Southern Grampians Shire Council:

Bioenergy industrial development feasibility study – Contract No. 44-17

Study report by Enecon Pty Ltd

Rev 1 – final report

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1 Executive summary

The Southern Grampians Shire Council has commissioned a feasibility study to examine the opportunity for third-party investment in a commercial bioenergy production at a new industrial estate in Hamilton, western Victoria. This report summarises the findings of that study.

The proposed bioenergy plant would generate renewable energy, fuelled with residues from the region's well-established, sustainable plantation industry. It could provide heat or electricity to other businesses in the industrial estate; for example via pipework for steam or via a mini-grid for electricity. It could also provide electricity to customers in the broader Southern Grampians region; via the existing electricity network.

Several bioenergy technologies were considered during the study, and two bioenergy plants were examined in some detail:

- A combustion plant sized at 5 MW, to generate steam for other businesses in the industrial estate that have a need for process heat.
- A combustion plant sized at 10 MW to generate power via a steam turbine, targeting approximately 2.1 MW of electricity for sale.

Biomass residues are available from the region's hardwood and softwood plantations. They can be recovered in parallel with existing harvesting operations (but without disrupting those operations) and delivered to a bioenergy plant in Hamilton. During this feasibility study the availability of plantation resources was calculated and then matched to different strategies for harvesting and infield drying. Then supply chain costs were determined, using models developed in cooperation with the plantation industry. It was found that all the biomass required for either bioenergy plant could be delivered to the plant at $30 per tonne after infield drying and with a small fee for stumpage. Fees and supply chain costs may increase over time if competing uses develop for this biomass.

Capital cost estimates were prepared for the two bioenergy plants, using pricing from experienced vendors as well as in-house data and standard estimating references. The capital cost estimates, together with operating cost estimates and costs for delivered feed provided the basis for financial models to determine the pricing needed for heat or electricity to meet various investment criteria. It was found that:

1. **Heat** (as steam) can be provided from a bioenergy plant at lower cost than steam generated with natural gas as fuel, provided the utilisation of the bioenergy plant (the number of hours per year that it is making and selling steam) can be kept above 40 - 50%. If the bioenergy plant can sell steam 24 hours per day and 7 days per week throughout the year it can provide this steam at approximately half the cost of steam from a boiler using natural gas at $20 per GJ.

2. **Electricity** generated in a bioenergy plant at the industrial estate is more expensive than electricity generated via fossils fuels or wind farms. It cannot compete on the open market with these other providers of electricity. However, by co-locating the bioenergy plant at the industrial estate, its electricity may be sold to local businesses via a mini-grid (included in the cost estimate), which allows network charges to be avoided.

A bioenergy plant generating electricity should be operated continuously, which may not match the operating hours of its customers in the industrial estate. In addition to sales within the industrial estate, it is feasible to sell electricity to Council, businesses and domestic customers within the Southern Grampians Shire via the existing electrical network. While the competitive position of such sales is not yet clear, this approach would provide benefits for the bioenergy plant:

- As a local generator there may be scope to reduce the network charges paid by its customers for this electricity, which will improve its competitive position.
- As a provider of electricity for the regional community, as well as being a new local business, the bioenergy plant may attract community investment. Such investment recognises social benefits as well as financial benefits, and may be available at lower rates of return than commercial funding. Depending on quantities and rates, this alternative funding can provide a significant reduction to the cost of electricity generation.

As with solar and wind energy, carbon-neutral electricity from the proposed bioenergy plant is eligible to create Large Generation Certificates under the Australian Government's Renewable Energy Target (RET). Unfortunately the RET is in its final stages of the phase that encourages new generating capacity. It is doubtful that the proposed bioenergy plant can be established in time to secure any meaningful contract for LGCs. There are no other schemes, either current or planned, that will provide an equivalent benefit for the renewable energy from this plant.

The study provides Council with relevant data and costings for two bioenergy plants that can be used to progress discussions with potential site users and third-party investors.

2 Introduction

2.1 Background to study

Southern Grampians Shire Council (Council) is keen to see a commercial bioenergy plant operating in the Shire. Council hopes that such a plant will:

- Be located at the industrial estate near Hamilton.
- Provide sustainable energy at a competitive price for other companies in the industrial estate.
- Utilise biomass residues from the region's established and sustainable plantation industry.

The Southern Grampians Shire Council recognises that a bioenergy plant in Hamilton would provide a valuable new business for the region. Long term employment from such bioenergy facilities covers all skill levels, providing benefits that are greater and more diverse than for other forms of renewable energy.

Council received funds from the Victorian Government[1] to develop this concept, and in November 2017 a contract was awarded to Enecon Pty Ltd to undertake a feasibility study for bioenergy plants at the industrial estate. These plants could provide heat, electricity, or a combination of the two (cogeneration).

Enecon's work was guided by a specification prepared prior to the study, a kick-off meeting with the Council and its bioenergy working group, and then ongoing discussions with Council as the study progressed.

2.2 Structure of report

This report presents the various elements of the feasibility study in the following order:

- Markets – The anticipated markets define the scale and viability of the project. What are the markets for the heat and electricity at the industrial estate and the broader Southern Grampians region?
- Biomass feed supplies – How can the large volumes of plantation forestry residue (softwood and hardwood) and other wood waste products available in the region be captured, processed and utilised as an energy source?
- Bioenergy systems – Bioenergy plants generate heat, electricity or a combination of both. The scale of plants is very flexible and may be set to match the markets for energy and the available feeds. What is the recommended type and size of bioenergy system for the Hamilton site?
- Sustainability – Does the biomass proposed for use in this plant comply with the legislation for the Australian Government's Renewable Energy Target and like wind and solar energy, can the proposed bioenergy plant generate renewable electricity that creates Large Generation Certificates?
- Support for renewables – Are there initiatives at national and state levels that could be of assistance in the establishment of a bioenergy plant near Hamilton?

[1] Department of Environment, Land, Water and Planning through the New Energy Jobs Fund

- Financial analysis – Once the market, feeds, plant costs and renewable energy schemes are considered, does financial modelling indicate commercial viability of the proposed bioenergy plants?
- Management structures – What are the steps to reach project implementation and which organisations can lead or influence project development and implementation and operation of a bioenergy plant?
- Discussion – For the opportunities that have been analysed, what are their strengths and weaknesses and what are the next steps in developing a business case for a commercial bioenergy plan at the Hamilton industrial estate?

3 Markets for energy

3.1 Heat

Many industries in regional Victoria use heat in their processes and facilities. The meat, dairy and food processing sectors, as well as the forest products industry, all routinely use significant quantities of heat. Many other industries use heat in their daily operations. This may be as hot air, hot water or steam.

Natural gas is a major energy source for industrial heating. In recent years the cost of natural gas has risen considerably, causing financial difficulty to many companies. Council believes that bioenergy may offer a competitive alternative to natural gas, which would be of financial benefit to heat-using companies that locate in the Hamilton industrial estate. These customers could be sold heat energy as steam (or hot water, or thermal oil) that is distributed within the industrial estate via a suitable piping system. The design and operation of such a system is quite straightforward.

3.2 Cooling

Cooling is a significant part of the operations of many companies. Their needs may include chillers, refrigeration or cold storage. Energy for such cooling is typically provided by electricity, however it is also possible to use heat to drive coolers, via equipment called adsorption chillers. These heat-driven adsorption chillers are not as energy efficient as chillers driven by electricity, but if the cost of heat is sufficiently below the cost of electricity they may provide a cost-effective source of industrial cooling.

The technical and economic feasibility of these units needs to be assessed on a case by case basis.

3.3 Electricity

Potential customers for electricity from a bioenergy plant include:

- Businesses in the industrial estate, which may be served via a mini-grid within the estate.
- The Council and commercial and domestic customers within Southern Grampians Shire, which may be served via the existing electrical network.

3.4 Scale of bioenergy plants

At the time this study was carried out, Council advised that there were no companies with significant energy use that had commitments or plans to use the Hamilton industrial estate. In the absence of specific company data for heat and power use, there is no direct guide for the scale of a heat plant or a power plant fuelled with biomass. As a result, it was agreed that the study would consider two alternatives:

a) A bioenergy plant to provide heat only, with 5 MW of output[2].

b) A bioenergy plant at double this scale, capable of generating 10 MW of thermal energy. This plant would be coupled to a system for electricity generation. Marketable electrical output from such a plant (after the bioenergy plant's own electrical use is deducted) is approximately 2.1 MW.

[2] The 'watt' is the SI unit of power, representing the application of energy over time. A watt is defined as the application of a 'joule' of energy per second. A megawatt (MW) is one million watts. If one MW is applied for one hour it is called a MWh, and it is equivalent to 3,600 MJ or 3.6 GJ.

The proposed bioenergy plant is to be located at the Hamilton industrial estate. A plant layout has been prepared to determine land requirements. This is shown below, for the larger plant (10 MW boiler plus power generation and feed storage for five days.) This is indicative only, based on the dimensions and layout of typical equipment items, however it is useful to provide data on the amount of land need for the plant.

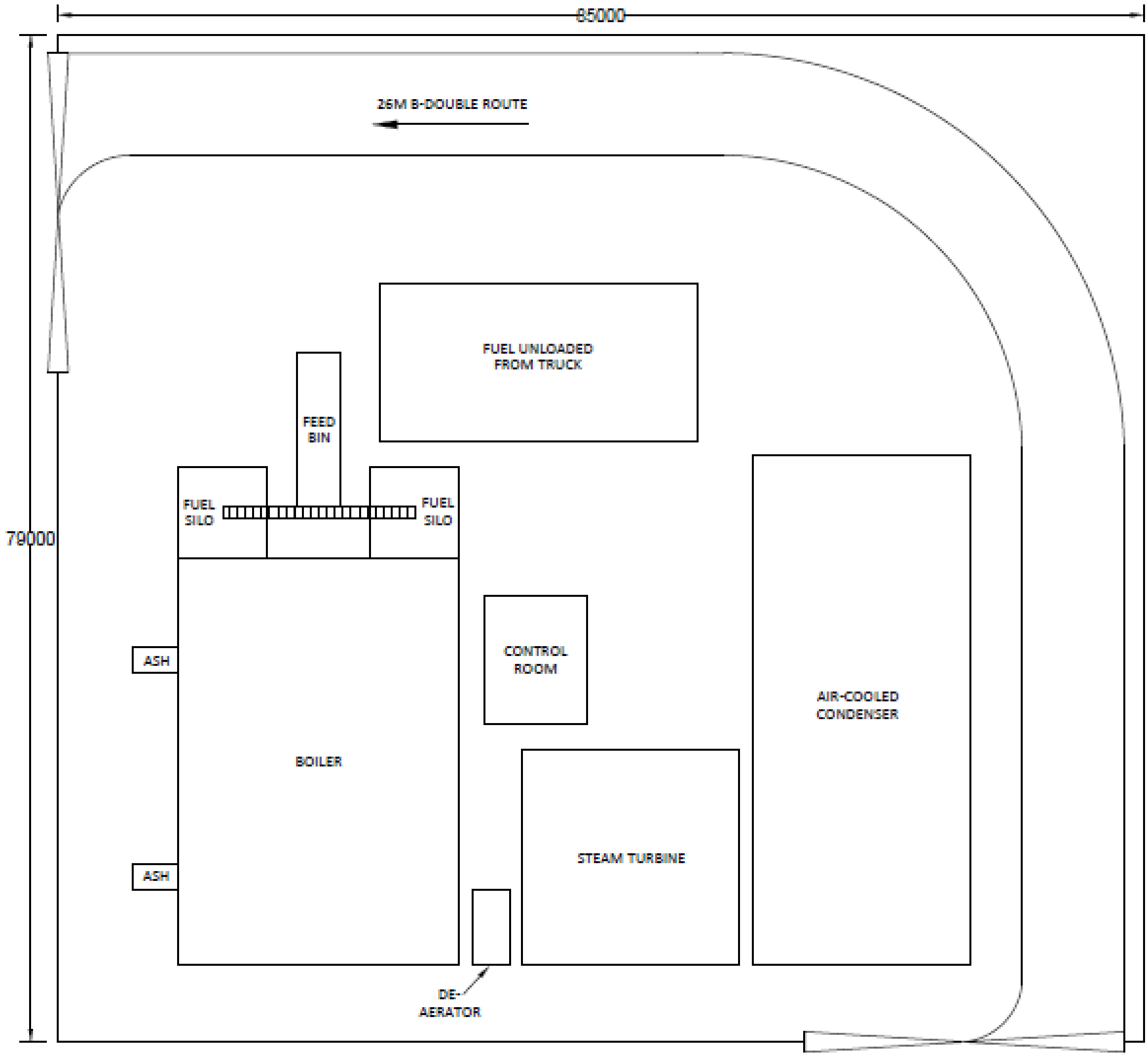

Figure 1 - Indicative layout for 10 MW combustion plant coupled to steam turbine

The proposed location of the bioenergy plant is the 6,800 m2 site at the north west corner of the industrial estate as shown in Figure 2 below.

Figure 2 - Overall site plan for new industrial estate at Hamilton

4 Biomass feed – plantation residues[3]

4.1 Scope

The Southern Grampians Shire is part of a region known as the Green Triangle, which covers south western Victoria and south eastern South Australia. The Green Triangle is one of Australia's most productive regions for plantation forestry, with large tracts of land utilised for growing softwood and hardwood. Primary outputs are export wood chips and commercial timber for structural and other applications. Only part of each tree is used for these outputs and significant quantities of residues are generated during the harvesting process. These residues are a potential feedstock for bioenergy plants

Plantation harvest residues are considered as feed for two bioenergy plants:
- 5 MW thermal, which needs approximately 20,000 tonne at 50% moisture content (MC) per year of green biomass feed.
- 10 MW thermal, which needs approximately 40,000 tonne (at 50% MC) per year of green biomass feed.

This section discusses different levels of residue recovery in order to determine transport distances from the bioenergy plant. That work leads to supply chain cost data, which is used in subsequent financial modelling.

There is no conscious effort to differentiate between softwood and hardwood residues, as both are considered acceptable feed for the bioenergy plant.

The recovery of residues modelled here is based on activities that would occur independently of normal pulpwood and sawlog harvesting and delivery. There is no expectation of any significant adverse impact on timing or costs for existing harvesting operations.

4.2 Biomass availability

Data for biomass availability was sourced from the Australian Biomass for Bioenergy Assessment (ABBA) project funded by the Australian Renewable Energy Agency (ARENA). The data from ABBA will ultimately be the biomass component of the Australian Renewable Energy Mapping Infrastructure[4]. Some validation and was carried out with a range of active biomass assessments done post harvesting trials done by FIRC with industry. The foundation of this additional work[5] was supplemented with data from more recent trials.

This data has been modelled to represent the total estimated forestry residues from Victorian softwood (Pinus radiata) and hardwood (Eucalyptus globulus) plantations at Local Government Area (LGA) level. Forestry residue dry mass was estimated from data on sawlog and pulp log production available from

[3] This section has been prepared by Dr Mark Brown, Director of the Forest Industries Research Centre at USC in Queensland - https://www.usc.edu.au/research-and-innovation/forests-for-the-future/forest-industries-research-centre
[4] http://nationalmap.gov.au/renewables/
[5] Ghaffariyan MR, Remaining slash in different harvesting operation sites in Australian plantations – Silva Balcanica 14(1)/2013

ABARES (2016a[6]) and spatial data on showing plantation areas obtained from ABARES (2016b[7]). Because the number of logs harvested from hardwood plantations has been increasing substantially over time, data for future log production (2016-20) was used.

Log production data is available only at a state or regional level. So, to estimate forestry residue amounts at an LGA level, the area of hardwood and softwood plantations at an LGA level was used with the assumption that the number of logs produced was the same for each hectare of plantation. To convert wood volumes to dry mass, wood density estimates (Illic, et al.2000[8]) for P. radiata and E. globulus were used.

Residue amounts were estimated by applying residue factors derived from Ximenes et al. (2008[9]), Greaves & May (2012[10]) and information provided by various plantation growers for softwood and hardwood species. These amounts per hectare were further validated with proprietary study results from work undertaken by the Forest Industry Research Centre, USC (FIRC-USC) for a number of plantation management companies. These biomass availabilities were then checked with plantation area within 25km, 50km, 75km and 100km of the bioenergy plant site at Hamilton through data analysis in GIS, to determine the amount of biomass available within those distances from Hamilton.

From the gross biomass availability determined with the ABBA dataset, recoverable biomass was determined based on FIRC-USC field study experience.

4.3 Biomass recovery and transport distance

There are several alternative approaches to the recovery and delivery of harvest residues. In addition to the form of the residues that are recovered, this analysis has considered costs for the supply chain:

- When all available residues are directed to the bioenergy plant.
- When there are competing uses for the residues and only 25% are directed to the bioenergy plant (which means that supply needs to be drawn from a larger area).

4.3.1 Stem wood recovery

The most conservative biomass recovery strategy focusses on only the recovery of residual stem wood[11], which is not normally used for production of export wood chip - Figure 3.

[6] http://www.agriculture.gov.au/abares/publications/display?url=http://143.188.17.20/anrdl/DAFFService/display.php?fid=pb_afwpsd9abfe20161103_11a.xml

[7] http://www.agriculture.gov.au/abares/research-topics/forests#australian-plantation--statistics

[8] Illic J, Boland D, McDonald M, Downes G and Blakemore P. (2000) Wood Density Phase 1 – State of Knowledge. Technical report no. 18. Australian Greenhouse Office.

[9] Ximenes F et al, Proportion of above-ground biomass in commercial logs and residues following the harvest of five commercial forest species in Australia, Forest Ecology & Management 256 (2008) 335-346

[10] Greaves B and May B, Australian secondary wood products and their markets, FWPA April 2012

[11] Stem wood is a term that covers both softwood and hardwood. At the time of harvest, after the traditional forest products are recovered (veneer logs, saw logs and pulp fibre) there is a portion of material left that is generally referred to as residue. This residue is made up of tree tops, limbs, branches, needles/leaves and portions of the main stem (stem wood) that did not meet product requirements due to size or form.

Figure 3 - Stem wood only biomass residues (may be softwood or hardwood)

This strategy is seen as the least disruptive to current equipment and operations and is favoured in cases where nutrient extraction is a key concern because it allows the leaf material to be retained in field. Field trials have shown total biomass recovery with this approach to be between 30% and 40% depending on the quality of the stand, the forest product markets in the region and operator skills. For the purpose of this assessment the lower end of the range was used (30%). Where all the recoverable biomass in the region was delivered to the project, Figure 4 shows the requirements for the 5 MW project could be met within 50 km of Hamilton regardless of the combination of plantation source. Where only 25% of the recovered biomass is available for the new project, the distance for supply goes out to 100 km for a pine only resource and 75 km for Eucalypt or mixed supply.

Supply for 5 MW plant available within	Stem only	
	no other market	75% goes to alt market
Eucalypt only	50 km	75 km
Pine only	50 km	100 km
All plantation residue	50 km	75 km

Figure 4 - Distance to supply for 5 MW project with stem wood only

For the larger 10 MW project the details are presented in Figure 5 where the non-comparative market would provide supply within 50 to 75 km. Only a combined Eucalypt and pine supply could meet demand within 100km if only 25% of the recovered biomass could be captured by the project.

Supply for 10 MW plant available within	Stem only	
	no other market	75% goes to alt market
Eucalypt only	50 km	>100 km
Pine only	75 km	>100 km
All plantation residue	50 km	100 km

Figure 5 - Distance to supply for 10 MW project with stem wood only

4.3.2 Stem wood plus tops and limbs

In operations where nutrient extraction is less of a concern, strong markets exist for biomass, and available equipment is adapted to handle limbs and tops as part of the extraction, a greater percentage of the available biomass can be recovered. Using traditional forest product harvest methods, trials have shown recovery of 50% up to 60% of the recoverable biomass being captured, Figure 6.

Figure 6 - Stem, tops and some limbs

When the methods are modified to better target biomass recovery the recovery can be increased to 60% to 65% as shown in Figure 7.

Again, analysis uses the lower end of the range for each of these methods. With the inclusion of limbs and tops, the recovery of additional biomass means that supply range can be shortened, as presented in Figure 8 for the 5 MW project and Figure 9 for the 10 MW project.

Figure 7 - Modified harvest system for biomass recovery

Supply for 5 MW plant available within	Stem, branches and tops	
	no other market	75% goes to alt market
Eucalypt only	25 km	50 km
Pine only	50 km	100 km
All plantation residue	25 km	50 km
Supply for 5 MW plant available within	Modified harvest system for biomass recovery	
	no other market	75% goes to alt market
Eucalypt only	25 km	50 km
Pine only	50 km	75 km
All plantation residue	25 km	50 km

Figure 8 - Distance to supply for 5 MW plant - stem & limb recovery and modified biomass harvest

Supply for 10 MW plant available within	Stem, branches and tops	
	no other market	75% goes to alt market
Eucalypt only	50 km	75 km
Pine only	50 km	>100 km
All plantation residue	50 km	75 km
Supply for 10 MW plant available within	Modified harvest system for biomass recovery	
	no other market	75% goes to alt market
Eucalypt only	50 km	75 km
Pine only	50 km	100 km
All plantation residue	50 km	75 km

Figure 9 - Distance to supply for 10 MW plant - stem & limb recovery and modified biomass harvest

Within biomass supply chains from plantation residues it is increasingly common to store the biomass in the forest to reduce moisture content ("seasoning"), which increases the heating value of the biomass and reduces the logistics costs. For availability of the biomass the same volume needs to be available whether delivered green or seasoned and availability in the figures above are based on the green mass required for the project.

4.4 Supply chain cost estimates

Supply chain cost estimates have been calculated based on field trials and observed operational experience that FIRC-USC has had in the Australian plantation industry. The individual trials are proprietary. However the combined results of the trials are used by FIRC-USC as part of the industry collaborative R&D program in the indicative costing models used for this project, including an infield chipping costs model (CHIPCOST), the Australian Productivity And Cost Assessment model (ALPACA) and a truck costing framework (Truck cost). All these models are available for review upon request.

Actual costs of the supply will be influenced by market conditions, local contractor skills/knowledge, and locally available equipment. Note that these supply costs do not include a return to the land owner/manager, which will need to be added. A brief consultation with plantation owners indicated they would expect a return in line with the market and risk in their business. No one would commit to a number but the current expected range would be between $5 and $20 per green tonne. Early supply chains would likely expect to be at the lower end of that range but need to consider it may increase as the market matures and competing markets come online.

The supply chain cost estimates provided are based on efficient operations with equipment that is fit for purpose. This is particularly important for the transportation costs, where purpose-built, high-volume vans (similar to those used in the pulp export industry) will be needed to avoid volume restriction of the payload that can significantly increase the cost of transport; especially when transporting the seasoned biomass.

The costing model assumes that extraction of the biomass material to the forest road side is integrated with the extraction of traditional forest products and is treated as a separate product in the operations.

With the green supply chain (for biomass delivered to the bioenergy plant at 50% moisture content) the biomass material is stacked at road side with the other forest products, to be chipped within a few days of extraction. For the seasoned supply chain (for biomass delivered to the bioenergy plant at about 30% moisture content) the biomass product is stacked at road side and stored for 4 to 8 weeks to naturally dry (prediction curves based on climatic conditions are available) before being chipped. In this case a small storage cost is incorporated in the estimates. In both cases the biomass product is chipped at the road side directly into the vans while the transport truck waits and then is transported to the bioenergy plant.

Two supply chain variations were considered in the cost estimates. One uses the large chippers currently available in the region and used in the pulp export industry and the other uses a smaller chipper more suited to the smaller bioenergy plant. The smaller chipper provides a more agile operation that can move between small product piles quickly and easily and comes at a significantly lower capital cost, but it will have a lower production rate when chipping. The cost estimates also consider two different transportation vehicles, one as a self-unloading semi-trailer and the other as a high productivity B-double configuration. The B-double option is based on the equipment currently used in the export pulp industry and offers the highest payload and thus productivity but will require unloading infrastructure at the energy facility to dump the trailers, while the semi-trailer option can unload itself in any yard or facility. It would be an option to run a mixed fleet which would result in a weighted average cost.

Figure *10* presents the range of supply chain costs, excluding returns to land owner, estimated for the different scenarios. For the 5MW project the supply chain costs ranged from $23 per tonne at the lowest, B-double sourcing stem only residues from all plantations in a non-competitive biomass supply market with a small chipper, all the way up to just over $45, semi-trailer sourcing stem, limb and top pine residues only in a competitive market for biomass supply with a large chipper. For the larger 10 MW project the supply chain costs are slightly higher, by about $1 per tonne for the similar scenarios with the lowest estimated cost at $23.82 and the highest estimated cost at $46.13. The B-double option, for the same supply chain is between $3 and $4 per tonne lower than the semi-trailer transport option.

Based on the ranges found the supply could be achieved at a cost, excluding return to the land owner, below $30 per tonne. (A figure of $30 per tonne is used for the base case in the financial modelling later in the report, to allow for a small return to land owners.)

While the seasoned supply chain will deliver 13,500 tonne@30%MC to the 5MW project and 27,000 tonne@30% MC to the 10MW project each year, the costs are presented as they apply to the original green mass of the recovered biomass 20,000 tonne@50%MC and 40,000 tonne@50%MC respectively; ultimately paid based on a delivered volume.

5MW demand Large Chipper	Stem only							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$27.66	$24.12	$32.05	$26.88	$31.52	$27.22	$36.68	$30.47
Pine only	$30.12	$25.68	NA	NA	$35.22	$29.57	$41.38	$33.42
All plantation residues	$27.51	$24.03	$30.96	$26.20	$31.24	$27.04	$35.48	$29.72
	Stem, Tops & Limbs							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$31.55	$28.53	$35.48	$31.01	$36.50	$32.75	$40.81	$35.50
Pine only	$34.85	$30.63	$38.91	$33.16	$41.53	$35.95	$45.25	$38.26
All plantation residues	$31.30	$28.37	$34.44	$30.37	$36.50	$32.75	$40.73	$35.44
	Modified Harvest System for Biomss recovery							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$29.23	$26.42	$33.02	$28.82	$34.75	$31.00	$38.83	$33.59
Pine only	$33.05	$28.85	$36.30	$30.87	$39.69	$34.14	$43.10	$36.26
All plantation residues	$29.23	$26.42	$32.56	$28.53	$34.75	$31.00	$38.73	$33.53
5MW demand Small Chipper	Stem only							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$26.72	$23.18	$31.11	$25.94	$30.27	$25.97	$35.43	$29.22
Pine only	$29.19	$24.75	NA	NA	$33.97	$28.32	$40.13	$32.17
All plantation residues	$26.57	$23.09	$30.02	$25.26	$29.99	$25.79	$34.23	$28.47
	Stem, Tops & Limbs							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$30.99	$27.97	$34.92	$30.45	$35.75	$32.00	$40.06	$34.75
Pine only	$34.29	$30.07	$38.34	$32.60	$40.78	$35.20	$44.50	$37.51
All plantation residues	$30.74	$27.81	$33.88	$29.81	$35.75	$32.00	$39.98	$34.69
	Modified Harvest System for Biomss recovery							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$28.67	$25.86	$32.46	$28.26	$34.00	$30.25	$38.08	$32.84
Pine only	$32.49	$28.29	$35.74	$30.31	$38.94	$33.39	$42.35	$35.51
All plantation residues	$28.67	$25.86	$31.99	$27.97	$34.00	$30.25	$37.98	$32.78

10MW demand Large Chipper	Stem only							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$28.73	$24.80	NA	NA	$33.51	$28.48	NA	NA
Pine only	$31.93	$26.80	NA	NA	$37.39	$30.91	NA	NA
All plantation residues	$28.65	$24.75	NA	NA	$33.37	$28.39	$38.29	$31.47
	Stem, Tops & Limbs							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$33.33	$29.66	NA	NA	$38.68	$34.14	$43.86	$37.39
Pine only	$36.04	$31.37	NA	NA	$41.77	$36.10	NA	NA
All plantation residues	$33.20	$29.58	$36.74	$31.80	$38.45	$33.99	$42.86	$36.77
	Modified Harvest System for Biomss recovery							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$31.22	$27.68	$35.61	$30.44	$36.27	$31.97	$41.43	$35.22
Pine only	$33.69	$29.25	NA	NA	$39.97	$34.32	$46.13	$38.17
All plantation residues	$31.07	$27.59	$34.52	$29.76	$35.99	$31.79	$40.23	$34.47
10MW demand Small Chipper	Stem only							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$27.79	$23.86	NA	NA	$32.26	$27.23	NA	NA
Pine only	$30.99	$25.86	NA	NA	$36.14	$29.66	NA	NA
All plantation residues	$27.71	$23.82	NA	NA	$32.12	$27.14	$37.04	$30.22
	Stem, Tops & Limbs							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$32.76	$29.10	NA	NA	$37.93	$33.39	$43.11	$36.64
Pine only	$35.48	$30.81	NA	NA	$41.02	$35.35	NA	NA
All plantation residues	$32.64	$29.02	$36.17	$31.23	$37.70	$33.24	$42.11	$36.02
	Modified Harvest System for Biomss recovery							
	Delivered MC 30%				Delivered MC 50%			
	no other market		75% goes to alt market		no other market		75% goes to alt market	
	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain	Live floor semi	Btrain
Eucalypt only	$30.66	$27.12	$35.05	$29.88	$35.52	$31.22	$40.68	$34.47
Pine only	$33.12	$28.68	NA	NA	$39.22	$33.57	$45.38	$37.42
All plantation residues	$30.51	$27.03	$33.96	$29.20	$35.24	$31.04	$39.48	$33.72

Figure 10 - Supply chain cost estimates

4.5 Total biomass

The table below summarises the total amounts of residues that are estimated to be available at various distances from the site for the proposed bioenergy plant. Data is based on green tonne per year at 50% MC.

	Distance from site for bioenergy plant (km)					
	0-25	**25-50**	**50-75**	**75-100**	**100-125**	**Total**
Forest Harvest Residue - Hardwood Plantation	48,281	190,656	235,182	147,047	60,027	681,193
Forest Harvest Residue - Softwood Plantation	3,402	78,494	167,172	133,872	29,366	412,306
Total	51,683	269,150	402,354	280,919	89,393	1,093,499

Figure 11 - Estimates of total biomass available from plantation harvest residues

5 Other biomass material

The investigation of plantation residues shows that there are sufficient residues to operate either of the bioenergy plants under consideration. Other sources of biomass are also available in the region. These other feeds include:

- Plantation stands that have been damaged by fire, which makes them unusable for production of export wood chip.
- Farm trees (individual trees or small stands)
- Green waste from council collections and the activities of contractors (for example clearing of public land or around power lines).

These materials can be used as feed for the bioenergy plant provided they meet a number of requirements:

- **Composition** – all such biomass must meet the speciation for fed to the bioenergy plant, which will be based around the expectation of feed from plantation harvest residues. It can be expected that other feeds will meet this specification, but depending on the source of this material, particular attention may need to be given to the removal of soil, or contaminants in green waste such as plastics and metals.
- **Eligibility** – if Large Generation Certificates (LGCs) or similar credits are to be created by the power plant, it is essential that all biomass meets the eligibility requirements for the scheme in question. The requirements for the Renewable Energy Target have been reviewed (see Appendix 2) and it is expected that these other feeds will be eligible for creation of LGCs.
- **Cost** – If composition and eligibility requirements are met, the alternative feeds may be used, provided they are available at the same or lower cost than plantation harvest residues. It can be expected that some of these feeds will have costs for alternate methods of disposal that can make sale to the bioenergy plant financially advantageous for both parties.
- **Availability** – the financing for the bioenergy plant will most likely be predicated on the plant owners having secure feed supply agreements with plantation managers, so financiers can be confident that the performance of the plant is based on low-risk supply of feed (quantity, composition, cost). There can be scope within this arrangement for other feed but they will be considered as a minor part of the overall feed supply.

These other feeds will vary in quantity and cost on a case by case basis and they cannot be modelled accurately in this feasibility study. Instead, the financial modelling discussed in sections 13 and 14 makes allowance for variation in average feed cost to determine its impact on project viability.

6 Bioenergy systems – overview

6.1 Thermal bioenergy systems

There are three different thermal processes for generation of heat and power from biomass: combustion, gasification and pyrolysis. These are summarised below.

a) **Combustion systems** heat biomass in the presence of excess air. The biomass burns and this generates heat. The heat may be recovered in useful form as hot air, hot water, steam or thermal oil. Steam and hot oil both may be used to generate electricity, normally via steam turbines or Organic Rankine Cycle turbines.

Almost all of the commercial bioenergy plants around the world use the combustion process. Combustion systems offer considerable flexibility for biomass feed. They may be designed for a biomass with a wide range of moisture contents, particle sizes and compositions (particularly in relation to the quantity and composition of material that creates ash and that may cause fouling in the combustion plant).

An example of a commercial bioenergy plant in Victoria is the 10 MW_t plant at Australian Tartaric Products in northern Victoria. This plant uses agricultural waste (spent grape marc) as fuel. It has been designed to provide heat (as steam) and electricity to the adjacent factory.

The photograph below (Figure 12) was taken during construction: the red section is the combustion area and the tube bundle above it is where the steam is generated. To the left are filters that clean the exhaust gas before it is released to the atmosphere via the stack. Power generation is via an ORC unit (not in photograph).

Figure 12 - 10 MW combustion bioenergy plant at industrial site in northern Victoria

b) **Gasification systems** heat biomass in the presence of a restricted amount of air (or oxygen), which is insufficient for full combustion. Gasification produces a combustible gas, normally referred to as syngas or producer gas. The gas may be burnt directly to create heat, or used for power generation in reciprocating engines connected to alternators.

Most commercial biomass gasifiers around the world use a process called downdraft gasification. These gasifiers require feed to be prepared to particular standards of moisture content and particle size. Such gasification normally occurs at lower temperatures than many combustion systems, which provides gasifiers with some ability to utilise fuels that may cause difficulties in normal combustion plants.

We have not considered gasification for this study:

- Almost all of the world's downdraft gasifiers are small units built in India and China. They are generally designed for attended operation (i.e. one or more personnel each shift, taking advantage of labour rates in developing countries that are considerably lower than rates in Australia) and without the need for compliance with standards such as are found in Australia. They require separate feed dryers and greater attention to feed preparation. Our experience is that with the addition of a range of extra equipment to provide a complete, automated system they offer little cost advantage over combustion systems.

- A number of companies in Australia, Europe and North America have sought to make a business building commercial scale gasifiers, however there are no companies operating at present with regular sales or the level of experience of many specialist suppliers of combustion equipment.

c) **Pyrolysis systems** heat biomass in the absence of air. With no air present, the biomass cannot burn and the heat breaks it down into solid, liquid and gaseous components.

- When pyrolysis is carried out slowly the reaction products are mainly solids (charcoal, also called biochar) and a combustible gas. In comparison with commercial downdraft gasification systems, there is more charcoal production and less gas production, so this approach may be preferred if there is a viable, long-term market for the charcoal that is more valuable than the syngas that was not produced.
- When the pyrolysis process is carried out very quickly the main product is a combustible liquid. Several commercial fast pyrolysis plants operate in the Northern hemisphere, producing liquid fuels that are transported to industrial and commercial customers and used for carbon-neutral heating.

The applications for energy at the Hamilton industrial estate do not match either slow or fast pyrolysis and these technologies were not considered in this study.

6.2 Technology selection and cost development

The use of experienced vendors reduces risk for any bioenergy project. This study did not consider any technology that is not already used in numerous commercial applications in Australia or overseas.

- Combustion and downdraft gasification systems are readily available from experienced commercial suppliers.

- Steam turbines, ORC units, and reciprocating engines suitable for syngas are also available from experienced commercial vendors.

Capital cost estimates have been developed via communications with experienced vendors for the major items. Where possible, we have sought multiple prices and used the average price in the capital cost estimate. The estimates use a mixture of in-house data and standard references for the balance of costs. Pricing has been developed for complete plants, including (as required for each alternative):

  - Feed receival from B-double trucks.
  - Feed storage in large bins that facilitate automated operation of the bioenergy plant.
  - Combustion or gasification plant (including a feed dryer for the gasification plant).
  - Steam turbine or reciprocating engines and alternator, to generate electricity.
  - For the power plants - Cabling and transformer to allow the electricity to be reticulated to local industry or into the network.
  - For the heat plant – Pressure piping to allow stream reticulation to local heat users.
  - For the power plant - air cooled condensers for waste heat removal.
  - All associated civil costs.
  - Design and project management costs.

We have included a contingency but have not made any allowance for recovery of costs incurred prior to implementation or any contractor's fee for project delivery on a lump sum, turnkey basis.

For the combustion power plant we examined material and energy balances and capital costs for:

- A combustion plant heating thermal oil, with power generation via an Organic Rankine Cycle turbine.
- A combustion plant raising superheated steam (400^{O}C and 40 bar) and a condensing steam turbine.

Each system as its own strengths and weaknesses, which need to be assessed on a case by case basis. For the bioenergy plant in this study the steam cycle approach was found to offer more cost-effective electricity. Its benefits include:

- The ability to reach higher temperature with superheated steam than with thermal oil, which translates into greater efficiency for energy conversion and greater electrical output.
- The ability to reach a lower flue gas temperature with the steam system approach, improving the efficiency of energy recovery from the combustion plant.
- Lower electrical loads for the motors needed in the steam plant when compared with the thermal oil plant.

The overall effect of these differences is a higher operating cost for the thermal oil plant combined with a lower net electrical output. So while capital costs for steam and thermal oil were similar, the steam approach yielded a better overall result.

We also considered a bioenergy plant based around a downdraft gasifier from an experienced Asian supplier. There are many such gasification units in India and other similar countries. In those countries the gasification plants operate with significant levels of staffing on a continuous basis, however such an approach in Australia is cost prohibitive. Our capital cost estimate made allowances for automated feed handling and an allowance for automation of the whole plant. It also include cost estimates for all of the equipment and activities not included in the core gasifier supply offer. When all costs were included, the total plant cost was still somewhat lower than the cost for a combustion plant with a steam turbine. However the availability of the gasification plant (the hours that it is expected to be operational each year) is lower that the combustion plant, and preliminary financial modelling showed that gasification did not offer any benefits over a combustion plant based on boiler and steam turbine.

6.3 Attributes of proposed feeds

The project is predicated on using plantation industry harvest residues as feed. Examples of such residues are shown in the images below (in this case from the Victorian plantation hardwood industry):

Figure 13 - Examples of residues created during harvesting operations

As noted in section 4 above, harvest methods vary and the availability of wood, leaf and bark for bioenergy from these residues is also impacted when plantation managers keep some residues on site (leaf in particular) for nutrient retention.

So by using harvest residues, the bioenergy plant may receive feeds that vary from clean wood chip through to feeds with significant quantities of bark and leafy material. These latter materials can be used as biomass fuel provided certain precautions are taken in the equipment design. Most importantly the combustion or gasification plant needs to be capable of dealing with elevated levels of ash and also ash with greater slagging potential than normally found in clean wood. This issue, coupled with the moisture content of the fresh feed, will dictate design of the combustion zone and ash handling equipment of the plant. Careful design will ensure a reliable plant but it is important to work with equipment vendors that understand these issues and have experience in solving them. Furthermore, it is essential to design the plant for all feeds that are expected.

Moisture content is another major variable, both in feed supply and in acceptable levels for combustion and gasification plants.

- Freshly harvested biomass is in the range of 50% moisture content (measured on a wet basis).
- Trials by FIRC show that if biomass is left in field for some time after harvest, this moisture content can be reduced to approximately 30%. Reduction of the moisture content in this way can lower transport costs and also improve combustion efficiency.

Combustion plants routinely manage both the above moisture contents, and some combustion plants can use feed with moisture levels as high as 60%. However commercial gasification plants typically require feed at less than 20% moisture content, and so a feed dryer is required for use of such plants.

A more extensive discussion of biomass attributes and their impacts on bioenergy systems can be found in the report Biomass energy production in Australia. The 2004 edition is available as a download from Agrifutures[12] and the 2012 update is available as a download on Enecon's website[13].

6.4 Location for bioenergy plant

It is intended that the bioenergy plant be located at the new industrial estate on the Hamilton-Port Fairy Road in Hamilton (Lot 1 TP179163). The industrial estate is rectangular in shape and has a total area of 7.5ha, with the possibility of expansion to the north as the need arises. Zoning is Industrial 1.

It is proposed that the bioenergy plant be located at the western end of the estate. A plot of approximately 6,500 square metres is required, with some flexibility as to layout, but with a need for sufficient space to be able to have B double vehicles enter, unload biomass and exit conveniently.

The Victorian Planning Provisions (VPP)[14] describe the use of land in the state. Clause 33.01 describes the activities that may be carried out in land designated as Industrial Zone 1. It further describes those activities that do not require a permit and those that do. Uses that do require a permit include some "uses with adverse amenity potential", which are described in more detail in Clause 52.10.

Uses within Clause 52.10 include "combustion, treatment or bio-reaction of waste to produce energy". This use carries advice on threshold distance between the use and a residential zone, noting that the threshold distance is "variable, dependent on the processes to be used and the materials to be processed or stored."

The Hamilton industrial estate is bordered by a Farming Zone on the south west and a Rural Activities Zone to the east (on the eastern side of the Hamilton-Port Fairy Road). While neither is zoned residential, both these areas show dwellings, as does the industrial zone immediately to the west of the industrial estate.

The distance from the proposed location of the bioenergy plant to these dwellings varies from approximately 200 metres to more than 300 metres. We understand from the VPP that a permit will be required for the bioenergy plant and that acceptance of these distances as being adequate is up to the permitting authority. We are not aware of any precedent for determination of such a distance in Victoria. We have been involved in a bioenergy project in rural Western Australia where permission was given to build and operate a bioenergy plant approximately 300 metres from the nearest dwelling.

In both states the EPA gives clear guidance on emissions that are acceptable for such plants. This includes gaseous, particulate, liquid and noise emissions. Specific items of equipment or design features needed for compliance will be considered on a case by case basis, but it is worth noting that there are multiple bioenergy plants operating for decades around Australia in full compliance with EPA requirements.

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[12] https://www.agrifutures.com.au/publications/biomass-energy-production-in-australia-status-costs-and-opportunities-for-major-technologies/
[13] http://www.enecon.com.au/downloads.php?section=renewable_energy
[14] http://planningschemes.dpcd.vic.gov.au/schemes/vpps

7 Thermal energy only

A bioenergy plant for thermal energy is shown in the schematic below. It will provide heat as steam to industrial customers within the industrial estate.

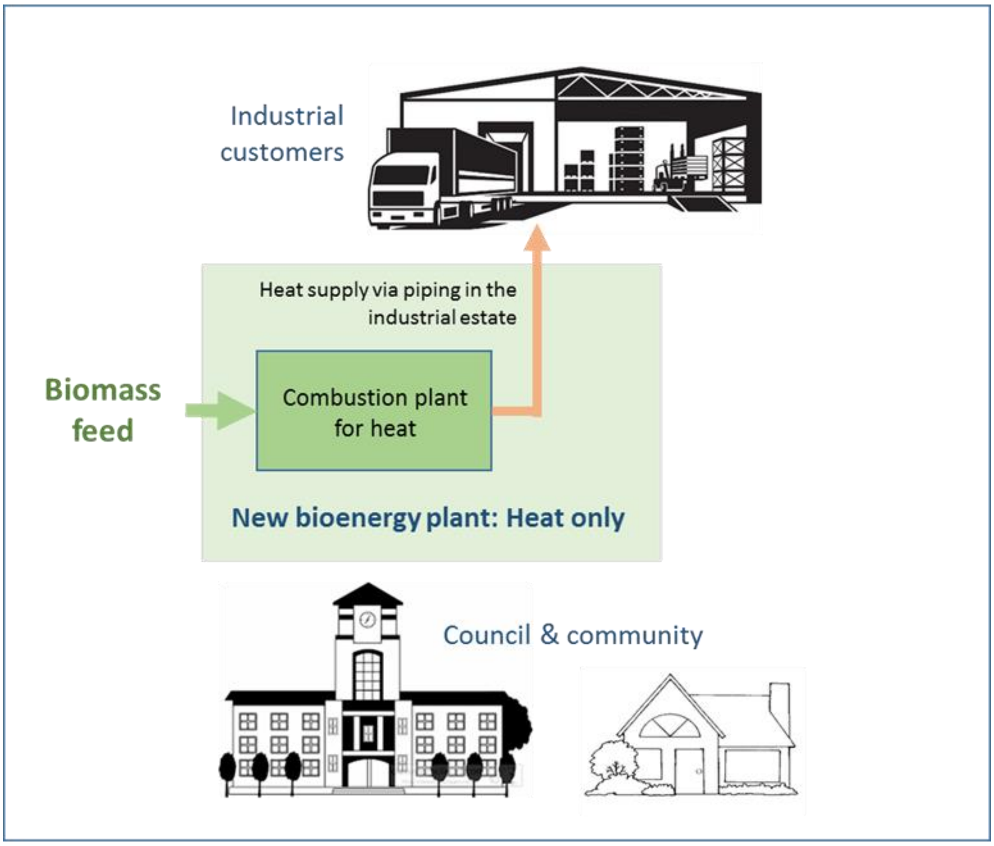


Figure 14 - Schematic for combustion heat plant

Combustion plants are best operated continuously; this avoids wear from thermal cycling and also allows the significant capital cost of such a plant to be recovered via the maximum use possible. For this plant:

a) Biomass feed will be received during day shift on weekdays. Two or three B-double trucks each day will provide biomass for a stockpile at the bioenergy plant. The stockpile will be of sufficient size to allow the plant to keep operating over a long weekend or other period when supply contractors are not making deliveries.

b) From the stockpile, biomass will be moved into large storage bins that allow for automated feeding of the combustion system 24 hours per day.

c) The combustion plant will generate steam in a boiler. Boilers less than 10 MW in scale may be certified for unattended operation in Victoria.

d) Steam will be sent via piping to nearby companies that have a requirement for heat. While steam has been modelled for the study; in practice the bioenergy plant could generate hot water or thermal oil for its customers.

e) The main emissions from the combustion plant are:
   - Gaseous emissions via the stack – These will be managed to allow the plant to comply with Victorian EPA emission standards. Typically this includes the installation of a filter system for particle removal and design to ensure that nitrogen oxide emissions are within specified limits.
   - Ash, which is discharged into bins beside the combustion plant and removed periodically. Ash from bioenergy plants contains useful nutrients for plant growth and can be applied to land as a soil amendment. For any bioenergy business in Hamilton it may be possible to do this with local farmers and plantation owners.
   - Noise – The plant will operate continuously. Careful attention will be given to the selection of low noise equipment and acoustic enclosures if needed, so that the plant meets EPA noise requirements.

Dust is not expected to be an issue at the plant. The biomass feed is chipped elsewhere and is not expected to contain significant levels of fine material. It will be stored on a concrete pad (uncovered) or in large silos before use.

7.1 Heat reticulation in industrial estate

Heat may be reticulated to users within the industrial estate in several different ways:
- Hot water for users needing heat at less than 100 ^{O}C.
- Steam for users needing heat at higher temperatures (for example 180 ^{O}C steam at 10 bar in pressure).
- Thermal oil for users requiring heat at up to 300 ^{O}C.

It is expected that only one alternative will be used, and steam and thermal oil can be used in low temperature applications as alternatives to hot water. While the nature of the piping will vary somewhat for these three alternatives, the overall cost of reticulation will not vary greatly as the trenching and installation costs will be similar for all approaches. Our estimate in this report is based on steam reticulation as it is considered to be the most likely choice of industry.

Heat may be reticulated throughout the estate, but it is unlikely that all tenants will require it. For the purposes of cost estimating it has been assumed that users of heat will be placed close to the bioenergy plant to keep reticulation costs to a minimum. The capital cost estimate for the bioenergy plant includes pricing for steam reticulation using the following assumptions:
- 10 bar saturated steam to be supplied to 3 customers on neighbouring blocks, within 225 metre of the boiler.
- Steam piping and condensate return piping located in a concrete service trench with removable concrete covers.
- Piping terminated near the front gate of each customer's property. It will be the user's responsibility to provide additional piping to bring the steam into the site also to provide heat exchangers to utilise the heat (such heat exchangers are readily available from a number of equipment manufacturers).
- Metering of steam to each customer included.
- Trench provided with a sump pump to remove any water leaking into the trench, and an allowance made for strengthening where road traffic would cross the trench.

The reticulation system can be expanded if additional heat users come to the estate at a later date. The total amount of heat that is available is set by the bioenergy plant, and additional users may only be supplied with heat if there is capacity in the bioenergy plant to do so.

7.2 Storage of heat

Bioenergy plants are normally operated continuously; to maximise energy sales and avoid wear from thermal cycling. However customer demand for energy:

- May vary with time.
- May only occur for a part of each day or each week.

Many bioenergy plants can be operated at less than maximum output, which provides some capability for the bioenergy plant to follow changes in load. The rate at which changes in output can be made in bioenergy plants is slower than energy plants fuelled by natural gas.

Many industrial users of heat only operate for part of each day or week. As it is preferred to operate a bioenergy plant continuously this raises the question of energy storage, i.e. store the heat that is generated outside the normal operating hours of the energy users.

Hot water storage can be used this way. Water can be heated to 95 ^{O}C overnight then pumped to a customer for use in that customer's process directly or to provide indirect heat. Direct use of such hot water would require a customer that needs more than 600 tonnes of hot water on a daily basis.

Thermal oil could also be used to store the heat, at temperatures as high as 300 ^{O}C. This should provide for a greater variety of uses relative to hot water storage. However it also comes at a significant cost. Depending on the return temperatures for the thermal oil[15], more than 400 tonnes of this material will probably be required to store the heat generated over a 12 hour period. The initial purchase of this quantity of oil could cost $3 million or more. The working life of thermal oil varies with its use; more rigorous conditions for temperature cycling reduce the working life. So the economic viability of heat storage via thermal oil can only be considered on a case by case basis with knowledge of the heat requirement of the customers that will use it.

It is also important to remember that if the bioenergy plant is generating 5 MW of heat on a continuous basis and customers are using that heat (directly and via storage) for fifty percent of each day, these customers must have a collective requirement for 10 MW of heat.

[15] The temperature at which the energy users return the thermal oil will depend on the temperatures that they need in their processes.

8 Power generation

A bioenergy plant for power generation energy is shown in the schematic below. It will provide electricity on a continuous basis. Customers can include:

- Companies within the industrial estate, whose electricity can be provided via a mini-grid in the estate
- Customers in the Southern Grampians Shire – council, other industry, businesses and domestic consumers could all access electricity from the plant via the existing network.

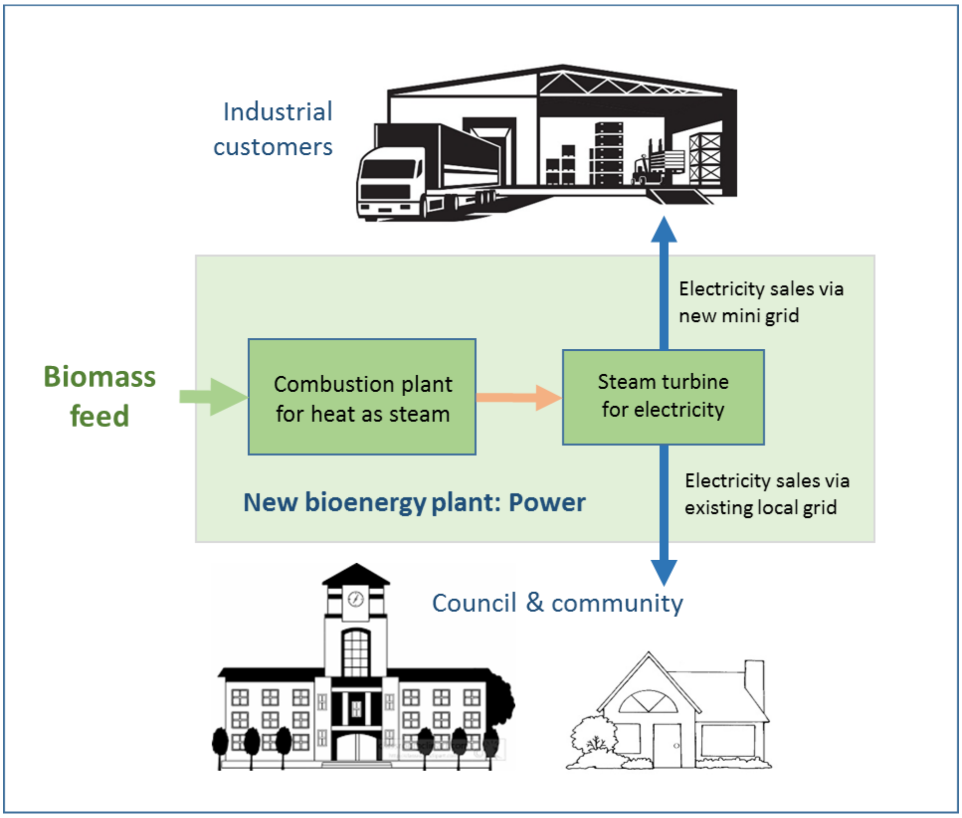


Figure 15 - Schematic for combustion power plant

Operation of this power plant will be very similar to the operation of the heat plant described above. The main difference is that the steam will be generated at higher temperature and pressure, to optimise power generation rather than use for local heating. The steam will be sent to a turbine and alternator and electricity will be generated, nominally at 11 kV.

Power generation in this way creates low-grade waste heat. In a plant focused on power generation this heat is produced at a temperate that is too low for industrial use and it must be disposed of via condensing equipment. These condensers may use water or air to remove the waste heat. Our design has used air-cooled condensers, as water-cooled units have significant water requirements and generate waste water that contains chemicals[16].

Electricity reticulation in the industrial estate
The capital cost estimate for the bioenergy plant includes electricity reticulation to neighbouring businesses in the industrial estate. This has been developed using the following assumptions:

- 11 kV electricity assumed to be supplied to 3 customers on neighbouring blocks, within 225 metre of the bioenergy plant.
- 3-phase electrical cabling located in a concrete service trench with removable concrete covers.
- Trench provided with a sump pump to remove any water leaking into the trench, and an allowance made for strengthening where road traffic would cross the trench.
- The cabling terminated at a transformer (11kV/400 V) and meter near the front gate of each customer's property.
- There is no specific allowance for other equipment that may be required if customers are connected to the general electrical network as well as to the bioenergy plant.

It is quite feasible to reticulate electricity to more users around the estate. It can be seen from data later in this report (See Section 14.1) that the cost of reticulation for the configuration described above is less than 5% of the total capital cost for the project.

Electricity reticulation via network
The capital cost estimate for the bioenergy plant includes an amount for connection to the existing electricity network so that electricity may be sold to customers via that network. The preliminary nature of this study has meant that the local network manager (Powercor) was not able to provide pricing for a network connection for the plant, so pricing in the capital cost estimate has been based on similar work undertaken for network connection on another bioenergy project.

[16] The steam turbine exhausts low pressure steam. The efficiency of electrical generation is improved by having the exhaust at as low a temperature as possible. The temperature achieved is limited by the ambient conditions. Typically the exhaust can be cooled by water from a cooling tower to 10°C above ambient, or cooled by air to 20°C above ambient. Cooling with water requires a lot of water to be evaporated from the cooling towers; in this case around 12,000 litre per hour. Cooling with ambient air is considered to be more appropriate in areas short of water. An air-cooled condenser is used for this purpose, and in this case it is assumed it will condense exhaust steam at 40°C with an ambient temperature of 20°C. The condensate is recycled back into the boiler to minimise water consumption.

9 Cogeneration

9.1 Combustion

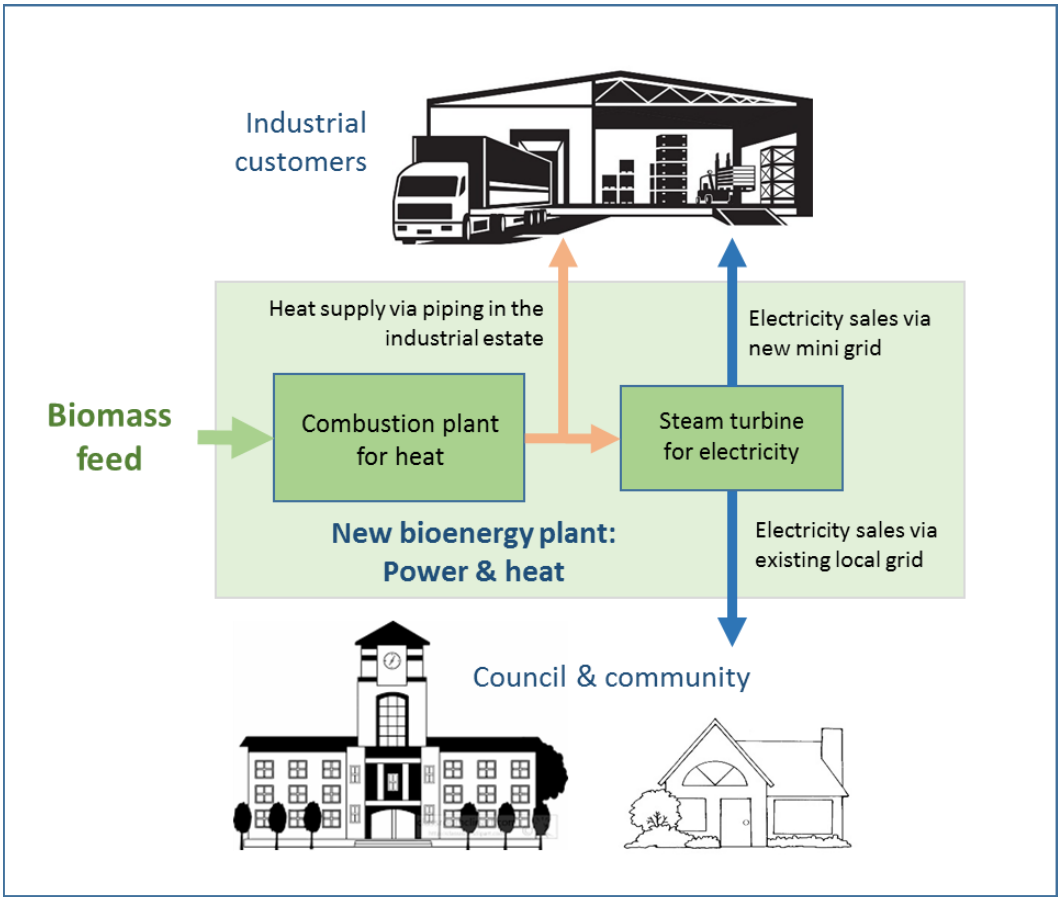


Figure 16 - Schematic for cogeneration via combustion plant

Most combustion bioenergy power plants use steam turbines that are configured to extract the greatest amount of electricity possible from the steam. Waste heat is produced, but at a temperature that is too low for use in commercial applications, and it is typically removed via cooling towers or air-cooled condensers.

There are other configurations for combustion power plants that allow the recovery of thermal energy in addition to electricity. These include:

- Diversion of some steam prior to the turbine for thermal use, as shown above.
- A pass-out turbine may be used, again to provide some energy as process steam and some as power.
- An ORC unit may be configured for hot water recovery in addition to electricity.

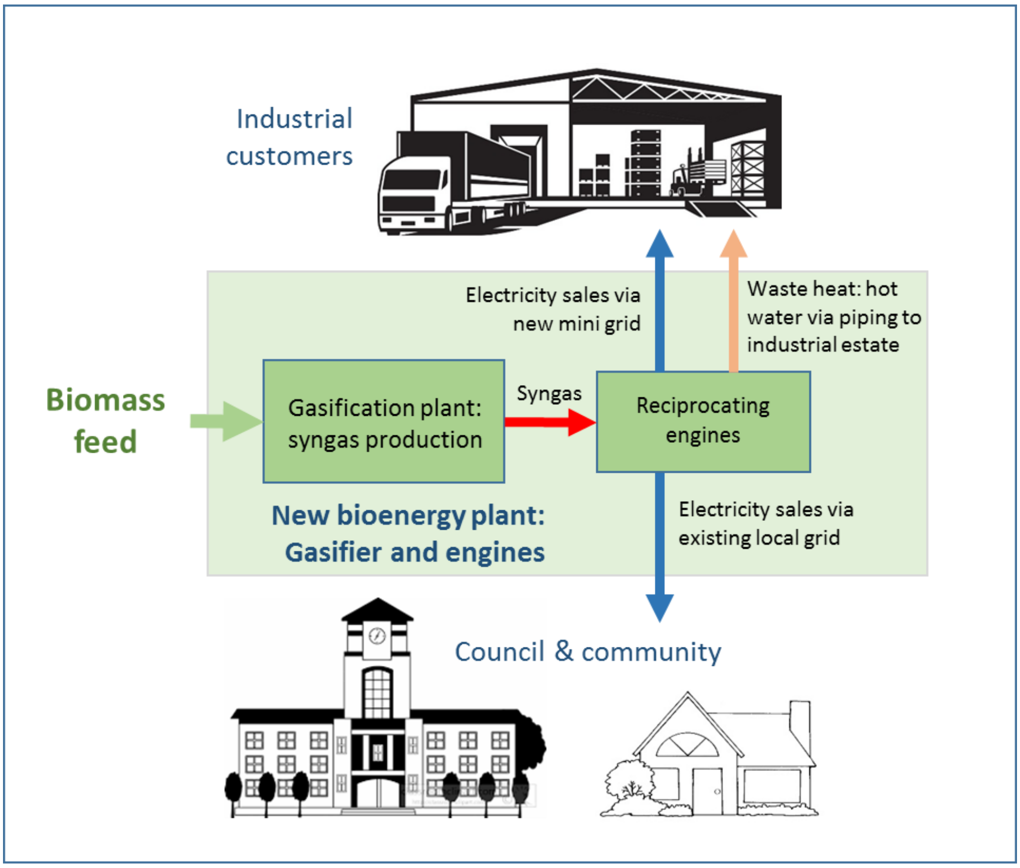
In every case, the supply of useful thermal energy for customers (as steam or hot water) reduces the production of electricity. So while the overall production of useful energy may be increased, the financial viability of the system may be adversely affected, as electricity is normally sold at higher prices than heat energy.

9.2 Gasification

Gasification plants generate power via reciprocating engines, and as such they offer a different path to cogeneration in comparison to combustion plants.

Reciprocating engines produce waste heat at the same time that they drive an alternator to generate electricity. Most of the waste heat is available in the engine exhaust and jacket coolant, while smaller amounts can be recovered from the lube oil cooler and the turbocharger's intercooler and aftercooler (if so equipped). 45 to 55 percent of the waste heat from engine systems is recovered from jacket cooling water and lube oil cooling systems at a temperature suitable for hot water but too low to produce steam. Steam can be produced from the exhaust heat if required, but if no hot water is needed the amount of heat recovered from the engine is reduced and total CHP system efficiency drops accordingly[17].

When this waste heat is captured and used there is no reduction in electricity generation. Cogeneration with reciprocating engines is already widespread in commercial applications, where natural gas-fired engines in buildings provide electricity, plus heat at a temperature that is well suited to building heating.



[17] Catalog of CHP Technologies - U.S. Environmental Protection Agency Combined Heat and Power Partnership, September 2017

Figure 17 - Schematic for cogeneration via gasification plant

9.3 Cogeneration at Hamilton industrial estate

The opportunity for cogeneration at the Hamilton industrial estate will need to be assessed on a case by case basis, using data that is specific to particular users of heat and power:

If a business in the industrial estate has a significant need for hot water, there may be merit in considering a gasification plant that can generate large quantities of hot water without any reduction in power generation.

Alternatively, consider a business that needs heat via process steam rather than hot water, but only requires this heat for a part of each day. Given that it is best to operate the bioenergy plant continuously, an intermittent demand for heat creates an opportunity to use the bioenergy plant for electricity generation when the heat is not required. This allows complete utilisation of the bioenergy plant, with revenues from sales of heat or power on a continuous basis. However it may not be attractive financially for a number of reasons:

- Because of the additional costs for generation equipment and a more sophisticated boiler, a bioenergy plant to make heat and power is considerably more expensive than a plant to make heat alone. If power generation is only possible for part of each day, this additional plant cost must be recovered from electricity sales over a limited period.
- Heat demand will typically occur during peak times Monday to Friday, so electricity generation will take place in off-peak times. This may have a significant adverse impact on the sale price for the electricity.

10 Sustainability

10.1 Carbon cycle and bioenergy

The carbon cycle for bioenergy is shown in the schematic below[18]. In summary, carbon dioxide that is released into the atmosphere during combustion of the biomass is matched by carbon dioxide that is removed from the atmosphere via photosynthesis in the growing plantations.

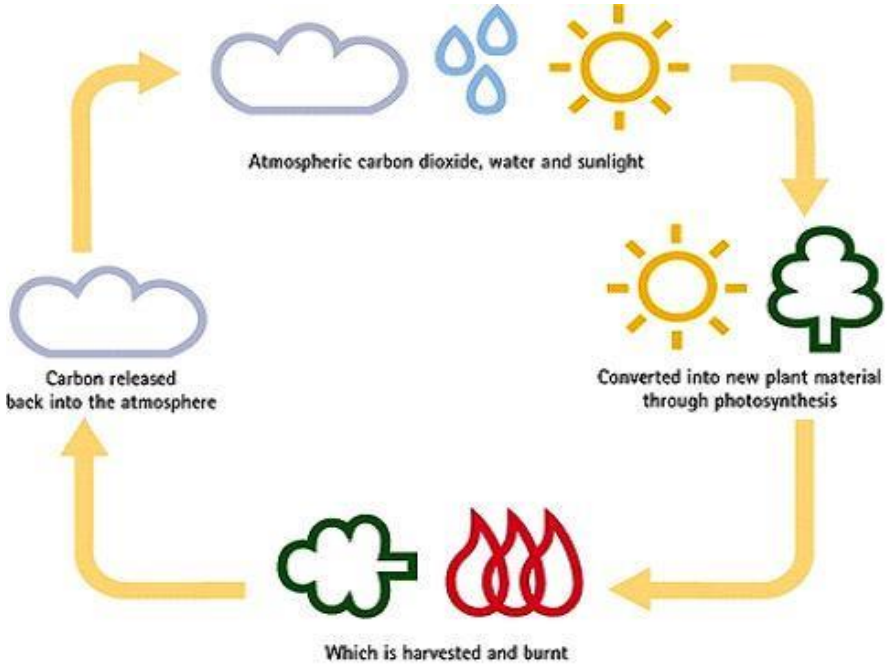


Figure 18 - The carbon-neutral cycle for bioenergy

It is for this reason that bioenergy is recognised under the original Kyoto Protocols and is also recognised alongside wind and solar energy in the Australian Government Renewable Energy Target (RET).

A summary of the eligibility of the proposed biomass under the RET is provided as Appendix 2.

10.2 Life cycle assessments

All forms of renewable energy actually have some emissions. The chart below shows indicative emissions associated with bioenergy, geothermal energy and solar energy. However, while these forms of energy have emissions they are still considerably closer to carbon-neutrality than fossil fuels.

[18] https://www.renewableenergymagazine.com/ritesh-pothan/captive-biomass-plantations-a--a-sustainable

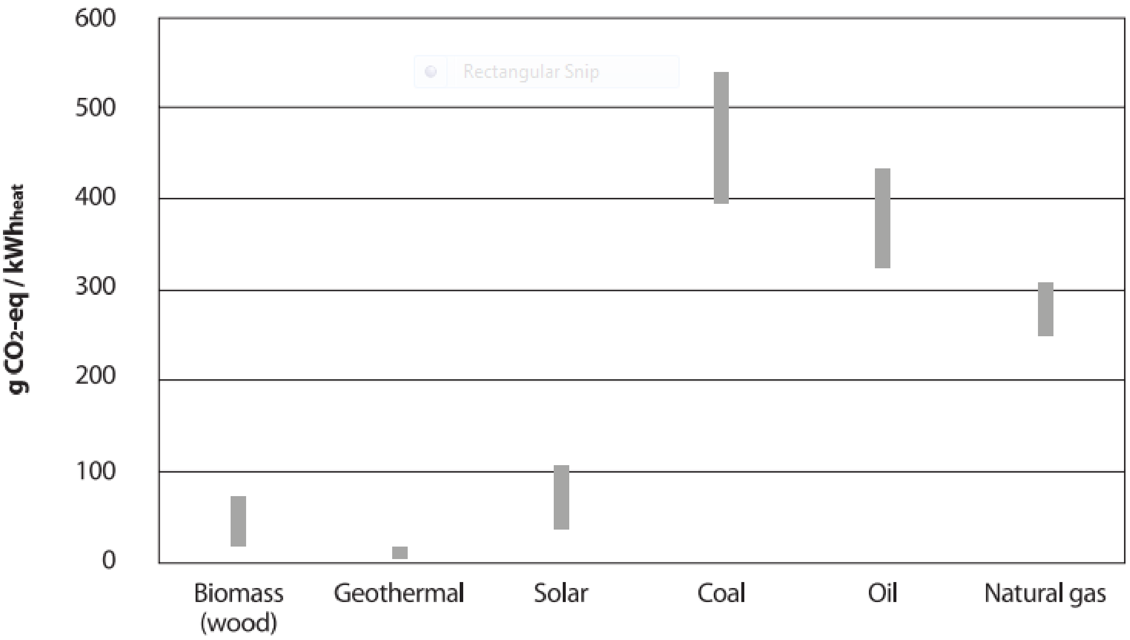


Figure 19 - Ranges of GHG emissions for heat supply from different sources[19].

The carbon balance for an energy source may be determined via a life cycle assessment (LCA). Done properly, this a comprehensive and costly process that is guided by the requirements of specialist bodies such as the International Standards Organisation (ISO 14040, 14044).

The Bioenergy section of the International Energy Agency has put considerable time and effort into the understanding of LCAs for bioenergy projects. They have released a number of reports on this subject, including an overarching document that was co-authored by Professor Annette Cowie of the National Centre for Rural Greenhouse Gas Research, based in NSW[20]. That report contains a number of case studies. Two that are of relevance to the Hamilton bioenergy plant are:

- Heat production in Europe via purpose-grown energy crops, offering GHG reductions of 75 – 85%.
- A hypothetical bioenergy power plant in New South Wales, fuelled with biomass from existing and new hardwood eucalypt plantations. The bioenergy system was compared with power generation from black coal. The GHG reductions for the project varied from 108 – 128% (which includes allowance for some carbon sequestration in the eucalypt plantations).

[19] Cherubini et al. 2009. Energy- and GHG-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations. Resources, Conservation and Recycling. 53: 434-447.
[20] Lifecycle Assessment Approach to estimate the net greenhouse gas emissions of bioenergy – Bird N *etal*, IEA Bioenergy ExCo: 2011:03

11 Government support

Federal and state governments have instigated a number of programs to support carbon mitigation and the uptake of renewable energy. The main programs with possible relevance to the bioenergy project in Hamilton are discussed below.

11.1 Australian government

11.1.1 Large Generation Certificates

Large Generation Certificates (LGCS) are a tradeable commodity under the Australian Government's Renewable Energy Target (RET). LGCs are created via the generation of eligible renewable energy from accredited power stations (one LGC is created per MWh of electricity). They may be sold to power companies, who have annual targets for LGCs to be surrendered under the RET. LGCs can be sold via long-term agreements or on a spot market, and the value of an LGC has been seen to vary with time and with method of sale.

Under the RET, the number of LGCs to be surrendered rises each year, until it corresponds to a total of 33,000 GWh in 2020. From 2020 there are no further increases and that quantity of LGCs is to be surrendered each year through to 2030.

The intent of a target that increases each year is to provide a growing market for LGCs as the renewable industry expands. The Clean Energy Regulator (CER) manages the RET and monitors the amount of eligible generation - in place, committed and probable - to determine how closely the annual target for LGCs is being matched by increasing generation capacity. In its most recent summary (27 April, 2018[21]) it shows total projects for renewable energy generation that are well in excess of those needed to generate 33,000 GWh of renewable energy in 2020 and beyond.

The CER also report on prices being paid for LGCs on the spot market and within longer-term power purchase agreements (PPAs). While publicly announced spot market prices at the start of 2018 have been as high as $85 per LGC, the prices for LGCs within PPAs have been far lower[22].

From this data it can be assumed that a new bioenergy project at Hamilton may have difficulty finding a reliable market for any LGCs that it creates. Also, if such a market can be found, the price received for each LGC is very difficult to predict.

11.1.2 National Energy Guarantee

The National Energy Guarantee is a program that is being promoted by the Australian Government to guide both renewable and fossil fuel electricity generation in the future. It is yet to be agreed to by the states so its final form, content and longevity are unclear. At present it contains no mention of a scheme similar to the current Renewable Energy Target, suggesting that beyond 2020 there will be no

[21] http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/Large-scale-Renewable-Energy-Target-market-data

[22] http://www.cleanenergyregulator.gov.au/RET/Pages/About%20the%20Renewable%20Energy%20Target/How%20the%20scheme%20works/Large-scale%20generation%20certificate%20market%20update%20by%20month/Large-scale-generation-certificate-market-update-January-2018.aspx

equivalent national scheme and no opportunity for a bioenergy project established after 2020 to create and sell Large Generation Certificates or an equivalent item.

11.1.3 Emissions Reduction Fund

The Emissions Reduction Fund (ERF) is an alternative to the other state and federal schemes described in this section. As its name suggests, the ERF is a mechanism to reduce Australia's CO_2 emissions. A number of activities are eligible under the ERF and eligible participants can earn Australian Carbon Credit Units (ACCUs) for emissions reductions. One ACCU is earned for each tonne of carbon dioxide equivalent (tCO2-e) stored or avoided by an eligible project. ACCUs can be sold to generate income, either to the government through a carbon abatement contract, or in the secondary market. At the time of writing, pricing for ACCUs is reported as being between $4 and $11 per unit[23,24].

There are certain criteria for eligibility to participate in the ERF[25] and the proposed bioenergy projects at Hamilton (thermal and electrical energy) are not eligible at present.

11.1.4 ARENA

The Australian Renewable Energy Agency (ARENA) was established by the Australian Government to lead the commercialisation of renewable energy in this country.

ARENA launched its latest investment plan on 1st May 2018[26]. The plan, titled Innovating Energy, sets out four new priorities that will guide funding over coming years. The priorities are:

1. Delivering a secure and reliable electricity system
2. Accelerating solar PV innovation
3. Improving energy productivity
4. Exporting renewable energy

The only relevant mention of bioenergy in the plan is within the narrative for the third priority, where it is noted that examples of proposals sought include: *"Feasibility studies, demonstrations and pre-commercial deployments integrating energy productivity and renewable energy into manufacturing or other processes, with renewable energy supplied through process electrification or direct thermal input (bioenergy or solar thermal)"*.

It may therefore be possible to secure ARENA's support for the more detailed developed activities associated with a bioenergy plant for industrial heat.

11.2 Victorian government

11.2.1 Victorian Renewable Energy Target (VRET)

The Victorian government has set a renewable energy target for the state and implemented a number of programs to help reach that target. Two major programs are of particular interest:

23 http://www.demandmanager.com.au/certificate-prices/
24 http://www.reputex.com/research-insights/update-outlook-for-accu-supply-and-prices-in-australia-to-2030/
25 http://www.cleanenergyregulator.gov.au/ERF/About-the-Emissions-Reduction-Fund
26 https://arena.gov.au/assets/2017/05/AU21397_ARENA_IP_Document_FA_Single_Pages_LORES.pdf

a) **Victorian Renewable Energy Auction Scheme –** This scheme supports new renewable energy in Victoria. It requires generators to be least 10 MWe in capacity[27]. Unfortunately this is several times larger than the plant proposed for Hamilton, which would be ineligible as a result.

b) **Victorian Renewable Energy Action Plan -** The Victorian Government has developed an action plan for the promotion of renewable energy in the state. This Plan will invest $146 million across three focus areas[28]:
   - Supporting sector growth.
   - Empowering communities and consumers.
   - Modernising our energy system.

   While the main focus of the Plan is wind and solar energy, there is also an allocation of $2 million towards the development of waste-to-energy facilities in Victoria, and investigation of the potential for solar thermal and bioenergy technology for industrial heating applications to support investment in alternative technology. This may provide an avenue for funds toward further development of the business case for a bioenergy project in Hamilton.

11.2.2 Victorian Energy Upgrades

The Victorian Energy Upgrades program helps Victorian households and businesses to cut their power bills and reduce greenhouse gas emissions. It does this by providing access to discounted energy-efficient products and services that provide savings on energy bills. As such it is not applicable to the proposed bioenergy plant.

[27] https://www.energy.vic.gov.au/__data/assets/pdf_file/0014/80510/VRET-fact-sheet-Auction.pdf
[28] https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-action-plan

12 Community energy

Community energy is a growing component of the renewable energy sector in Australia. It can take many forms, starting with groups of domestic properties with solar panels and battery storage being connected via smart micro-grids. At a larger scale community energy can take the form of community ownership of generation assets, such as the two wind turbines owned by Hepburn Wind[29].

The Hepburn wind farm is comprised of two wind turbines, each 2.05 MW. Funding for the purchase and installation of these turbines was raised as equity from community investors (augmented by a mix of debt and grants). Some 1,700 investors contributed a total of $9 million toward the $13.1 million cost of the project[30]. The wind farm began generating in 2011.

The Hepburn Wind project provided a learning opportunity for community engagement and investment that has been applied to other renewable energy projects in regional Australia. One recent example is the community investment proposed within the funding for the Sapphire Wind Farm in the New England region of northern New South Wales[31]. A Community Investment Testing Report was issued in late 2017[32], which provides a useful introduction to the process of community engagement and the positive response that was found in the New England region.

More recently, community energy has also involved a significant retail component. This ranges from electricity retailers offering products in collaboration with community generators (such as is offered here in Victoria by Powershop in conjunction with Hepburn Wind) through to the provision of "backroom" services, whereby an experienced and licensed electricity retailer can support the sale of electricity to customers under the naming of the company that owns and operates the energy project.

Enova Energy[33], in northern NSW, is Australia's first community-owned energy retailer. It commenced trading in 2016 after raising almost $4 million from more than 1,000 investors. Its activities include retailing and support for small scale solar installations. Like Hepburn Wind, it has a program for assisting the local community. Enova currently has a retail licence for NSW and is reportedly working towards licences for other states.

Community energy can therefore involve some or all of financing, generation and retail electricity sales.

Recent experience with community funding of wind and solar projects in Australia indicates that a community will view investment in a local renewable energy project somewhat differently to corporate investors. Financial support from community investors is expected to be available at lower rates of return than those available from traditional project equity. This will improve the chances that a project reaches financial viability.

29 https://www.hepburnwind.com.au/
30 https://en.wikipedia.org/wiki/Hepburn_Wind_Project
31 http://www.sapphirewindfarm.com.au/community-investment/
32 http://www.sapphirewindfarm.com.au/wp-content/uploads/2018/01/Sapphire-Wind-Farm-CIT-Report-2017.pdf
33 https://enovaenergy.com.au/

13 Financial analysis – heat

13.1 Base case

The financial model for the bioenergy heat plant, to be owned and operated by a third party, is based on the following values for the main financial parameters:

Parameter	**Base case value**
Capital cost ($million)	4.92 (includes $0.5 M to distribute and meter steam in the industrial estate)
Plant utilisation	100%, meaning that apart from maintenance etc, it is assumed to be operating and selling steam continuously.
% of capital cost:	
• Debt	60
• Equity	40
Debt terms	5% interest, principal repaid at 20 years
% IRR after tax	15
Length of period modelled (years)	20
Escalation	Included at 2% per year

Figure 20 - Financial model parameters for heat plant

The financial model also includes feed purchase, operating and maintenance cost, interest payments etc. For these conditions, the selling price for steam is calculated to be $34 per tonne of steam.

13.2 Comparison with natural gas.

A cost comparison between heat from a bioenergy plant and heat from a plant fired with natural gas is not straightforward.

- The cost of heat from each plant is determined by the cost of fuel, operating expenses and return on capital for the heat plant.
- When compared with natural gas-fired heat plants, bioenergy heat plants are characterised by significantly higher capital costs and lower costs for fuel.

Our comparison has considered all these costs. It is not possible to make a meaningful cost comparison in GJ because this does not adequately address the different impacts of capital cost on the final energy cost needed for each system, particularly when the energy must be made available in a form that can be reticulated to and used by customers.

The price of natural gas has increased in recent years, in large part because of competition for gas created by the many plants built to export it as LNG (liquefied natural gas). It is difficult to predict future prices, as availability is influence by political and community concerns over expanded exploration, fracking for onshore gas and the construction of LNG import terminals. As recently as 5 July 2018, the Australian Industry Group called on the Australian government to expand the use of the Australian

Domestic Gas Security Mechanism to place restrictions on gas exports, warning that the alternative may be manufacturers leaving Australia[34].

We have estimated the capital and operating costs for a 5 MW heat plant fuelled by natural gas and modelled this system using the same parameters as above. This financial model applied to a gas-fired boiler shows that steam will cost $81 per tonne when natural gas is available at $20 per GJ.

So, for the base case, the bioenergy plant can provide steam at less than half the cost of the natural gas-fired plant.

13.3 Sensitivities

Several of the main parameters in the financial model have been varied to determine their impact on the selling price of steam. Results are provided in the table below.

Parameter for bioenergy plant	Value	Price for steam($ per tonne) using:	
		Bioenergy	Natural gas
Ave. cost of biomass feed			
• Base case	$30 per tonne	34	81
• Lower cost	$25	32	81
• Higher cost	$35	35	81
Capital cost for bioenergy plant			
• Base case	$ 4.92 M	34	81
• Lower	10% lower	33	81
• Higher	10% higher	34	81
Utilisation of energy[35]			
• Base case	100%	34	81
• Lower	75%	40	85
• Lower	50%	54	91

Figure 21 - Sensitivities for heat plant

From these data it can be seen that the financial viability of the plant is not very sensitive to changes in cost of feed. For example a total cost of $55 per tonne for biomass feed would represent a return to the biomass provider of approximately $30 per tonne and the bioenergy plant would still have the potential to provide energy at lower cost than natural gas. However, biomass supply will be a competitive process and a provider seeking a return as high as $30 per tonne may not be very successful if plantation owners are willing to accept lower returns for the removal of residues from their land.

The financial viability of the plant operating at capacity is not very sensitive to changes in plant capital cost. However financial viability is sensitive to the hours for plant operation and sale of the energy that is generated. Ideally the bioenergy plant will be operated 24 hours per day and 7 days per week. This not only maximises the potential for energy sales, it also avoids wear from thermal cycling. Combustion

[34] Latimer C, Canberra needs to keep its finger on gas trigger - The Age 5 July 2018
[35] Including allowance in the model for reduced purchase of biomass. Maximum availability for the bioenergy plant is assumed to be 8,000 h/y and for the gas-fired plant 8,500 h/y.

plants can vary their output if required but this takes some time because of the thermal inertia of the system. They are slower to start and change output than natural gas-fired plants.

In contrast to the bioenergy plant, local companies that require heat may only operate during normal business hours on weekdays. The competitive advantage for bioenergy over natural gas could be lost if the energy from the plant is only needed for part of each day or week and heat storage (see section 7.2) is not suitable for the needs of the energy users.

13.4 Summary

The data above are summarised in the following table, which shows annual operating costs and revenues at various plant outputs.

Assumed plant utilisation	100%	75%	50%
Capital cost	$4.92 M	$4.92 M	$4.92 M
Annual cost for biomass fuel (assuming fuel is $30/t delivered)	$418,000	$313,000	$209,000
Annual operating cost	$940,000	$860,000	$790,000
Annual steam production	56,000 tonne	42,000 tonne	28,000 tonne
Selling price for steam ($/tonne) to achieve 15% return on equity	34	40	54
Annual value of steam	$1.9M	$1.68M	$1.51M

Figure 22 - Summary of heat plant cost data

14 Financial analysis – electricity

14.1 Capital cost

The capital cost for the power plant, to be owned and operated by a third party, is made up of the following components:

Power station, including: • 2 combustor/boilers sets operating independently in parallel • feed silos 2 x 600 m3 • deaerator • multicyclone/baghouse • steam turbine/generator • synchronizing panel and other turbine controls • air-cooled condenser • control room • electrical panels • ash removal • demineralization plant • feed handling including front-end loader • freight • emissions monitoring • installation	$10.5 million
Civil works including: • site preparation • foundations • boiler and turbine house	$590 000
Grid connection	$1.4 million
Water supply	$80 000
Effluent treatment	$110 000
Miscellaneous	$520 000
Steam turbine acoustic enclosure	$200 000
Spare parts	$30 000
Project management and engineering	$1.4 million
Contingency	$2.7 million
Reticulation and metering of electricity to customers	$650 000
Total	**$18.2 million**

Figure 23 - Breakdown of capital cost for power plant

14.2 Operating costs (excluding biomass)

The annual operating costs for the plant are summarised in the table below.

Labour	$260 000
Maintenance	$370 000
Overheads, incl: • consultants • office supplies and telephones • rates • accounting	$300 000
Miscellaneous costs, incl: • water • boiler chemicals • effluent disposal • ash disposal • start-up fuel	$47 000
Total	**$980 000**

Figure 24 - Breakdown of operating costs for power plant

With proper maintenance, combustion boilers have been known to operate for many decades, particularly in the Australian sugar industry. The allowance for maintenance costs is factored from the capital cost.

To keep operating costs down, it is assumed that the bioenergy plants will operate on almost an unattended basis (which is within legislation for boilers up to 10 MW) and equipment for storage and automated feeding is included in the capital cost estimates. For the power plant it is assumed that all steam will be returned as condensate, while for the heat plant it is assumed that only 50% will be returned (with the balance being used by customers).

14.3 Base case

Financing scenarios can cover a wide variety of combinations of grant, debt and equity, with different ratios, different costs for debt and different returns sought on equity. To illustrate this, two different financing scenarios have been modelled:

- The base case for industry finance uses parameters expected for a project with no grant support and seeking funds from commercial sources.
- The base case for community finance assumes that a grant is received for half of the capital cost and that remaining funds are raised from community investors, with a lower threshold for return than commercial investors. The grant is assumed to be taxable at normal company tax rates.

These and other parameters are presented in the table below:

Parameter	***Base case – industry finance***	***Base case – community finance***
Capital cost ($million)	18.2	18.2
Plant utilisation	100%, meaning that apart from maintenance etc, it is operating and selling electricity continuously.	
% of capital cost		
• Grant	0	50
• Debt	60	0
• Equity	40	50
Debt terms	5% interest, principal repaid at 20 years	No debt, but grant assumed to be taxable
% IRR after tax	15	5
Length of period modelled (years)	20	20
Escalation	Included at 2% per year	

Figure 25 - Financial model parameters for power plant

The financial model also includes feed purchase, operating and maintenance cost, interest payments etc. For these conditions, the electricity prices needed to meet equity returns are:

- For commercial return (15% IRR) - $210 per MWh for electricity and any credits.
- For community return (5% IRR) – $155 per MWh for electricity and any credits.

Figure 26 below provides a summary of capital and operating costs, and revenues from electricity sales.

Parameter	***Value***
Capital cost	$18.2 M
Assumed plant utilisation[36]	100%
Annual fuel cost (assuming fuel is $30/t)	$840,000
Annual operating cost	$980,000
Max potential annual electricity production	16,700 MWh
Annual value of electricity at $155/MWh	$2.69M
Annual value of electricity at $200/MWh	$3.34M

Figure 26 - Summary of power plant cost data

14.4 Sensitivities

Key parameters have been varied while maintaining the targeted return to investors, to assess the impact of such variations on electricity prices.

[36] Based on operation 8,000 hours per year, which allows time for maintenance and shutdowns.

Parameter	***Value***	***Electricity price ($/MWh)***	
		Commercial funding	***Community funding***
Ave. cost of biomass feed			
• Base case	$30 per tonne	210	155
• Lower cost	$25	202	147
• Higher cost	$35	218	164
Capital cost for bioenergy plant			
• Base case	$ 18.2 M	210	155
• Lower	10% lower	200	151
• Higher	10% higher	220	160

Figure 27 - Sensitivities for power plant

From these data it can be seen that the price required for electricity is not very sensitive to changes in cost of feed or plant capital cost. However, as the two base cases show, it is sensitive to form of funding, in particular to the return expected by equity investors.

14.5 Price comparison - small business customer in industrial estate

The Hamilton industrial estate is in its formative stages and there are no tenants available to provide data on energy consumption or cost. In the absence of such data, the following chart[37] shows the breakdown of an electricity bill for a typical small business. Note that these are generic figures and they may vary from actual bills for businesses in the estate. The wholesale charge (for the electricity itself) is $66 per MWh which is 22% of the total bill. This is considerably lower than the cost of electricity generated in the proposed bioenergy plant. However, a bioenergy plant that is operated within the industrial estate can use a local mini-grid to provide electricity to its customers and avoid the network charges shown below. Depending on its business model it may also be able to avoid some of the retail charges that are shown. In the chart below wholesale, transmission and retail costs make a total of $247 per MWh, which is more than the localised generation and reticulation costs of the electricity from the proposed bioenergy plant.

[37] Independent Review Into The Electricity And Gas Retail Markets in Victoria", published in August 2017 - https://engage.vic.gov.au/application/files/7415/0267/4425/Retail_Energy_Review_-_Final_Report.pdf

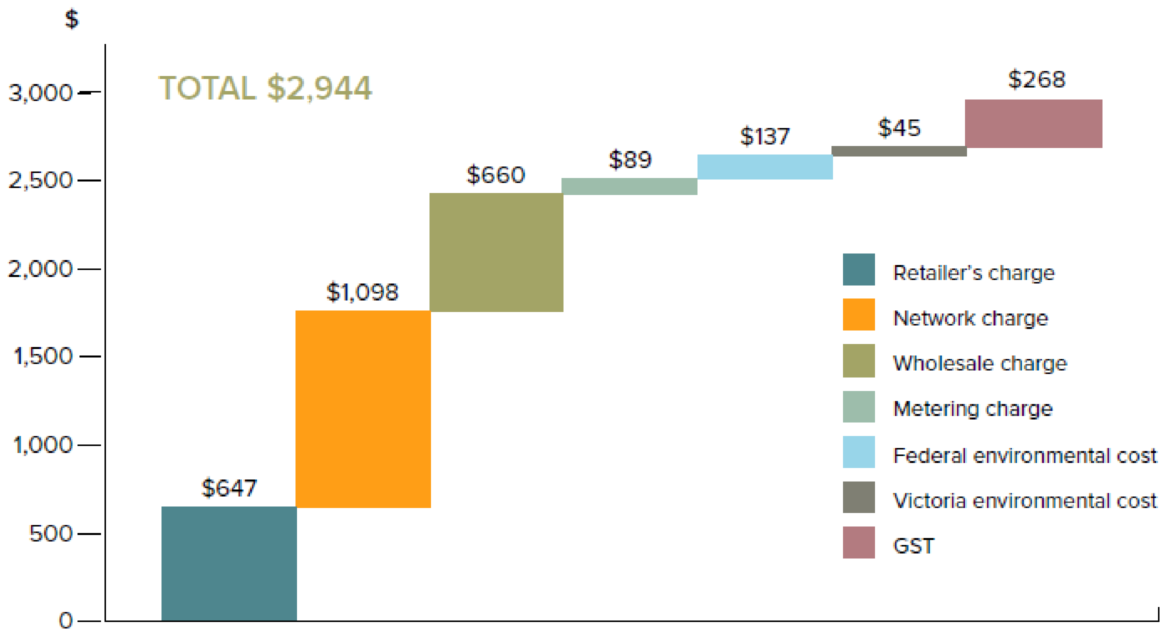


Figure 28 - Small business bill disaggregation, 10 MWh p.a. electricity

Costs for a typical mini-grid have been included in the cost estimates and financial modelling for this report.

14.6 Price comparison - domestic customer in the Southern Grampians Shire

The following chart[37] shows the breakdown of an electricity bill for a typical domestic customer using a total of 4 MWh per year. Note that these are generic figures and they may vary from actual bills in the Shire. The wholesale charge (for the electricity itself) is a cost of $66 per MWh, which is 18% of the total bill. As with the small business above, this is considerably lower than the cost of electricity generated in a bioenergy plant.

In the chart below wholesale, transmission and retail costs make a total of $291 per MWh.

- A bioenergy plant that is operated within the industrial estate can sell electricity to customers in the Shire via the existing distribution network. Our financial model includes an allowance for connection into the existing electricity grid. Sales of electricity within the local region will be able to avoid some of the network charges shown below. These are made up of the local distribution costs to reticulate electricity around the Shire (called Distribution use of system, or DUOS) and the transmission costs to use common transmission network and bring electricity from its source (called Transmission use of system or TUOS).
- Depending on its business model it may also be able to avoid some of the retail charges that are shown.

As noted, the total costs in these examples may be different to costs experienced by industrial, commercial and domestic customers in the estate and the broader region. We could not find any data to provide further guidance on the scale of reduction for network charges or retail charges and suggest that these should be discussed with a potential retail service provider such as Powershop.

Any comparison is further complicated by the volatility in pricing paid by customers, with wholesale electricity, network and retail charges all showing considerable variability over recent years. In contrast to this volatility, a bioenergy plant could offer long-term power purchase agreements at a fixed price, with the only cost variation being an escalation clause governed by CPI increases.

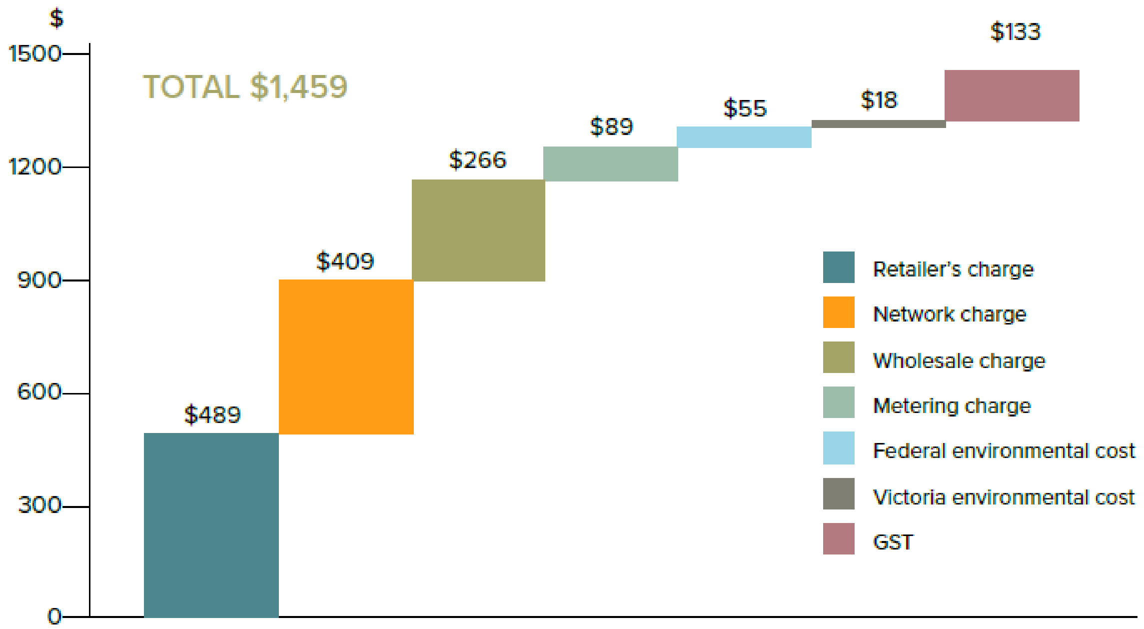


Figure 29 - Residential bill disaggregation based on generally available offers, 4 MWh p.a. electricity

Another complication to making cost comparisons is the uncertainty that surrounds the value of any renewable credits associated with the electricity from the bioenergy plant. Although the electricity is considered eligible for LGCs, the RET scheme already appears to be oversubscribed, and it is reaching the end of the period for new generation to secure LGC sales contracts. There is no similar scheme under discussion to replace the RET scheme.

Electricity consumption in Southern Grampians Shire

Electricity consumption for a three person household in Victoria is approximately is 7.4 MWh each year[38], suggesting that individual consumption is 2.5 MWh per year.

In the 2016 census the Southern Grampians Shire showed a population of 15,944. Combined with the typical domestic electricity consumption of 2.5 MWh per person, this suggests total domestic electricity consumption in the Shire of 40,000 MWh per year.

Data provided by Council indicates that their total consumption of electricity is approximately 2,300 MWh per year (for the financial year 2016/17).

Therefore the combined electricity use of Council and domestic customers in the Shire is in excess of the 16,000 MWh per year that will be generated by the bioenergy plant.

[38] Table 5.7 – Energy consumption benchmarks – electricity and gas for residential customers, Report by Acil Allen to the Australian Energy Regulator, 13 October 2017

15 Management models

15.1 Stages

As part of a discussion of management structure it is important to understand the stages of project development that lead up to an operating plant.

These stages allow the progressive development of the details of a bioenergy project, including scale, output, commercial viability and financial structures. Each stage provides greater definition of the business opportunity, and defines and reduces risk. It is common for the high risk, early stage work to be supported by Government. As the business opportunity is better defined, private industry may also participate and provide funding.

The current study, funded by the Victorian Government, is the first quantitative analysis of this bioenergy opportunity for the Southern Grampians Shire, looking at typical bioenergy plants for heat and power and comparing the energy they can produce with energy from fossil fuels.

A viable market for the energy is essential for this project to be implemented. The current work makes generalised assumptions about the customers for energy for a bioenergy plant at Hamilton. The next stage of development could consider and engage with possible customers in greater detail; looking at industry, council and community as appropriate to determine quantities of energy to be purchased, capacity to pay for renewables and risks associated with the offtake agreements that will underpin the financing of any bioenergy plants.

Development work can proceed until the project is ready for implementation. For implementation it should have, as a minimum:

- A management structure to take the project through implementation and operation.
- Agreements with energy customers and feed suppliers.
- An optimised design and capital cost estimate.
- Ownership or lease agreement for a site.
- Finalised and agreed mechanism(s) to connect the bioenergy plant to customers (local reticulation, grid connection etc).
- Preliminary work or better on permits and approvals.
- Project funding.

15.2 Participants

The table below summarises the main participants in the development, implementation and operation of a bioenergy plant.

Participant	***Main role(s)***	***Management role for ongoing plant?***
Council	• Facilitator • Potential customer for electricity.	• Promotion of green energy opportunity
Industry in the estate	• Potential customer. • Could build, own, operate.	• Possible lead role in ongoing management if the energy is sufficiently important to their business and they have requisite skills.
Community	• Potential customers. • Potential investors.	• Board or advisory role if there is community investment and/or energy purchase.
Equipment vendors	Provide equipment, e.g. boiler, turbine, feed handling.	No management role. Role during plant operation is normally limited to any warranty actions, typically over first year of operation.
Financiers	Funding for plant construction.	Very unlikely.
Specialty company	• Manage construction. • Own and operate.	Lead role in management. This company could be: • Existing company or new company set up for this business. • Could include community, either permanently or for agreed period of plant operation.

Figure 30 - Summary of project participants

At present, Council has the greatest interest in seeing the successful development of a local bioenergy plant for heat or power by a third-party investor, because of the broader economic and social benefits to the shire.

Council could facilitate the involvement of a third-party organisation to take over the lead role in project development and implementation. This organisation could be:

1. A local energy user.
    - If an energy user in the industrial estate has a particular need for heat, that company may take on the development of a bioenergy heat plant.
    - At present there are no such companies known to Council or Enecon.

2. A specialist company.
    - For some forms of renewable energy there are companies that can build, own and operate generation plants. In Australia this is true for solar and wind energy and also for bioenergy plants that use anaerobic digestion. In each case the company has built up specialist knowledge for the technology involved so that they can understand and minimise risks and justify their investment.
    - However, for bioenergy combustion plants, Enecon is not aware of any company in Australia at present that owns and operates plants similar to those proposed for Hamilton. Most similar bioenergy plants in Australia are owned and operated by the companies that directly use the energy they produce.

3. A new company.
    - The third alternative is to set up a new company that will own and operate the bioenergy plant.
    - Such a company could include equity from local energy users, the community and funding bodies such as the Clean Energy Innovation Fund and the Foresight Group.
    - This new company could be set up during the development phase to provide a focus for development work.

4. Bioenergy equipment vendors.
    - The bioenergy plant will use equipment made by a variety of experienced vendors. Their equipment specialities include:
        - Feed handling and storage equipment (or complete systems)
        - Boiler
        - Turbine
        - Condensers
    - These vendors normally supply their equipment to the company that is responsible for the construction of the complete plant. It is also possible for vendors to aggregate equipment, for example a boiler supplier offering a steam turbine as part of a larger package.
    - For the scale of bioenergy plant envisaged we are not aware of any vendors in Australia that will offer complete plants, or take a lead role in development, implementation or operation.

16 Discussion

The study has determined the selling prices for heat and power that will support investment in commercial-scale bioenergy plants at the Hamilton industrial estate.

16.1 Heat supply

A bioenergy plant can offer heat at a lower cost than heat from a boiler fuelled by natural gas when the heat is required for more than 40 - 50% of the year.

However, if heat is only needed for 40 or 50 hours per week, bioenergy will struggle to compete with natural gas unless cost-effective heat storage can be used to provide a balance for bioenergy supply and customer demand. The relative economics of bioenergy with storage and energy from natural gas will be heavily influenced by the particular heat requirements of the energy users and cannot be modelled with any accuracy in the absence of such data.

16.2 Electricity supply

The generation cost for electricity from bioenergy at the industrial estate is greater than generation costs using fossil fuels such as coal or renewables such as wind. However the location of the bioenergy plant helps to counter the relatively high cost of generation.

By selling power directly to businesses in the industrial estate, the bioenergy plant can help those customers avoid network charges, which can be significantly greater than the actual cost of generation.

Ideally a bioenergy plant will be operated continuously, but it is to be expected that most businesses in the industrial estate will not operate 24 hours per day and 7 days per week. Therefore a bioenergy plant producing electricity only will need other customers for its electricity at times when its nearby business customers are not operating. Electricity sales to other customers in Southern Grampians region may be feasible. These customers can be reached via the existing electricity network but potentially without the full network cost being applied.

Discussion with a provider of retail services is important to understand whether there is a business case for the purchase and sale of electricity within the Shire. Examples of electricity sales in Victoria correlated with renewable energy include the association between renewable generator Hepburn Wind and retailer Powershop, and the support for a solar energy plant in Victoria's north-west via the purchase of electricity for Melbourne's tram network.

The introduction of electricity sales to the broader Southern Grampians region may also create an opportunity for community funding of the bioenergy plant. This funding recognises local benefits as well as financial returns and may be available at lower rates than commercial funding, which would help the competitive position of the bioenergy plant.

16.3 Operating hours

If a bioenergy plant is built to provide energy on a continuous basis, and customers at the industrial estate only require energy during normal working hours each week, the bioenergy plant will have capacity outside those working hours to generate additional energy. It is important to keep the bioenergy plant operating and utilise that capacity if possible:

- The high capital cost of a bioenergy plant is recovered more quickly if that plant can be used productively on a continuous basis.
- Bioenergy plants are not normally designed to be switched on and off with any frequency.

For a bioenergy plant that is providing heat during normal working hours it is feasible to make more heat outside normal working hours and store it for use the next day. Power generation at night with this plant is not preferred as:

- The capital cost of such a system is quite significant relative to heat storage.
- The efficiency of such a power generation system will be as much as 50% lower when coupled to a bioenergy heat plant than when coupled to a combustion plant designed specifically for power generation.

For a bioenergy plant that is providing power during normal working hours the optimal use outside those hours will depend on markets for heat and power:

- Heat could be stored for use the next day within the industrial estate if a suitable customer exists for that heat.
- Power could be exported to other customers via the existing electrical grid, subject to the costs of connection and the suitability of pricing for those customers.

Appendix 1 - Glossary

<	Less than
>	Greater than
ACCU	Australian carbon credit unit
Ash	Inert material in biomass that does not undergo energy conversion.
CER	Clean Energy Regulator
ERF	Emissions Reduction Fund
FIRC	Forest Industries Research Centre - https://www.usc.edu.au/research-and-innovation/forests-for-the-future/forest-industries-research-centre
GJ	Giga joule. One thousand million joule
GW	Giga watt
HHV	Higher heating value
IEA	International Energy Agency. An Implementing Agreement of IEA is IEA Bioenergy.
J	Joule, the unit of energy in the metric system. A Joule is a Watt multiplied by a second.
LGC	Large Generation Certificate
LHV	Lower heating value
MC	Moisture content. On a wet basis, moisture content is the percentage of water in the total biomass (i.e. the mass including any moisture).
MJ	Mega joule. One million joule
MW	Mega watt. One million watt
MWh	Mega Watt hour. One million watt of power over a one hour period. Because there are 3,600 seconds in an hour and a Joule is a Watt by a second, one MWh is equivalent to 3.600 MJ (which is 3.6 GJ)
NOx	Oxides of nitrogen, a pollutant produced during combustion processes. Partially formed from atmospheric oxygen, and partially from the nitrogen in the fuel.
o.d.t.	Oven dry tonne (of biomass)
PPA	Power Purchase Agreement
Ton	Measure of mass. Equivalent to approximately 909 kg.
Tonne	A unit of mass in the metric system, equivalent to 1,000 kg
Volatile matter	Biomass, when heated to about 400°C to 500°C, gives up a large fraction of its weight in the form of combustible gases. The percentage of volatile matter on a dry basis in biomass typically ranges from 63 percent for rice hulls to over 80 percent for wood. One consequence of high levels of volatiles is that energy may be lost from fuel storage piles, via the loss of volatile organic compounds.
VRET	Victorian Renewable Energy Target
W	Watt, the unit of power in the metric system

Appendix 2 - RET compliance of feeds for electricity generation

Renewable Energy Target
The Renewable Energy Target (RET) is the defining instrument in Australia for the generation of carbon-neutral electricity. Established by the Australian Government to encourage an increase in Australia's use of renewable electricity, it is described in:

- Renewable Energy (Electricity) Act 2000
- Renewable Energy (Electricity) Regulations 2001

Section 17 of the Act lists eligible renewable energy sources. These include hydro, wind and solar. They also include, *inter alia*: energy crops, wood waste, agricultural waste, waste from processing of agricultural products, and biomass-based component of municipal solid waste.

Further definition is provided in the Regulations:

1. A plantation is defined as "*an intensively managed stand of trees of native or exotic species, created by the regular placement of seedlings or seed."*

2. Biomass from a plantation is considered to be an energy crop (and thus an eligible material for the RET) when "*all of the following apply to it:*
   a) *it must be a product of a harvesting operation (including thinnings and coppicing) approved under relevant Commonwealth, State or Territory planning and approval processes;*
   b) *it must be biomass from a plantation that is managed in accordance with:*
      - *a code of practice approved for a State under regulation 4B of the Export Control (Unprocessed Wood) Regulations; or*
      - *if a code of practice has not been approved for a State as required under subparagraph (i), Australian Standard AS 4708—2007—The Australian Forestry Standard;*

   c) *it must be taken from land that was not cleared of native vegetation after 31 December 1989 to establish the plantation*."

3. *"Biomass-based components of municipal solid waste means the biomass-based components of wastes that are directly sourced from, or eligible to be disposed of in, landfill or a waste transfer station that is licensed by a State or Territory government body or by a local government authority, but does not include biomass-based components of wastes originating from:*
   a) *Forestry or broadacre land clearing for agriculture, silviculture and horticulture operations; or*
   b) *Fossil fuels."*

4. *"Waste from processing of agricultural products means the biomass waste produced from processing agricultural products."*

5. Wood waste – from Regulation 8 (1): *"Wood waste means:*
   a) *biomass:*
      i. *produced from non-native environmental weed species; and*
      ii. *harvested for the control or eradication of the species, from a harvesting operation that is approved under relevant Commonwealth, State or Territory planning and approval processes; and*

   b) *a manufactured wood product or a by-product from a manufacturing process; and*

c) waste products from the construction of buildings or furniture, including timber off-cuts and timber from demolished buildings; and
d) sawmill residue; and
e) biomass from a native forest that meets all of the requirements in subregulation (2)."

Subregulation (2)- *"Biomass from a native forest must be:*
a) harvested primarily for a purpose other than biomass for energy production; and
b) either:
   i. a by-product or waste product of a harvesting operation, approved under relevant Commonwealth, State or Territory planning and approval processes, for which a high-value process is the primary purpose of the harvesting; or
   ii. a by-product (including thinnings and coppicing) of a harvesting operation that is carried out in accordance with ecologically sustainable forest management principles; and
c) either:
   i. if it is from an area where a regional forest agreement is in force—produced in accordance with any ecologically sustainable forest management principles required by the agreement; or
   ii. if it is from an area where no regional forest agreement is in force—produced from harvesting that is carried out in accordance with ecologically sustainable forest management principles that the Minister is satisfied are consistent with those required by a regional forest agreement."

Interpretation for farm woody biomass

Woody material from farms may include residues, logs or whole trees from harvest of:
1. Trees grown in plantations (including suitably managed windbreaks)
2. Native forests
3. Trees that are not grown as plantations or forests (e.g. paddock trees, some windbreaks)

For the eligibility of this material we interpret the Act and Regulations as follows:

Plantations – material from plantations can include wood (as whole logs or as chip), harvest residues, and fire-damaged material. We assume that all material is eligible as "energy crops" provided it meets the criteria in the Regulations:
- The management of plantations on farms in accordance with harvesting and code of practice requirements set out in the Regulations appears to be regulated on a state by state basis. In Tasmania for example it is a legal requirement to manage in accordance with a harvesting code of practice and a Forest Practice Plan.
- The requirement that material comes from land that was not cleared of native vegetation after 1989 is not expected to be a problem as these plantations have typically been established on what was previously farm land. However this will need to be verified on a case by case basis with prospective suppliers of plantation biomass.

Native forests –
1. If a native forest is harvested solely for biomass for bioenergy then that material is not eligible
2. If it is harvested for any other reason, we interpret the Regulations to say that if a native forest is managed and harvested in accordance with "ecologically sustainable principles" (as broadly defined

in the Regulations,8(4)) then the by-products of the harvesting operation are eligible for bioenergy under the RET.

Purpose-grown but non-plantation material – for example a windbreak that is being removed – will probably not be eligible under the RET as:

- For native species it is neither a plantation nor a suitably-managed native forest.
- For exotic species, unless it is an environmental weed species that is harvested using an approved process.

Appendix 3 - Victoria's regulatory system for electricity

Regulatory system

Generation, transmission, distribution and retailing of electricity in Victoria is regulated by the Electricity Industry Act 2000, and administered by the Essential Services Commission[39] (ESC). While licences are usually required to carry out any of these activities, certain exemptions are available.

Exemptions fall into three categories:

1. Exemptions gained by application to the ESC. These require the applicant to show that they fit into an exempt category.
2. Deemed exemptions, where no application is required.
3. Individual exemptions. These allow an applicant to make a case for exemption where they do fit into Categories 1 or 2.

The exemption system came into force on 1st April 2018, via General Exemption Order 2017.
More information on exemptions can be found at https://www.esc.vic.gov.au/energy-licensing-and-exemptions/electricity-licencing-exemptions/electricity-licensing-exemptions-categories/.

Relevance to Hamilton Bioenergy Estate

Activity	***Effect of regulations***	***Reference***
Generation of approx. 2.5 MW of electricity	Generation deemed exemption VGD1, if output of generator connected to grid at common point is < 30 MW	Ref 1, generation exemption categories
Distributing electricity at low or medium voltage to customers, within industrial estate *If none of the exemptions applies, seller of electricity would need to be/become a registered distributor, or work with an existing licensed distributor.*	Network exemption VNR1 if more than 10 business customers, each with peak demand < 500 kVA and annual consumption < 160 MWh, all on a site owned by the distributing entity.	Ref 1, network exemption categories Ref 2, definition of small customer
	Network deemed exemption VND1 if fewer than 10 business customers, each with peak demand < 500 kVA and annual consumption < 160 MWh, all on a site owned by the distributing entity.	Ref 1, deemed network exemption categories Ref 2, definition of small customer
Selling electricity to customers *If none of the exemptions applies, seller of electricity will need to*	Retailer exemption VR1 if more than 10 business customers, each with peak demand < 500 kVA and annual consumption < 160 MWh, all on a site owned by the distribution entity.	Ref 1, retail exemption categories Ref 2, definition of small customer

39 www.esc.vic.gov.au

Activity	***Effect of regulations***	***Reference***
be/become a registered retailer, or work with an existing licensed retailer.	Retailer exemption VR5 if selling only to large business customers, each with peak demand > 500 kVA or annual consumption > 160 MWh.	Ref 1, retail exemption categories Ref 2, definition of large customer
	Retailer deemed exemption VD1 if fewer than 10 business customers, each with peak demand < 500 kVA and annual consumption < 160 MWh, all on a site owned by the distribution entity.	Ref 1, deemed retail exemption categories Ref 2, definition of small customer
Back-up connection to grid	No regulatory requirement, but installation must meet local distributor's (Powercor) requirements.	Ref 3
Selling surplus electricity to grid	Retailer exemption VR5 if the electricity is sold only to large business customers, each with peak demand > 500 kVA or annual consumption > 160 MWh.	Ref 1, retail exemption categories Ref 2, definition of large customer
	No exemptions if any electricity is sold to other (small) customers, such as domestic. Effective exemption could be achieved by selling the electricity through a licensed retailer, whereby the licensed retailer would act as a "large business customer".	Ref 1, deemed retail exemption categories Ref 2, definition of small customer
	No regulatory requirement, but Powercor would need to be paid for distribution of the electricity through their system.	

References
1. https://www.esc.vic.gov.au/energy-licensing-and-exemptions/electricity-licencing-exemptions/electricity-licensing-exemptions-categories/
2. General exemption order 2017
3. https://customer.portal.powercor.com.au/mysupply/CIAWQuickCalculator#checklist

Likely scenario

A generation licence will not be required.

Until there are sufficient customers in the industrial estate, all electricity generated will need to be sold through the grid. Normally the bioenergy plant would sell to a licensed retailer, and/or to "large" customers remote from the industrial estate. In this case, retailer licence exemption VR5 could be applied for.

When selling electricity to customers outside the industrial estate the bioenergy plant should use Powercor's assets for all distribution.