent amount of greenhouse intensive fossil fuels (LPG, natural gas or coal) is also prevented.

2.3.4 Financial viability

Until recently it was considered in Australia that biogas was only financially viable at the large scale associated with centralised sewage treatment facilities. However, in recent years there has been a growing interest in the use of biogas at dairies and piggeries. In dairies the biogas can be burned to provide hot water for wash-down and sterilising equipment. In piggeries it can be used for heating farrowing sheds.

Factors which determine the financial viability of biogas projects at dairies and piggeries include the number of livestock, the time each day they spend on concrete or in stalls, the climate, the retail price of gas and electricity and any government incentives which may be available. International and Australian case studies show that generally speaking biogas projects are more likely to be viable when there are around 1000 cows or more for indoor animal dairies, 500 sows or more for piggeries (approximately 5000 pigs for grow-out piggeries). They are less likely to be viable when the livestock spend a lot of time grazing pasture because the manure is difficult to collect. There are approximately 16 dairies with 1000 cows or more and 16 piggeries with 5000 pigs or more in the south-west of WA, which suggests there could be a number of suitable sites for livestock based biogas projects in WA.

Recently an additional income stream has become available to biogas projects due to Australian Government initiatives to provide credits for reductions in greenhouse gas emissions caused by flaring biogas. These credits are not sufficient to justify flaring biogas alone but they do provide an additional incentive. For a solid financial case, the biogas needs to be used for heat and/or electricity generation. In suitable situations it can take approximately six years for the initial capital expenditure to be repaid in energy savings. The cost of biogas plants is decreasing as more companies enter the market, and the cost of electricity and gas will probably continue rising, so it is likely the business case for biogas projects in WA will continue to improve.



Figure 2.3.6 Covered pond and flare at a piggery in Grantham, Queensland



Figure 2.3.7 Enjoying the benefits of biogas heating: hot water coils are cast into concrete slabs in the farrowing shed (Grantham, Queensland)

2.4 Fuel ethanol

Ethanol, or ethyl alcohol, can be used as a liquid fuel for transport, heating or electricity production. It can be blended with petrol up to 10% and used in existing petrol engines. With modifications to the fuel system up to 100% ethanol can be used. The most convenient configuration is a 'flexi-fuel' vehicle which can run on any combination of petrol and ethanol. Conversion kits are available for many makes of petrol vehicles.

Fuel ethanol has traditionally been made from sugar- or starch-based crops (sometimes referred to as 'first generation ethanol'). There are crops suited for tropical (sugar cane), subtropical (sorghum) and temperate (corn, sugar beet) climates.

Fuel ethanol can also be made from cellulose, the fibrous part of plants (referred to as 'second generation ethanol'). Cellulosic ethanol has been drawing increasing attention because it is possible to use the non-food portion of food crops (wheat or rice straw, corn stover, sugar cane bagasse), other waste streams (paper, cardboard, woodchips, municipal solid waste) or non-food cellulosic crops (grasses, canes). This can eliminate the need for additional land and fossil fuel inputs required to grow specialised sugar or starch crops.

2.4.1 Conversion process and technologies

Making ethanol from biomass is fundamentally a biological process. With limited oxygen, yeasts ferment sugars into ethanol and carbon dioxide. The main differences between fuel ethanol and beverage alcohol are that for fuel ethanol taste is not a consideration in the selection of feedstock (inedible feedstocks can be used), and (undrinkable) high ethanol concentrations are required. The specific details of conversion processes vary according to feedstock but in general they include the following steps:

Pretreatment

The biomass is physically reduced by pulping, grinding, milling or chopping. For cellulosic ethanol additional thermal or chemical treatment is used to make the cellulose more accessible. Water is added and a slurry is formed. Physical pretreatment is usually carried out with an appropriate milling machine or grinder. Thermal and chemical pretreatment take place in a pressurised reactor.

Hydrolysis or saccharification

Large starch or cellulose molecules are broken down into fermentable sugars using a combination of high temperatures and specialised micro-organisms or the enzymes obtained from them. The use of high temperatures not only facilitates hydrolysis but also helps to sterilise the mixture. Contaminating bacteria can reduce ethanol yields by consuming sugars and producing unwanted by-products. An advantage of sugar-based feedstocks, such as molasses (from sugar cane) or fruit, is that they already contain simple sugars so this step is not required, resulting in a simpler overall process.

Fermentation

Yeasts are added to the hydrolysed 'mash' and left to ferment for a few hours to a few days as they consume the sugars and produce ethanol. Typical fermentation temperatures are between 30°C and 40°C. Some form of gentle mixing is generally employed. Saccharification and fermentation can either be carried out in a single stirred tank or vessel or in separate vessels. Separate saccharification and fermentation allow for better control and optimisation of individual processes which can be carried out at different temperatures, different pH values and mixing regimes. Combined or simultaneous saccharification and fermentation, in a single vessel, requires a compromise on optimum conditions of saccharification versus fermentation, but can be more efficient overall because the end products of saccharification are removed as they are produced, allowing the saccharification reactions to proceed at a faster rate.

Distillation

When the fermentation is complete, the resulting 'beer' typically contains 10 to 15% ethanol for sugar- or starch-based feedstocks, or 4 to 6% for cellulosic feedstocks. Ethanol is separated from water and other unwanted compounds by distillation in one or two distillation columns. The maximum ethanol concentration obtainable by conventional distillation is 96%. The vapour is removed and passed through a condenser where it returns to the liquid state and is collected. Remaining in the vessel at the bottom of the column is a liquid/solid mixture with most of the ethanol removed. Distillation is carried out in one or two columns (tall thin vessels) containing plates or packing which enable the continuous condensation and re-vaporisation of ethanol-water vapours. The water trickles down and the ethanol vapours rise, so that the overall ethanol concentration increases further up the column. The ethanol vapours from the top of the column are then condensed into liquid with a water-cooled condenser. A low ethanol concentration liquid 'stillage' (as well as some solid residue) remains at the bottom of the column.

Additional processing

Quality control, licensing or excise may dictate a higher purity than that obtainable by conventional distillation. Further dehydration can be carried out by the use of molecular sieves or special distillation techniques. Australian Government proposed quality standards for fuel grade ethanol specify a minimum purity of 94%. The standards also specify the ethanol be denatured, which means substances are added to render it poisonous to discourage recreational drinking.

The process for making fuel ethanol from traditional sugar- and starch-based feedstocks is well-established. There are hundreds of medium and large scale operating facilities around the world. The biggest ethanol producing countries are the United States, which produces most of its ethanol from corn, and Brazil, which uses mainly molasses, a by-product of making sugar from sugar cane. There are three ethanol refineries in Australia which are summarised in Table 2.4.

Table 2.4 Ethanol refineries currently operating in Australia

Location	Capacity (ML/y)	Feedstock
Sarina, Qld	60	Molasses
Dalby, Qld	80	Sorghum
Nowra, NSW	300	Residual flour

There are also a number of (second generation) cellulosic ethanol pilot and demonstration plants around the world (including two in Australia), producing in the range of 0.1 to 5ML/y and a rapidly increasing number of commercial scale plants under development (20 to 75ML/y).

One popular criticism of ethanol as a transport fuel is that it takes too much fossil fuel energy to make it. In some cases it has been claimed that more energy is needed to produce the ethanol than is contained in it. However, many analyses have shown the opposite, and energy yield ratios (output:input) significantly greater than one have been widely reported.

The value of the energy yield ratio depends not only on the feedstock but also on the situation, a point highlighted in Table 2.5 by the sharp contrast between the values for the molasses ethanol plants. The vast difference is due to the Indian distillery being fully integrated into a sugar mill where excess steam is used and transport of feedstock would be negligible, whereas the South African distillery was remote from sugar mills and was utilising coal and grid electricity.

Table 2.5 Feedstock effect on energy yield ratio (source: Von Blotnitz & Curran 2007)

Feedstock and country	Energy yield ratio
Sugar cane, Brazil	7.9
Sugar beet, United Kingdom	2.0
Corn, United States	1.3
Molasses, India	48.0
Molasses, South Africa	1.1
Corn stover, United States	5.2
Wheat straw, United Kingdom	5.2
Bagasse, India	32.0

To reduce fossil fuel consumption used in the production of ethanol, renewable energy can be used. Solar hot water, photovoltaics (solar electric), biogas and combustion of processed solid residues can provide process heat and electricity.

The liquid residue from distillation columns (stillage) has a high organic loading and is a good source of energy for biogas digesters, as is manure. When grains are used as feedstock, the solid residue is a high quality livestock feed ('distillers' grains'). Integrated ethanol distilleries can achieve high efficiencies when they are located close to the source of feedstock and use by-products or surplus energy from an adjacent facility such as a sugar refinery, brewery or flour mill.

Cellulosic ethanol production has some drawbacks compared to making ethanol from sugar- or starch-based feedstocks. Cellulose is more difficult to break down into simple sugars than starch so pretreatments involving physical, chemical or thermal processes can be energy intensive. The 'beer' from a cellulosic ethanol fermentation has a low ethanol concentration (4 to 6%) so significantly more distillation energy is required compared to conventional ethanol. However, the heat for distillation can be obtained by burning lignin, which is separated from the cellulose during pretreatment. Enzymes which break down cellulose are more complex and energy intensive to produce than enzymes to break down starch (and none are required for sugar-based crops).

2.4.2 Environmental impacts

The environmental impacts of ethanol production and use can be categorised into impacts on greenhouse emissions, impacts on air quality and other environmental effects.

Since the crops for ethanol feedstocks draw carbon from the atmosphere when growing, greenhouse emissions are reduced compared to using petrol. While there is broad consensus on this point among the life cycle studies (Quirin et al. 2004; Farrel et al. 2006; Von Blottnitz & Curran 2007), the degree of reduction reported varies widely, from around 10 to 100%.

It is even possible to achieve better than 100% reductions in greenhouse emissions, meaning that over the full life cycle (including crop growth, harvesting, processing into fuel and combustion) there is a net sequestration of carbon due to enhanced soil carbon levels. It is referred to as a 'carbon negative' process, and can be achieved using specialised cellulosic crops grown on marginal land with low fossil fuel inputs (Tilman et al. 2006).

The findings on air quality impacts of ethanol production and use are mixed (Brown 2008), with some emissions reportedly decreasing (particulate matter) and others reportedly increasing (hydrocarbons, aldehydes). In some cases there are mixed findings on the impacts of using fuel ethanol on the same pollutants ([carbon monoxide, nitric oxide and nitrogen dioxide [NO_x]) with some reports claiming a decrease, and others an increase in emissions compared to 100% petrol.

In a similar manner to energy ratios and greenhouse impacts, air quality impacts depend on many factors including fuel composition, engine technology and practices associated with crop growth and processing into ethanol. For example, it has been common practice in Brazil to burn sugar cane fields prior to harvest in order to remove the dried leaves, which increases volatile organic compound (VOC), NO_x and carbon monoxide levels (Tsao et al. 2012). So while there is broad consensus that the use of ethanol blends up to 100% can have a positive overall effect on air quality, in order for the benefits to be realised it is essential to ensure proper design, monitoring and the use of environmentally sound practices throughout the life cycle of the fuel.

There are also pollutants associated with the fossil fuel inputs used to grow, harvest and transport the crops (fertiliser, pesticides, machinery fuel). For second generation (cellulosic) ethanol based on the residue of a food crop, these inputs would normally be allocated to production of the food crop (e.g. wheat, corn, sugar) rather than to ethanol production because food is the primary reason for the crop.

The emissions associated with the use of the residue (e.g. straw) are consequently less than those associated with the use of a sugar- or starch-based crop. It is for this reason, as well as the limited availability of additional land for dedicated ethanol crops, that cellulosic ethanol is often reported as the renewable transport fuel most viable in the long term (Farrel et al. 2006; Hill et al. 2006).

Additional impacts may come from the disposal of waste water and solid waste from distilleries. These impacts can be reduced and productivity enhanced by reusing the waste streams for energy or other products. Liquid stillage from distillation columns is a good feed for biogas digesters. Solid residue from starch ethanol is a good stockfeed, and solid residue from cellulosic ethanol (lignin) can be burned to provide heat for the conversion process. Alternatively solid residues can also be fed to a biogas digester, composted aerobically, or applied to soils directly.

2.4.3 Viability in WA

DAFWA modelling of the Wheatbelt and Great Southern regions of WA shows that, after allowing for the retention of sufficient straw to maintain healthy soil, significant quantities of cereal straw (wheat, barley, oat) remain available for other uses (Table 3.1).

The conversion rate from straw to ethanol is around 300 litres per tonne. Existing and developing commercial scale plants process in the range of 50 to 250 000t/y of cellulosic feedstock to produce 20 to 75 million litres of fuel ethanol per year. Table 3.1 suggests there would be a number of suitable locations for such a processing facility in WA. Not only could it result in additional income streams for grains producers, it is also possible that such plants could be owned and operated by farmers' cooperatives, as are several ethanol plants in the United States.



Figure 2.4.1 Ethanol plant in Nowra, NSW, which produces 300ML/y of fuel ethanol from waste flour



Figure 2.4.2 The pre-hydrolysis reactor at the Mackay Renewable Biocommodities Pilot Plant, a pilot-scale facility owned and operated by Queensland University of Technology for research and demonstration of the conversion of lignocellulosic biomass, such as sugar cane bagasse, into cellulosic ethanol

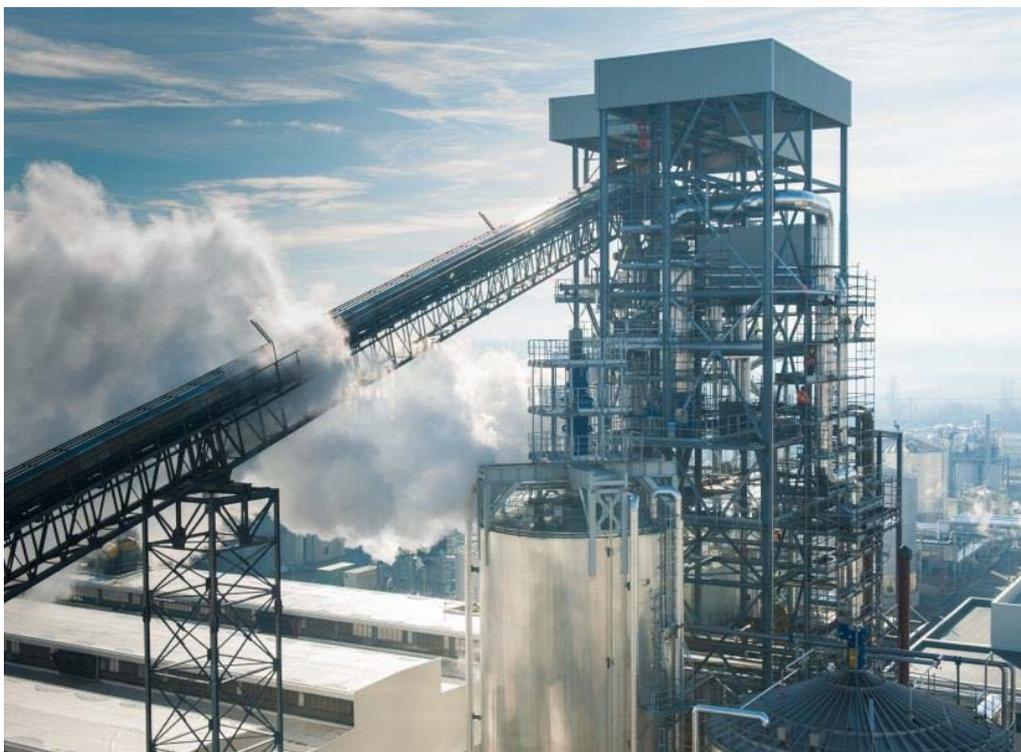


Figure 2.4.3 Full scale commercial cellulosic ethanol facility in Crescentino, Italy. The facility is designed to process 225 000 tonnes per year of agricultural residue and specialised cellulosic crops into 75 million litres of fuel ethanol

3 Current status of biofuels in WA, Australia and the world

3.1 Past project outcomes

The Biofuels Taskforce (2007) outlined a number of projects that had been proposed or were in development. None of the projects mentioned in the report eventuated and we felt it was important to analyse the reasons for the failure of these and other mooted projects in order to help future project proponents avoid a similar fate.

3.1.1 Kwinana BP ethanol refinery

The proposed ethanol plant that was to be built in Kwinana failed to proceed after BP pulled out of the 2006 memorandum of understanding with Primary Energy Pty Ltd, the company that had wished to construct and operate the facility. BP claimed that the project was no longer seen as commercially viable, but it is surprising that their due diligence analysis would not have alerted them to this earlier in the process. The plant under consideration was first generation technology planning to use wheat and other grains as a feedstock, which was affected by the fuel versus food debate. Cancelling the project may have been the right decision since second generation technology is now in full commercial operation around the world.

3.1.2 AGL steam boiler

Energy company, AGL, runs one successful steam boiler project that burns waste macadamia shell from Suncoast Gold Macadamia in Glanmire, in south-east Queensland. While they have had success with the Glanmire facility, other projects they have attempted have been unsuccessful as they were unable to run 24 hours a day, five days a week, and the costs involved to buy in their biomass material and/or transport the biomass material to site have made the process too expensive. In order for them to have gone ahead, the electricity produced would have had to be sold at a high enough price (e.g. similar to European electricity prices), the avoided costs needed to be high enough (e.g. the cost of disposal of the biomass material is high enough and is avoided by installing the plant) or if they received subsidisation.

3.1.3 Colac Biogas Plant

This project planned to develop a biogas plant and cogeneration system to process organic waste generated from a number of food processing industries within the south-western region of Victoria. It included grease trap waste, fish waste from a nearby fish processor, paunch from a local abattoir, waste broiler chickens, and waste milk and whey from cheese making. The infrastructure was to be located adjacent to the Colac abattoir. Surplus generation capacity was to be sold to the grid. The estimated cost was approximately \$6 million, with \$1.55 million coming from a state government grant. It would have diverted up to 25 000t/y of organic waste from landfill, recycle and sell up to 925 tonnes per year of recovered solids from the digester as an organic fertiliser and reduce the greenhouse gas emissions of the abattoir by up to 90%.

This project failed to eventuate due to several factors. It was difficult to get the waste producers to agree to a gate price for delivering their waste products as they wished to remain flexible if other options arose. AGL announced that the natural gas price would go up by about 26% over the following 12 months to bring it in line with export pricing. As the system was designed to run on both natural and biogas, this added

extra financial pressure. The Renewable Energy Certificate (REC)'s price was very volatile due to an oversupply of certificates from solar energy. Finally the Victorian government decided to leave a coal fired power station open, which created an oversupply of energy that pushed prices down.

3.1.4 Narrogin Integrated Wood Processing plant

A 1MW integrated wood processing (IWP) demonstration plant was completed in Narrogin in 2006, but is not functional in 2014. Western Power lost the drive to continue the process after contributing half the \$20 million spent on the Narrogin plant mainly due to technical difficulties. Analysis of the reasons for not proceeding suggests the decision to attempt to build a plant integrating three separate technologies was overly ambitious. Had the proponents commissioned each technology separately with the ultimate aim of integrating the three once each part was proven, this plant may have been viable.

3.1.5 Summary

While there are many successfully operating bioenergy projects both overseas and in Australia, there have also been failures. Some projects which have been planned have been cancelled due to changing government policies or market conditions. Others have been built but failed to operate properly due to incomplete or faulty design, construction or commissioning procedures. In other cases nothing went wrong, but the funding bodies underestimated the time it would take to iron out all the operational difficulties associated with scaling up from pilot to commercial scale, and therefore withdrew funding support.

When a new technology is scaled up from pilot or demonstration scale to commercial scale, or an established technology moves to a new region, it is common for there to be some failures before there will be successes. To minimise the risk of failure, the following are some precautionary recommendations from past projects, overseas and local:

- review the claims, proposals, technical data and detailed designs from suppliers using appropriately specialised independent engineers and include in the costing
- include all capital costs: processing equipment, interconnecting pipework, valves, instrumentation, controls, electrical connections, civil, structural and building works
- include all operating costs: feedstock supply and transport, other materials, labour and energy required to drive the process
- test the proposed feedstock with the actual conversion technology to be used and test the resulting product for compliance with market requirements
- investigate the long-term reliability of the fuel supply chain. Have backup feedstock options in case the planned feedstock ceases to be available (e.g. syngas and cellulosic ethanol can be produced from straw or forestry wastes). This is especially important when local feedstocks have overseas markets. The best locations for processing facilities are where the biofuel will be used onsite, or where feedstock presently has no market in the region and the new processing facility is creating one
- understand and include the cost of all regulatory processes (e.g. local council, Department of Environment and Regulation, Western Power, WorkSafe)

- include contingency for changing economic conditions such as exchange rates (for capital equipment) or value of feedstocks (operating costs). The cost of presently low value waste streams may increase as the uptake of biofuels conversion processes increases
- allow adequate time for proper detailed design and independent design review (do not try to 'fast-track' new processes)
- allow plenty of extra commissioning time for unforeseen difficulties
- design, build and commission novel designs with several unit operations producing a number of different energy streams and other products in stages
- allow for changes in government policy and mandates
- allow for higher financing costs for (locally) unproven technologies.

3.2 Relevant international activity and examples

The reasons for switching to renewable fuels include reducing waste streams, reducing reliance on imported fossil fuels, promoting regional growth and reducing greenhouse gas emissions. These drivers have seen the global production of biofuels accelerate in recent years. In the United States, for example, there are an estimated 239 operational anaerobic digestion systems working at commercial livestock farms, 193 of them on dairy operations.

An example of a biogas plant on the same scale that would be viable in Australia is the Butler Farms piggery operation located in North Carolina. The farm has been in operation since 1995 and has upgraded from two covered lagoons (covers installed in 2008) to a covered lagoon anaerobic digester. In 2012 the new covered lagoon digester was installed and the digester began operation. The operation has approximately 8000 head of swine that feed the anaerobic digester. Currently no codigestion is conducted; however, the farm is considering codigestion of a food waste feedstock: potato sludge. The food waste feedstock will be hauled to the farm in tanker trucks. The total cost of the digester was estimated to be US\$550 000 to US\$650 000. There was an estimated payback period of eight to 10 years, with the expectation that the equipment has a life of 15 to 20 years.

The United Kingdom has experienced a 28% growth in renewable fuel and an emissions cut of 1.9% in the last year according to the Department of Energy and Climate Change (DECC). The generating capacity of renewable energy is 19.4GW. In 2012 the United Kingdom produced nearly 400 million litres of biofuels, which accounted for 2.4% of fuel usage on its roads. As of late 2013, there were approximately 130 anaerobic digestion facilities, mostly on-farm. In 2010 biogas was injected into the gas grid for the first time. Sewage from over 30 000 Oxfordshire homes is sent to Didcot sewage treatment works where it is treated in an anaerobic digester to produce biogas, which is then cleaned to provide gas for approximately 200 homes.

Another biogas example in the United Kingdom is Staples Vegetables which uses its waste vegetables as feedstock for an anaerobic digester. The gas generated is used to produce electricity, heating and cooling. With a capacity of 3MW the biogas plant is capable of producing 24 million kWh of electricity every year. Staples Vegetables uses a large part of the electricity production for its own needs, with enough surplus delivered as green electricity to the National Grid to power approximately 3000

households. A large part of the heat generated from the electricity production is used for cooling the company's vegetable stores by using an absorption chiller, and there is also sufficient surplus to heat the company offices during winter. The digested biomass is turned into a valuable biofertiliser, rich in nitrogen, which will be replacing the mineral fertiliser used on Staples Vegetables' fields.

New Zealand currently produces about 8% of its total energy requirements from biomass energy (mainly biogas and woody biomass). There are approximately 20 companies working with alternative fuels in New Zealand over a variety of different applications.

There is a demonstration truck in New Zealand that runs on biogas produced from landfill. The truck is in operation 250 days a year and substitutes 12 000 litres of diesel with biogas. Six biogas projects have been commissioned in New Zealand, with one of the most successful being that of the Lepperton piggery. Following complaints concerning the odour emanating from their two open sludge ponds the operators covered their anaerobic ponds, thus capturing the biogas. The system currently produces about 300 cubic metres of biogas every day, which is compressed, cleaned and used to power their existing 40kW generator. This system produces about 50% of their electricity needs, they no longer experience any blackouts and the system also produces heat that is used to warm the piggery. The piggery owner expects to recoup the NZ\$120 000 investment in approximately three years.

Germany has over 6000 on-farm anaerobic digestion facilities.

3.3 Current Australian projects

There are now a significant number of biomass energy projects operating successfully across Australia at a commercial scale. Some examples follow.

3.3.1 Berrybank Farm Piggery

Berrybank Farm Piggery is located in Windemere, Victoria. It was originally opened in 1970. In 1991 the owners invested \$2 million installing a biogas system on their farm to collect methane from the piggery effluent and convert it into electricity for use for their own processes and for selling the excess back into the grid. By 2011 they had expanded their pig numbers to over 20 000 and had also started generating potting mix and fertiliser from the system. Daily output of electricity is 2900kW. This system allowed the piggery to remain at its current location, while managing effluent and odour.

Creating their own electricity, reducing water use by about 100 000 Litres a day (L/d) and deriving income from selling surplus electricity to the grid as well as selling their potting mix and fertilisers has resulted in approximate annual savings of \$425 000. The savings created through the production of their own fertiliser, which reduced their expenses on chemical fertiliser by about \$250 000 a year, plus the profits received through selling the potting mix and fertiliser, contributed to a shorter payback period than if they had relied on electricity savings alone. The payback period for this project was seven years. Based purely on the savings related to electricity generation the payback period may have been closer to 20 years. The biogas system has also saved 740 tonnes of carbon dioxide emissions a year.

The farm has plans to increase the efficiency of their system by using the heat generated by the biogas production to fit gensets with exhaust heat exchangers and a temperature control system, utilising this to heat the boilers that maintain the

temperature in the biodigester. Retrofitting thermal heat pads to farrowing pens to ensure piglet survival during cold months will replace a total of 492 heat lamps (175 watt each). Using an absorption chiller to convert excess heat in summer months for cooling will prevent heat related deaths. This could also deliver cool air into the grain silos to keep the temperature below 17°C and therefore inhibit weevil infestation.

3.3.2 Australian Tartaric Products

Australian Tartaric Products (ATP) in Mildura, Victoria, produces tartaric acid used in wine production. A major cost in their industrial process was the fuel required to produce the steam required for their distillation process. They commissioned a thermal plant that runs on 90 000 tonnes of waste grape products such as spent grape marc, grape lees and centrifuge by-products that are left over from the tartaric acid production process. Previously, this waste was stockpiled and sporadically sold as stockfeed.

This system cost \$7.5 million to build. Forty thousand dollars of that amount came from an Australian Industry Group – EPA Victoria grant, and \$1.8 million came from the Victorian Government's Regional Infrastructure Development Fund (RIDF). The remaining \$5.6 million was financed by ATP. This plant produces 12 tonnes/hour of steam that is used to distil ethanol and produce tartaric acid. During low processing periods the steam then powers an organic Rankine cycle (ORC) turbine that produces up to 400kW of electricity for the factory's internal consumption. This system has been estimated to reduce their overall energy costs by \$1.52 million annually, reduce their greenhouse gas emissions by 72% (9813 tonnes), completely cut their use of fossil oils and reduce their LPG use by 69%. The payback period on this system has been estimated at four and a half years. The value of using the spent grape waste as a biofuel is 10 times the value they received from it when it was being sold as stockfeed.

3.3.3 Suncoast Gold Macadamias

Suncoast Gold Macadamias is a macadamia processing plant located in Gympie, Queensland. Approximately 5000 tonnes of nutshell waste is produced each year. Previously this waste was sent to landfill or sold on as garden mulch. As of 2003, a 6MW steam boiler costing \$3 million was commissioned and the waste macadamia shells used to fuel it. This was motivated by the Australian Government's imposition of a legal obligation for electricity providers to be generating 2% of their power from renewable sources by 2010. It currently produces 9.5GWh/y, of which 1.4GWh are used onsite and the remainder exported to the grid. Over 9500 tonnes of greenhouse gas emissions are avoided annually using this system.

3.3.4 Reid Brothers Sawmill

Reid Brothers Sawmill in Yarra Junction, 70km north-east of Melbourne, were paying \$1200 a month to send their waste timber to landfill. In 2005 they installed a wood burning system costing \$360 000. This system burns 70 to 80 tonnes of mill waste weekly (mainly sawdust, clean-up material, green material and occasionally material from other timber processing businesses).

The benefits they have received from installing this system include saving \$270 000 a year on LPG and saving \$14 000 from no longer having to deliver their waste wood products to landfill. This resulted in a payback period of less than two years.

Reid Brothers also state that, as they already had infrastructure onsite that could be used to move the biomass from the mill to the burner, this reduced the installation costs. Sites that did not already have the necessary infrastructure such as sheds and concrete pads would expect higher initial capital expenses.

3.3.5 Gelliondale Nursery

Gelliondale Nursery 200km south-east of Melbourne installed a 1.5MW thermal generator in 2010 for their greenhouse powered by sawdust, in order to reduce their running costs and their dependence on fossil fuels. The furnace generates 100% of the heating requirements of the site. The wet sawdust is bought from nearby sawmills for approximately \$30 000 per year. The cost of a comparable LPG system would be \$200 000 per year, so they save \$170 000 a year on fuel costs and about 400 tonnes of greenhouse gas emissions. With the initial expenditure being approximately \$500 000, the payback period was three to four years. The system that was installed has a flexible design that would allow them to burn other biomass such as olive pits.

3.3.6 Murphy Fresh Hydroponics

Murphy Fresh Hydroponics, 190km north-east of Melbourne, is one of Victoria's largest hydroponic tomato growers. They commissioned an approximately \$600 000 6MW thermal generator system. Every year they buy \$450 000 of waste hardwood logs from local sawmills, a saving of 50% from their previous burning of coal briquettes. They had previously considered installing an LPG system and while the capital cost of installing a biomass system was about eight times more expensive than LPG, they save \$1.65 million a year on fuel costs by using biomass over LPG. The payback period was approximately two years.

3.3.7 Murray Goulburn

Dairy food company, Murray Goulburn in Leongatha, 130km south-east of Melbourne, partnered with Quantum BioEnergy to install two biogas powered turbines with 760kW capacity to utilise the biogas produced from their waste treatment system. The system cost \$1.82 million over the 18 months of construction, with \$140 000 of that coming from Sustainability Victoria's Renewable Energy Support Fund. The 760kW system provides enough electricity for all of their internal processes. The project had a payback period of approximately three years resulting in savings of around \$600 000 per year, including income from RECs.

3.3.8 Blantyre Piggery

Blantyre Piggery in south-eastern New South Wales invested \$1 million in a biogas generator to recover the methane produced by its pigs' effluent in order to generate 100% of the facility's electricity. The generator also produces heat which they use to warm the sheds the young piglets are housed in. They are currently saving \$15 000 a month on electricity and gas, and earn approximately \$5000 a month from excess power sold back into the grid. They have also earned nearly 9000 Australian Carbon Credit Units (ACCUs) of which, as of 2012, they were receiving approximately \$15 a tonne for each carbon credit. The payback period was about one and a half years if ACCUs were taken into account, but even without them it was only about three years.

3.3.9 Darling Downs Eggs

Darling Downs Eggs, in Pittsworth near Brisbane, has partnered with Quantum Energy to construct an anaerobic digester that will create biogas from chicken manure and other organic wastes in order to produce electricity for the company's processes. The \$2.86 million investment is estimated to return power savings of up to \$250 000 in the first year, with 100% of their electricity needs being provided from the system during off-peak times. They also estimate a reduction in carbon dioxide emissions of 1000t/yard and methane by 6000t/y. The system is currently under construction, but will be completed and working by the end of 2014.

3.3.10 Mt Gambier Aquatic Centre

Mt Gambier Aquatic Centre in South Australia is heated by a biomass boiler and two heat exchangers whose combined capacity is 520kW. The original biomass boiler ran on fresh sawdust from a local timber mill. After 30 years the original boiler became unreliable and difficult to operate. Replacement options were investigated and included a straight gas boiler, a combined solar hot water and gas option, and biomass boilers. All options were analysed for potential capital costs, operating costs, community benefits and costs, and environmental benefits and costs. The ultimate conclusion was that while a biomass boiler would have a higher capital cost than a straight gas boiler, the running costs would be cheaper, which over a 10-year period resulted in significantly reduced costs. Purchasing biomass from the local forestry industry supports local jobs, as opposed to importing gas from outside the region. When comparing the biomass system to the most likely alternative – a straight gas boiler – the payback period is approximately four years.

3.3.11 Beaufort Hospital

Beaufort Hospital in western Victoria received a state government grant to build a \$430 000 wood fired boiler to provide all the heating requirements for the hospital. The costs were slightly higher than a normal system because of the fact it was a demonstration facility, which means that additional items (such as viewing screens) were included that would not necessarily be present in a normal working system. A system of the same output without all the extras required for a demonstration facility would be approximately \$300 000. They were originally spending about \$60 000/year on LPG in their previous system. With the new wood fired system, they spend \$20 000/year buying in waste woodchips from the local saw mills — a saving of \$40 000 a year. With this, the payback period will be approximately 10 years depending on the future prices of LPG. They are also looking into using the system to provide the hot water requirements for the hospital, creating further savings.

3.4 Proposed Australian projects

A number of projects are in various stages of development across Australia. Following is a brief outline of a selection of those projects that are well-advanced.

3.4.1 Balfour Beatty

A grant of \$3 million from the Victorian Government's Regional Growth Fund will be allocated to the \$174 million biomass power station at Carwarp, near Mildura. The funds will be used to connect the Balfour Beatty Investments 35MW biomass power plant to the grid, helping to reduce power prices for Mildura residents. As well as lowering electricity prices for the region the project also means that local farmers will

get an alternative source of income by supplying the biomass plant with up to 215 000 tonnes of materials per year. Stockpiling of 200 000 tonnes of almond hulls and shells would begin at the start of the 2014 processing season. Ash from the residue will be also be used as nutrient for crops. The biomass steam power station is planned to be fully operational by mid-2016. A power purchase agreement has been made with energy company Power Corp and the power from the biomass plant will be delivered to Power Corp's Red Cliffs substation via a 66 000 volt power line.

3.4.2 Bindaree Beef

Bindaree Beef in northern New South Wales is one of the country's largest beef processors, with about 1100 animals handled daily. The plant's boiler currently burns 7200 tonnes of coal each year. They have approval and funding to install a new biogas system that will replace the old coal fired one. It is expected to reduce carbon emissions by 95%. The project is worth \$45 million, of which \$23 million has been secured and committed from the federal government as part of the Clean Energy Finance Corporation (CEFC). The project was projected to save Bindaree from having to pay the carbon price, creating potential savings of \$2.4 million; however, the project will still make economic sense even now the carbon price has been removed. They are currently lodging the formal environmental impact statement (EIS) with the state government and expect construction to begin in January 2015, with completion estimated for September 2015.

3.4.3 Horsham Aquatic Centre

The same city council that set up the Beaufort Hospital system is looking into setting up a similar system at their Horsham Aquatic Centre in Victoria, to heat the pool. The centre currently spends about \$80 000 a year on natural gas. The proposed system will run on wood waste from the local sawmills for approximately \$25 000 a year, saving them \$55 000. This same wood waste was costing the sawmills \$120 per tonne to dump at landfill meaning that both the sawmill and the aquatic centre benefit from this system.

3.5 Currently operating projects in WA

While the development of biomass projects in WA has been slow, there are a number of biomass energy facilities currently operating in WA. Following is a brief outline of the larger projects completed.

3.5.1 Woodman Point sewage to biogas

The Woodman Point sewage processing facility incorporates three biodigesters in its water treatment process. The biogas produced is fed into onsite generators that generate all the electricity and hot water requirements for the facility, saving the facility around \$9000 a month. The residue created from the sludge in these digesters is an excellent soil conditioner that is used for agricultural applications. The process produces about 180 tonnes of this residue a week which is provided for free to local farmers. The digesters produce roughly 1500kW of heat and 15 000m³ of biogas a day that powers the three 600kW turbines. This system produces approximately 7000kWh/day of excess electricity that is exported to the grid.

3.5.2 Shenton Park municipal waste to biogas

Shenton Park biomass processing trial facility currently converts approximately 33 000 tonnes of organic municipal waste into a solid fertiliser and generates biogas while diverting up to 75% of the shire's waste from landfill. They currently produce 16m³ of biogas per tonne of organic waste which produces about 8250MW hours of electricity per year. This covers their entire electricity requirements with surplus being sold back into the grid. The fertiliser that is produced is sold through Richgro who incorporate it into their products.

3.5.3 Trandos Hydroponics biomass heating

Trandos Hydroponics, in Neerabup, in 2011 commissioned a thermal generator from AIS Greenworks. Trandos buys in cleaned and dried waste woodchips from local sawmills for about \$30 000/year. Woodchips are put into the generator and burned to heat water which is then pumped through pipes throughout the greenhouse to maintain the temperature. A similar system running on LPG or natural gas would have yearly costs of \$280 000 and \$140 000 respectively, so they are saving \$110 000 to \$250 000 a year on fuel costs. While the installation of the system was \$150 000 more expensive than an LPG system, the payback period was still approximately only two years, with estimated savings of close to \$1 million over the following 10 years.

3.5.4 Richgro organic waste to biogas

Richgro in Jandakot is one of the top five garden products suppliers in Australia. A \$3.3 million anaerobic digestion plant with a 2MW electricity generation capacity is nearing completion and will produce enough power for Richgro's operations at Jandakot. That includes powering equipment and Richgro's onsite vehicle fleet. A sum of \$1.1 million was sourced from the federal government's Clean Technology Investment Program, with the remainder coming from a five-year loan from Low Carbon Australia. The by-product from the plant can be used as a raw material in Richgro's garden products. The plant has the capacity to process more than 35 000 tonnes per year of organic waste, diverting it from landfill. Over a 20-year life the project is expected to save 142 000 tonnes of carbon dioxide emissions.

3.5.5 AshOil waste oil to biodiesel

AshOil processes used cooking oil from the mining industry to produce biodiesel. Production began in 2006. The biodiesel production plant is situated in Tom Price. The cooking oil feedstock is currently collected from Port Hedland, Newman, Karratha, Roebourne and satellite mine camps such as Area C, Hope Downs and West Angeles. An agreement with ESS Pty Ltd, one of the major minesite catering and cleaning providers, currently secures them 20 000 litres of used cooking oil each year. AshOil currently produces about 10 000 litres of biodiesel each week. An agreement with Rio Tinto guarantees the purchase of 5000 to 7000 litres a week of fuel for drill and blast operations at the Tom Price mine.

3.5.6 WestGen biomass to electricity facility

A 40MW biomass power plant at Diamond Hill received EPA approval in 2008, and the owners have recently completed funding approval and signed 20-year contracts for the required feedstock which will be primarily plantation residues. Building is scheduled to begin in February 2015.

3.6 Proposed projects in WA

A number of large and small scale projects are currently in the planning phase by corporations and some farming operations.

3.6.1 Kimberley Agricultural Investments ethanol

Kimberley Agricultural Investments (KAI), a Chinese company, has announced plans to develop an Ord River irrigation scheme project to grow sugar cane for ethanol production. They are planning to trial growing sorghum, which is commonly used for ethanol production in Asia, while developing the infrastructure for the sugar cane. The investment of \$700 million will see 13 400ha of irrigated land and infrastructure developments. The proposed sugar mill and power plant are expected to create 400 jobs. The properties will be located in Goomig and Knox Plains and they will extract water from Lake Argyle. A 25-year lease agreement requires KAI to meet a series of investment deadlines including clearing 1000ha by October 2014.

3.6.2 Warrawagine Station biogas

Warrawagine Station has begun growing hay for stock and sorghum as feedstock for biofuel at the Woodie Woodie manganese mine, using water from the mine. The trial forms part of the WA government's Pilbara Hinterland Agricultural Development Initiative (PHADI) and is funded with some infrastructure already in place. The program is in development and will begin by irrigating and cropping 120ha, while there is capacity to irrigate 5000ha.

3.6.3 New Energy Corporation waste to energy

New Energy Corporation has received \$50 million from the CEFC for their waste to energy projects in WA. They have been granted EPA approval for a \$200 million, 18MW waste to energy plant in Port Hedland designed to take 130 000 tonnes of household waste each year and generate enough biogas to power 21 000 homes. A similar, \$160 million plant is also proposed for a site in east Rockingham. The Rockingham site has secured its funding and received conditional EPA approval and has also engaged engineering firm Kiewit to undertake the design.

3.6.4 Phoenix Energy waste to energy in Kwinana

Phoenix Energy has a \$380 million facility currently awaiting its environmental approvals. They have signed an agreement that will secure the City of Kwinana's residential waste as fuel for the plant. The plant will have a capacity of 300 000 tonnes a year and when completed will supply 15% of the City of Kwinana's energy needs. The agreement means the City of Kwinana will be the first in Australia to achieve 100% landfill diversion. The construction is scheduled to commence at the end of 2014 with operations beginning late 2016.

3.7 Available feedstocks in WA

Potential feedstocks for bioenergy can be broken into three broad classifications. Cereal straw is an abundant resource and can be used for either combustion or fermentation. High moisture content animal effluents from piggeries and dairies are well-suited to anaerobic digestion, while drier animal waste such as chicken manure can be either digested or combusted.

3.7.1 Cereal straw

Cereal straw is produced across the south-west in large quantities and currently has very little commercial value to grain producers. Not all crop residues are available for removal. A proportion must be left behind to provide soil cover to retain soil water, reduce erosion, maintain soil carbon levels or provide a source of animal feed. The amount of stubble that may be required to be left behind for maintaining soil health will vary depending on factors such as soil type, rainfall and topography. Also, not all biomass left behind after harvest will be physically possible to collect. In addition, transport costs and the distributed nature of cropping will limit the amount that is viable to collect. This figure may also vary if farmers choose to retain more stubble for ground cover or feed for stock. However, if there is a demand for biomass then farmers may possibly grow crops focusing on biomass rather than grain. Table 3.1 shows the average amount of cereal straw available within a 50km radius of ten 'hubs' that have been identified as possessing the necessary infrastructure to support a cereal straw to ethanol plant. Obviously, the inevitable seasonal production swings result in differing amounts of straw being available across the years. This means different contracting for straw regimes would have to be in place for regions with high variability, even if on average those regions can support a given number of plants.

This is illustrated by examining annual data for the Northam region (Table 3.2). As logistics play a key role in determining the cost of delivered biomass, the data on the potential cereal straw availability is manipulated into a 30 to 70km radius around Northam. The following tables describe the straw biomass potentially available within particular radii from potential agricultural hubs. Assuming that an average size cereal straw to ethanol plant requires 250 000 tonnes of feedstock a year, eight of the 10 hubs in Table 3.1 could each supply at least one full scale plant. Examples of the volumes of straw available at a range of distances from these hubs appear in Appendix B.

Table 3.1 Five-year (2006–10) average of potential WA cereal straw harvest less 1t/ha retention for soil conservation and harvest of chaff

Location	Available straw '000t	With chaff '000t
Geraldton	598	760
Three Springs	190	244
Moora	952	1207
Northam	754	963
Merredin	818	1154
Lake Grace	680	890
Narrogin	448	574
Katanning	1178	1495
Esperance	1212	1516
Albany	149	187

Table 3.2 Available biomass (x1000 tonnes) of straw within 30, 40, 50, 60 & 70km of Northam (a straw to ethanol plant requires 250 000 t/y)

Year	30km radius		40km radius		50km radius		60km radius		70km radius	
	Straw after 1t/ha retention	With all chaff	Straw after 1t/ha retention	With all chaff	Straw after 1t/ha retention	With all chaff	Straw after 1t/ha retention	With all chaff	Straw after 1t/ha retention	With all chaff
2010	44	58	68	90	93	124	122	163	155	208
2009	193	238	360	444	563	694	811	1000	1087	1342
2008	110	140	203	258	312	397	447	570	597	763
2007	116	145	219	273	349	435	513	641	699	875
2006	36	49	64	89	106	146	165	227	237	325
5-year average	100	126	183	231	285	359	412	520	555	703

3.7.2 Animal effluents

Animal effluent is a viable feedstock for bioenergy production. Methane produced from anaerobic digestion can be captured and fed to a methane powered engine for power generation. The dairy industry in WA could be a strong contributor, with 16 dairies with enough numbers (1000+ animals) to make an on-farm anaerobic digestion system financially viable on those farms (Figure 3.1).

Pork and poultry industries also have potential for biogas production through anaerobic digestion. There are 16 piggeries in WA of a size that would make on-farm power generation financially viable (Figure 3.2).

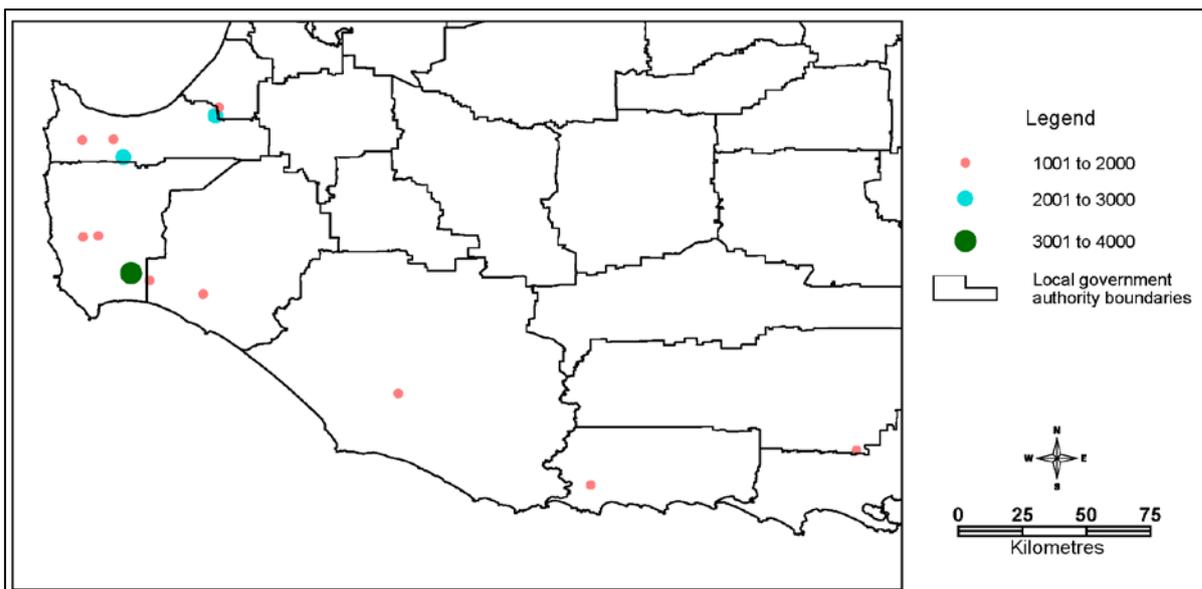


Figure 3.1 Locations of dairies of adequate size to support a biogas generation facility. Legend is number of animals

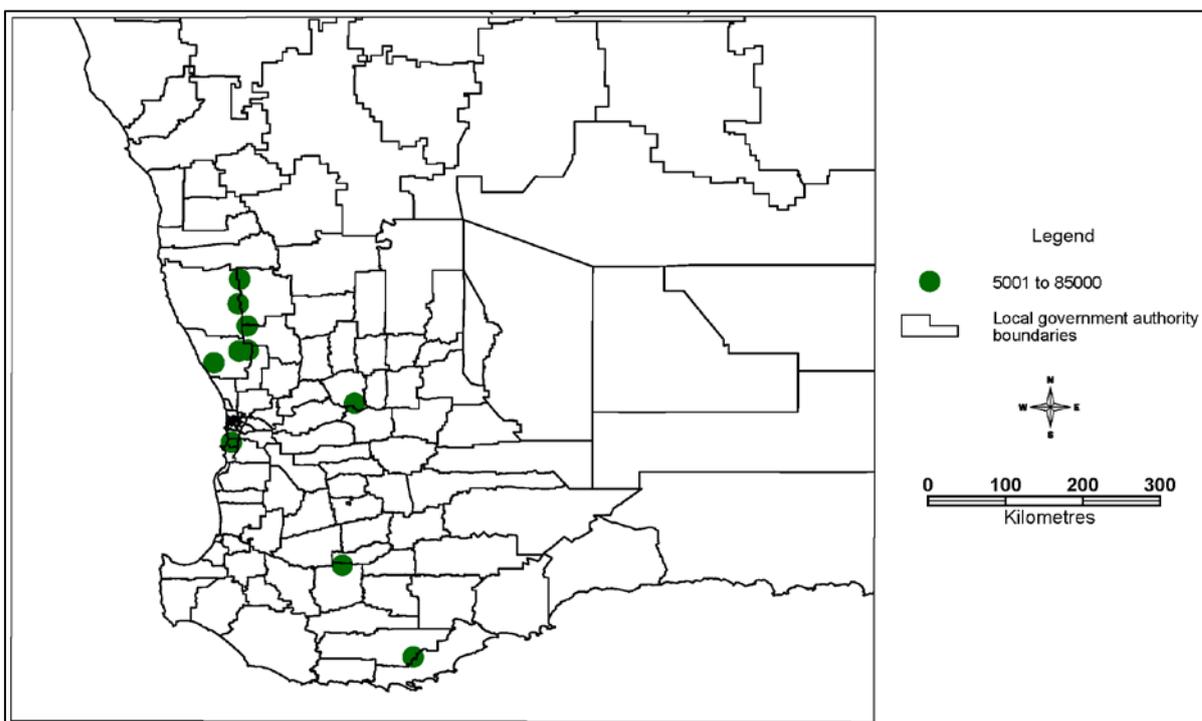


Figure 3.2 Locations of piggeries of adequate size to support a biogas generation facility. Legend is number of animals

Poultry industries produce a drier waste that may be more suitable as a feedstock for a pyrolysis or gasification process, rather than anaerobic digestion. At this stage DAFWA has limited information on the number and scale of poultry farms in WA. Some impression of the appropriate scale required can be gained from the biogas facility in use at the Darling Downs Eggs facility described earlier (3.3.9).

3.7.3 Horticulture

Horticultural producers and processors can provide feedstock for niche bioenergy enterprises. Pips from stonefruit and olives, prunings from vines, fruit and nut trees, and end-of-life trees and vines are all potential bioenergy feedstocks. Horticulture offers some business opportunities using existing technologies in areas where biomass can be concentrated – large production areas and manufacturing.

For example, bananas are geographically compact, grown in areas remote from population centres with high conservation value and are produced en masse with low margins. The 'banana waste to energy' (BW2E) project run in 2008 by Growcom and supported by the Queensland Sustainable Energy Innovation Fund showed that sustainable fuel could be produced from waste bananas. Approximately 10 to 30% of bananas grown in Australia do not make it to market, which in the Carnarvon area could equate up to 1500 tonnes of waste bananas.

The other main horticulture crops in WA include tomatoes, potatoes, pumpkin, corn, melons, onions and lettuce. An estimated 20 to 40% of horticultural crops do not make it to supermarket shelves due to superficial blemishes or irregularities. Most of these 'rejected' fruits and vegetables usually get ploughed back, dumped or sold as low value supplementary stockfeed which has been known to create issues relating to chemical residues in the animal products.

Table 3.3 Horticultural crop production in WA in 2008 and potential waste volumes available

Crop	2008 production (tonnes)	20% wastage (tonnes)	40% wastage (tonnes)
Tomatoes	12 000	2 400	4 800
Potatoes	96 000	19 200	38 400
Pumpkins	25 000	5 000	10 000
Corn	2 000	400	800
Melons	34 000	6 800	13 600
Carrots	65 000	13 000	26 000
Beans	1 000	200	400
Beans	1 000	200	400
Onions	16 000	3 200	6 400

WA's main horticultural region runs from Gingin (100km north of Perth) to Myalup (100km south of Perth), with other smaller hubs around Geraldton and Carnarvon in the north and Pemberton, Manjimup and Albany in the south, providing common zones where waste could be collected. More detailed spatial analysis of the available resource is required before recommendations can be made.

3.8 Potential WA biomass energy consumers

If industries generate electricity to feed into the grid they may get paid 10c/kWh. If they offset electricity use from the grid, they are saving the retail cost of the grid power which averages 25c/kWh. Given the substantial difference between the retail and wholesale prices of electricity, it makes sense to first look at using bioenergy at its point of generation.

There are 16 dairies and 16 piggeries in WA large enough (1000+ cows and 5000+ pigs respectively) to utilise their manure waste as a source of heat and electricity generation for use on-farm. Decentralising electricity production from these relatively small electricity generation operations decreases demand on electricity networks, which may be located several hundred kilometres from the centralised generation facility. These farming operations can use anaerobic digestion of large volumes of manure and organic material to produce heat and electricity which may be used on-farm in normal farming operations, and excess electricity may be exported to the grid. This form of electricity generation and use also attracts ACCUs under the Carbon Farming Initiative (CFI), although depending on political decisions regarding ACCUs and the CFI, in the future this could change.

Industrial complexes and institutions such as hospitals can acquire heat and electricity from the gasification of biomass. This activity not only reduces the volume of power consumed by the facilities but it creates biochar and ash as a waste product which may be put back into the soil. Applying biochar to the soil is an activity on the CFI positive list. Potential exists to include biochar facilities in municipal facilities such as hospitals. An example is that of Esperance Hospital which is of a similar vintage to Albany Hospital, which was recently extensively upgraded. Any plans to upgrade Esperance Hospital could include a gasification plant drawing on resources from surrounding crop wastes and/or crop dust from the port facility.

In the United States there are cars that are being run on compressed natural gas (CNG). While there are issues regarding mileage and refuelling times, it is cheaper to run on than petrol. This opens up possibilities of using biogas from anaerobic digestion to power onsite vehicles. There is currently a demonstration vehicle in New Zealand: a hauling truck that is fuelled by the biogas generated by the digesters at Redvale landfill. It operates 250 days a year, and replaces 12 000 litres of diesel by utilising the biogas onsite. The creators of the vehicle believe that if the technology was done at a commercial scale the Redvale landfill could provide enough biogas to displace 54 million litres of diesel a year.

Berrybank Farm Piggery is one of the longest running anaerobic digestion systems in Australia, and while they say using biogas to power their onsite vehicles would be viable economically, the process of compressing the biogas is quite complex and has various health and safety considerations that would add to the complexity of the process and could make it difficult for small on-farm facilities.

The Royal Australian Navy (RAN) has recently pledged to make all of its vessels and aircraft biofuel capable by 2020. They stated that exactly when the navy's ships and aircraft start using biofuels full-time in Australian waters would depend on the availability of sufficient, cost-efficient, high quality fuel. 'As the industry becomes established and alternative fuel blends' costs approach parity, the RAN will seek to use blended alternative fuels,' said an RAN spokesperson (Vorrath 2014).

The aviation industry intends to be a major consumer of renewable fuels in the form of Sustainable Aviation Fuel (SAF). As an industry it has agreed to reduce its emissions and improve its economics by developing SAF to be mixed 50% as a drop-in fuel (which can be used directly in existing engines). SAF may be produced from plant waste or plant based oils. The next developmental step for the aviation industry is the construction of a large scale plant to process plant residues into SAF.

3.9 Barriers to uptake

Bioenergy in Australia is facing several challenges that are additional to the usual issues associated with power projects.

3.9.1 Capital and maintenance costs

One of the main hindrances to the uptake of bioenergy projects is high capital and maintenance costs. There are also material costs involved in operating and maintaining a bioenergy plant. If a bioenergy plant is going to be co-located on a farm, plantation or vineyard it is unlikely to have a huge installed capacity, yet there will need to be substantial savings on energy costs and waste disposal costs in order to offset the capital and maintenance costs.

3.9.2 Feedstock availability

Production of feedstock may be seasonal. Biomass from agricultural by-products will logically be collected during the harvesting period and influenced by agricultural yield. Therefore biomass from agricultural by-products may not be a year-round source of feedstock. This may require farms, plantations or vineyards to have dual sources of energy in place: one from biomass production and the other through more traditional means. Storing excess feedstock for use throughout non-harvesting periods could mitigate the seasonality of feedstock production. There are also complexities and costs involved in transportation. Biomass is typically distributed over various locations and unless the bioenergy facility is located on-farm, there is a need to transport the biomass to the power station.

3.9.3 Regulatory frameworks

Berrybank Farm Piggery commented that it was easier to set up their system when they did (in 1991) than it would be to do so now. They say they set up their system prior to the major privatisation of the energy sector, which made hooking their system up to the grid and selling on their excess electricity a lot easier than it would be today.

Grid access is an issue named by many bioenergy proponents as a barrier to installation of infrastructure.

3.9.4 Other issues

Daryl Scherger from the Pyrenees local shire, responsible for setting up the Beaufort Hospital system in western Victoria, says the main barrier in setting up their biomass boilers was 'all in people's heads'. Getting people to believe that the systems work and are also economical was their biggest problem. The managers of the Horsham Aquatic Centre were sceptical of using such a system until they were shown the set-up at Beaufort Hospital. Scherger believes that, while such systems would need to be independent of government funding in the long term, there needs to be government support to set up similar demonstration systems to prove to people their worth and benefits. He also said that guaranteeing a continuous, reliable fuel source is another problem. The Royal Melbourne Children's Hospital installed Trigeneration comprising

two 1160kW gas reciprocating engines and two 1267kW two-stage absorption chillers. They were designed to burn compressed timber pellets from forestry waste. However, they were unable to secure a continuous and reliable source of that fuel so the system is currently non-operational.

Energy security is seen to be a strong influence on the uptake of biofuels worldwide; however, its influence is felt more strongly in different countries. Germany imports over 60% of its energy needs while Australia is a net exporter of energy, so energy security as a driver is much weaker here. Germany has over 6000 on-farm anaerobic digestion facilities, while as at 2011 Australia had only one (Wilkinson 2011).

Government cuts to support also influence some facilities' ability to take up bioenergy projects. Not only does this remove any incentive or requirement for companies to look into alternative energies, there is little or no funding available for those who are interested. It also removes funding available for research into making the technology more efficient and cost effective.

In countries such as Germany farmers have access to a wide range of subsidies encouraging the growth of biofuel crops, which has resulted in rapid growth in the cultivation of bioenergy crops. Approximately 500 000ha of crops were grown as feedstock for biogas plants and 1.25 million hectares for biodiesel and bioethanol plants in Germany by 2009. By comparison, Australian farmers receive fewer subsidies than any other farmers in the OECD apart from New Zealand (Wilkinson 2011).

3.9.5 Summary

What is clear is that biomass can be used to generate energy in the right circumstances, namely:

- where the regulatory environment is stable and supportive of the technology
- where feedstock is cheaply and readily available
- where transmission distances are relatively low
- where the cost of alternative sources of power are high.

Appendix A Economic comparison of three systems for delivering process heat

Table A1 Operating costs of LPG, woodchips and wheat straw for delivering process heat

Energy and material flows	LPG	Woodchips	Wheat straw
Thermal power	5.00MW _{th}	5.00MW _{th}	5.00MW _{th}
Thermal efficiency	0.8	0.8	0.8
Heating value	26MJ/L	14MJ/kg	13MJ/kg
Flow rate	865L/h	1 607kg/h	1 731kg/h
Operating costs			
Operating time	10h/d	10h/d	10h/d
Unit fuel cost	\$0.80/L	\$0.09/kg	\$0.095/kg
Unit energy cost	\$0.111/kWh	\$0.023/kWh	\$0.026/kWh
Consumption	8 654L/d	16 071kg/d	17 308kg/d
Daily cost	\$6 923	\$1 446	\$1 644
Annual cost	\$1 661 538	\$347 143	\$394 615
Additional operating costs	\$0	\$100000	\$100000
Total annual operating cost	\$1 661 538	\$447 143	\$494 615
Annual savings	\$0	\$1 214 396	\$1 166 923

Appendix B Extent of cereal straw production areas surrounding potential processing hubs

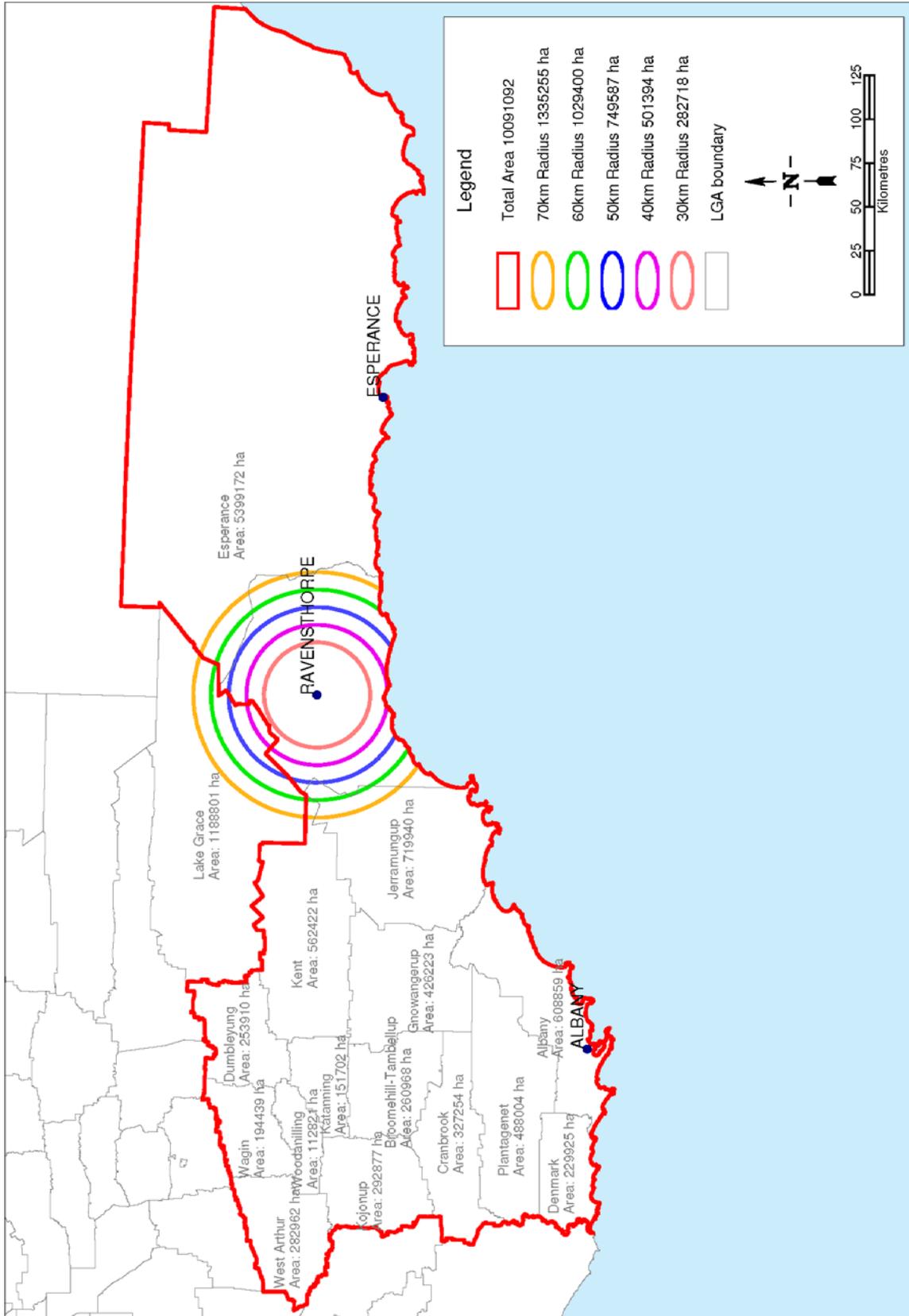


Figure B1 Potential area of cereal straw grown around Ravensthorpe

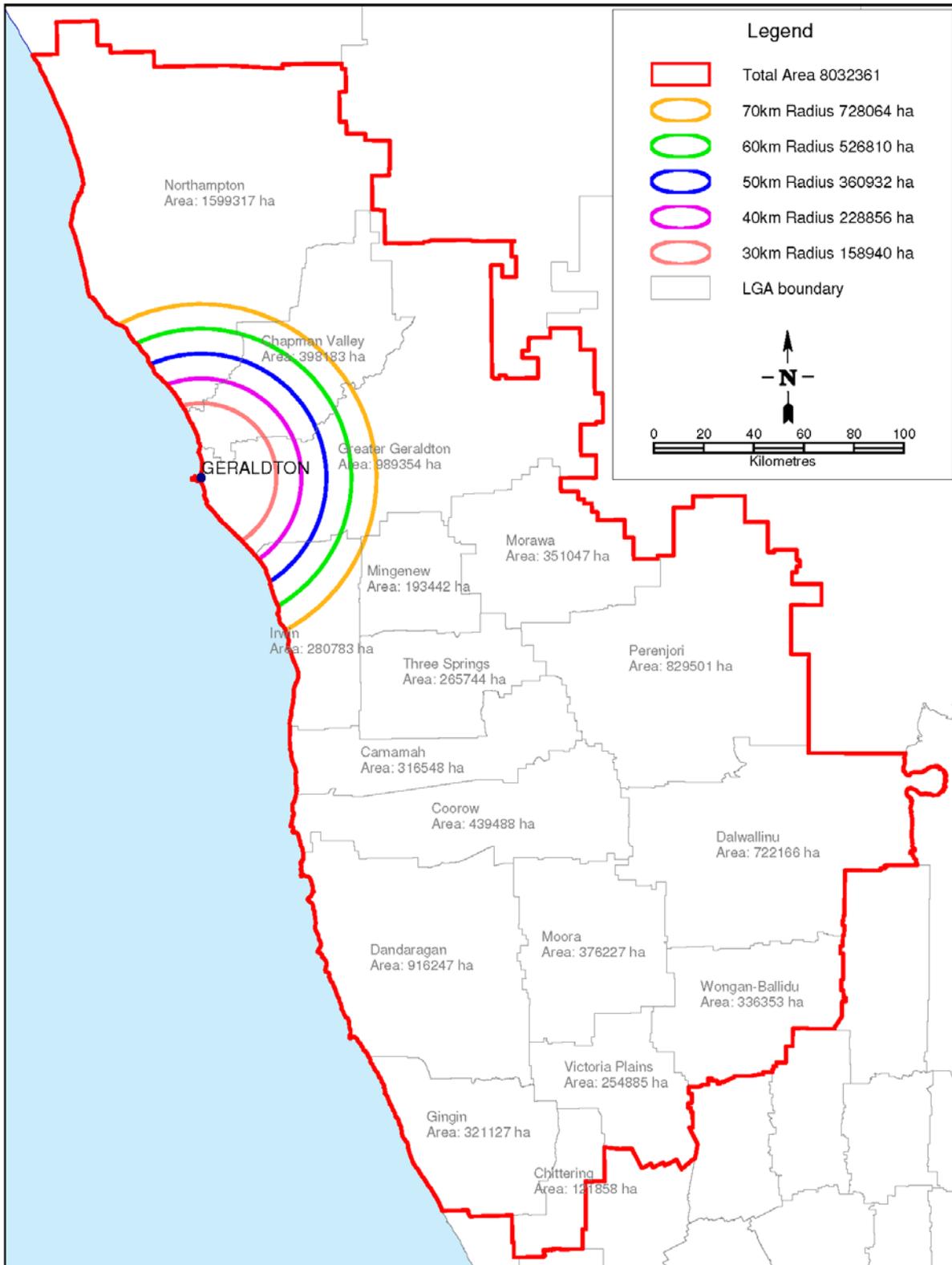


Figure B2 Potential area of cereal straw grown around Geraldton

Shortened forms

ACCU	Australian carbon credit unit	IWP	Integrated wood processing
AGL	Australian Gaslight Company	KAI	Kimberley Agricultural Investments
ARENA	Australian Renewable Energy Agency	kW, kWh	kilowatt or kilowatt hour
ASX	Australian Stock Exchange	\$/kWh	dollars per kilowatt hour
ATP	Australian Tartaric Products	LPG	liquid petroleum gas
BW2E	Banana Waste To Energy	ML, ML/y	megalitre, megalitre per year
CEFC	Clean Energy Finance Corporation	Mt	megatonne
CFI	Carbon Farming Initiative	MRET	mandatory renewable energy target
CHP	combined heat and power	MW, MW _{th}	megawatt, megawatt thermal
CNG	compressed natural gas	N ₂ O	nitrous oxide
CO	carbon monoxide	OECD	Organisation for Economic Co-operation and Development
DAFWA	Department of Agriculture and Food, Western Australia	ORC	Organic Rankine Cycle
DECC	Department of Energy and Climate Change	PHADI	Pilbara Hinterland Agricultural Development Initiative
EIA	Energy Information Agency	RAN	Royal Australian Navy
EIS	environmental Impact statement	REC	renewable energy certificate
EPA	Environmental Protection Agency	RET	renewable energy target
GHG	greenhouse gases	RIDF	Regional Industry Development Fund
GL, GL/y	gigalitre or gigalitre per year	SAF	sustainable aviation fuel
GWh	gigawatt hour	t/y	tonnes per year
h/d	hours per day	VOC	volatile organic compound

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