BIOENERGY RESOURCE ANALYSIS AND TECHNOLOGY FEASIBILITY FOR KANGAROO ISLAND:

Phase 1 – Resource Analysis and Technology Shortlist

Prepared for

KANGAROO ISLAND COUNCIL

By

EARTH SYSTEMS
Environment | Water | Sustainability

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Executive Summary

Earth Systems has been engaged by Kangaroo Island Council to conduct a Bioenergy Resource Analysis and Technology Feasibility Study for the island. Kangaroo Island (KI) is a unique Australian region known for niche, high-value agricultural exports and as a desirable tourist destination. With a permanent population of only 4,600, KI attracts more than 180,000 tourists per year.

KI’s energy supply is at high risk of failure, due to the electrical demand on the island rapidly approaching the capacity of the sole underwater cable. The cable itself is approaching end of design life, and replacement and augmentation of the KI electricity network is becoming prohibitively expensive. This energy shortage is compromising the ability of the island to support business and tourism growth. Due to the high risk of a power outage, most residents and businesses operate back-up petrol and diesel generators; this does not conform to the ‘clean, green’ branding the island trades on.

Several large forestry plantations are found on the island, totalling almost 20,000 ha of mature trees. These trees are effectively valueless due to the recent decline in demand for wood chip; consequently the opportunity exists to utilise this biomass resource to generate electricity on the island. Several feasibility studies have been performed in the past detailing the costs and benefits of various technology solutions. Other renewable energy sources have been evaluated, such as wind and tidal generators.

The intent of this study is to evaluate the biomass resource on the island, and suggest suitable technologies that would improve the profitability of the resource by examining potential bioenergy opportunities. The scope of the study was to survey and summarise the current biomass feedstock inventory, investigate the potential for alternative bioenergy crops, evaluate the electrical and thermal energy demands of the island and recommend suitable bioenergy technology options for further investigation. Phase 2 of the study will perform initial techno-economic feasibility analyses of the selected bioenergy options identified in this report.

The existing plantation forestry has the potential to yield approximately 176,000 tonnes of green wood per annum, which converted to electricity alone would generate 12 – 13 MW for 90% of the year. Other biomass residues such as sawmill residues, cropping residues and municipal green wastes total a further 30,000 – 66,000 tonnes per annum depending on sawmill and cropping operations. The established forestry species are the most suitable energy crops for the island; although numerous crops have been developed for their bioenergy potential, due to the restricted importation of new species of plants only a few of these can be accommodated on the island. For Phase 2 of this investigation, it will be assumed that the current plantation species will provide the fuel to the various bioenergy options under consideration.

In addition to a central biomass-fired power plant currently under review, other technologies exist for converting biomass to energy which may improve the profitability of the island’s biomass resources. A key determinant of any bioenergy solution will be the cost of delivering the energy to remote users, particularly those who require higher loads, such as luxury resort facilities.

The alternative processes that have been recommended for techno-economic feasibility in Phase 2 of this investigation are:

- A central generator and wood fuel densification plant, which produces fuel for smaller wood-fired distributed generators located in grid-constrained areas of the island
• A central generator and synthetic natural gas plant, which would produce and compress natural gas for use as a fuel in existing diesel and petrol engines
• An integrated biorefinery concept which could produce high-value products from wood, in addition to electricity

Note that these scenarios describe specific technologies as stipulated in the scope for Phase 2, as outlined in the proposal document, with the addition of the integrated biorefinery concept which potentially would generate higher value products than energy alone.

As part of Phase 2 of this study, it is recommended that the analysis of the above bioenergy options requires:

• Verification and validation of the costs of a stand-alone biomass power plant
• Confirmation of prior estimates for electricity network upgrade costs through consultation with SA Power Networks and independent consultants.

In the short term, it is recommended to implement a number of demand-side management opportunities that have been identified in the course of this investigation which would alleviate some of the constraints on the electricity network. These include:

• Rescheduling the J-tariff hot water heater loads in order to limit instantaneous demand which occurs at midnight each night
• Installing variable speed drives on larger motors around the island to mitigate high starting currents
• Reviewing building management systems to better manage space conditioning loads

Overall, while the central biomass-fired generator may help to alleviate the energy constraints on the island, several possibilities have been identified which could better utilise the island’s excellent biomass resource in order to provide energy security to outlying areas, and stimulate local business opportunities.
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1 Background

Earth Systems has been commissioned by Kangaroo Island Council to conduct a study into biomass and bioenergy options for improved energy supply on Kangaroo Island (KI). The study is divided into two phases. Phase 1 (this report) provides key information on current and future biomass resources and bioenergy technologies to feed into KI's future energy roadmap, and establish the basis for further detailed work on specific resource, technology and site scenarios to be investigated in Phase 2.

Kangaroo Island is a premier tourist attraction within South Australia, and enjoys the reputation of being a clean, green tourist destination. Major revenue sectors on KI are tourism and agriculture, especially niche high-value products that are economically competitive despite export costs. The island’s permanent population numbers about 4,600, however it caters to over 180,000 tourists annually.

1.1 Electricity Supply Network

The island has a history of electricity supply issues with respect to quality and availability. The 10 MVA, 33 kV submarine cable from Fishery Beach (on the mainland) to Cuttlefish Bay (on the island) on which KI’s entire electric grid depends is approaching full capacity during periods of maximum demand and is also at the end of its design life. Additionally, the grid infrastructure on the island itself is limited to relatively small 33 kV and 11 kV networks, with a large proportion of island residents, especially towards the western reaches of the island, dependent upon an extensive radial non-integrated distribution network consisting of 19 kV single wire earth return (SWER) lines.

The submarine cable capacity, the limited 33 kV backbone and the unreliable SWER system all conspire to consistently hamper economic development on the island, due to the connection and network upgrade costs associated with any substantial increase in power usage. Consequently, there is a considerable dependence on diesel generators, with large generators used for grid stability in peak demand times and as an emergency backup for the island in the event of a major outage. Smaller generators proliferate, functioning as backup and/or augmentation, especially in areas constrained by the SWER network. Some sites are solely dependent on their own generation due to the prohibitive costs associated with network connection. Total privately-owned diesel generation capacity on the island is estimated to be in excess of 6.4 MVA. The diesel consumption for power generation is costly, given the additional supply costs associated with providing liquid fuels to the island, and is also at odds with the island’s environmentally-friendly image.

A number of studies have considered various aspects of KI’s electric power situation focusing on grid upgrades, the replacement of the aging submarine cable and the installation of significant renewable energy generation on the island itself. A 4 MWₑ wind farm has been proposed for Ironstone Hill (near Penneshaw) and RuralAus Investments Ltd, the timber mill owner, has investigated a 2.5 MWₑ bioenergy plant at Timber Creek (near Parndana) utilising harvest and mill residues principally to supply their own processing power needs. Solar PV, concentrating solar power (thermal and PV) and a variety of other renewable technologies have also been reviewed, and consideration also given to demand-side improvements (curtailing electricity load during peak demand periods) and energy efficiency.
1.2 Biomass and Bioenergy

Fundamental to recent interest in island bioenergy opportunities is the large amount of plantation timber resource currently available on the island, and the difficulties in realising its economic value due to export constraints. Although several previous reports (Mohammed, 2003; Davidson, 2009; Davidson and Lee, 2011; Oliphant and Gorton, 2011) have mentioned the possibility of bioenergy playing a key role in the island’s future generation mix, the options have not been comprehensively evaluated to date. A key driver for the consideration of bioenergy is the ability to provide base-load power, coupled with the consistent 3 MW\textsubscript{e} base-load characteristic of KI’s current annual demand profile.

Mohammed (2003) briefly reviewed bioenergy technologies for KI including combustion- and gasification-based power generation, as well as anaerobic digestion. The review captured the key elements of these approaches and their technical and commercial maturity, but did not consider the options with detailed reference to the specifics of the KI situation or resource. Notably absent was mention of combustion-ORC (organic Rankine cycle) systems, which were entering commercial service at the time of the report and are now quite prevalent in the EU (over 100 commercial installations at time of writing).

The combustion-ORC option was considered in detail by RuralAus Investments (Ipsen, 2011) in relation to their timber mill needs at the 2.5 MW\textsubscript{e} scale, and to a lesser extent as a contributor to whole-of-island power needs (5 MW\textsubscript{e} scale). Their analysis did not present a compelling financial proposition, however it appears that they were unable to account for the plant heat production as a revenue stream (or at least an avoided cost). Although the premium paid for diesel-generation on the island improves the overall investment outlook for bioenergy, worldwide commercial experiences consistently show that without an economic incentive from heat utilisation, bioenergy plant at the single MW\textsubscript{e} scale are rarely viable.

Additional studies relating to biomass resources and bioenergy plants have been undertaken in the past (e.g. Enecon, 2002), and during a previous ownership period the Timber Creek sawmill management considered several bioenergy plant scenarios both at the Timber Creek site and at Ballast Head as part of a proposed export loading facility.

1.3 Motivation for This Work

Although there has been some reference to possible bioenergy solutions for KI and some specific consideration for biomass-based power generation in relation to RuralAus Investments’ timber operations, a comprehensive evaluation of the island’s entire current and future potential biomass resource and associated energy conversion opportunities has not yet been conducted. In particular, technology opportunities other than direct electricity production, such as drop-in liquid biofuels, diesel substitution via biogas, or producer gas repowering, have not been considered in sufficient detail to draw firm conclusions on their potential for KI.

Electricity generation options too have not been fully evaluated given the specific challenges of KI’s grid, especially in relation to supply problems at the Western end of the island which are unlikely to improve significantly even with upgrades to the main network and submarine cable.

The intention of this Phase 1 report is to provide key information on current and future biomass resources and bioenergy technologies to feed into KI’s future energy roadmap, and establish the basis for further detailed work in Phase 2.
2 Objectives and Scope

The objective of Phase 1 of this study (this Report) is to provide key information on current and future biomass resources and bioenergy technologies to sufficiently guide planning and policy decisions at local government level. The information gathered in this Phase 1 study will also establish the basis for further detailed work in Phase 2. The full Project Terms of Reference can be found in Appendix A. The breakdown of the objectives and scope for Phase 1 are provided below.

2.1 Current Biomass Resource - Assessment

Provision of a comprehensive set of current biomass resource data for the island. This will combine information on plantations, agricultural residues (including stubble and manure), and key biomass waste streams of relevance including 'wet' and 'dry' organic matter and the general composition of wastes exported from the island. Some non-biomass wastes may be included in the inventory if they have possible compatibility with a bioenergy process (e.g. waste oils, paper and cardboard, plastics and tyres may potentially be co-fired in some technologies without detrimental emissions).

2.2 Future Biomass Resource - Potential

Provision of a brief assessment of potential energy cropping opportunities for KI, including current and developing bioenergy crops, their energy yield, and their suitability to the island. Consideration will be given to land availability and current use; and any significant direct and indirect land use change likely to be associated with future bioenergy cropping.

The above biomass resource assessments will include a summary table of resources, including projected costs at farm gate, estimated transport costs and any additional processing requirements.

2.3 Heat Utilisation Opportunities

As economic outcomes are often influenced by the ability to create value from thermal output, a consideration of current and possible future heat users on the island will be made. These will also include any substantial refrigeration loads which could be serviced by a tri-generation process.

2.4 Technology Shortlist

The resource assessment outcomes will most probably exclude some potential bioenergy technologies on the basis of feedstock. Those that remain will be considered further, to the point where a go/no-go decision can be made in terms of some basic technology assessment criteria.

The range of technologies considered in this first-pass assessment will include various high-grade energy output options (only one of which is direct electricity production). Other possibilities, involving energy
densification through the conversion of the available biomass feed stocks to liquid or gaseous fuels, or densified solids (torrefaction, briquetting, pelleting, etc.) will be considered, as an alternative to the limitations imposed by the local grid. These alternative energy carrier methods will be considered in the context of other limitations, for example the road network and the extent to which any heavy vehicles would be required for energy transport.
3 Infrastructure & Demand

3.1 Project Scope

Numerous previous studies have detailed extensively the current state of the electricity network infrastructure on KI. Most notably, Wessex Consult’s 2011 report ‘Opportunities for Renewable Energy and Demand Side Solutions on Kangaroo Island’ (Davidson and Lee, 2011) comprehensively analysed the state of the electricity grid, building on a 2009 report (Davidson, 2009) which surveyed the use of distributed generation on the island. The conclusions from this report identified that not only is the network infrastructure on the island at capacity, but is also particularly vulnerable to failure.

For the purposes of analysing the potential of bioenergy technologies to solve some of the problems identified, this chapter briefly summarises the state of the electricity network and focuses attention on the critical aspects related to uptake of bioenergy around the island.

3.2 Electricity Distribution Network

3.2.1 Sub-Transmission Network

Kangaroo Island is connected to the National Electricity Market (NEM) via a single 33 kV underwater cable. The cable comes ashore from Cape Jarvis on the mainland, at Cuttlefish Bay and feeds a substation at Penneshaw. From Penneshaw a 33 kV ‘backbone’ extends southwest to American River, then west to MacGillivray and north to Kingscote substation. Figure 3.1 below shows an approximate network layout across the island. Tables 3.1 and 3.2 detail the Kangaroo Island substation and sub-transmission network capacities. The submarine cable has a capacity of 10 MVA import (Cape Jarvis to Kangaroo Island) and a 2 MVA export capacity. In addition to being almost at capacity, the cable is due for overhaul / replacement in the next 6 – 8 years. It is estimated that less than 1.9 MVA of available capacity is present on the existing sub-transmission network infrastructure (Davidson and Lee, 2011).
Figure 3.1 – Kangaroo Island electricity network layout (sourced from Davidson and Lee, 2011)

Table 3.1 – Kangaroo Island substation and regulator capacities and forecast demand (SA Power Networks, 2012)

<table>
<thead>
<tr>
<th>Substation</th>
<th>TF Nameplate Rating (MVA)</th>
<th>Normal Cyclic Rating (MVA)</th>
<th>N-1 Emerg. Cyclic Rating (MVA)</th>
<th>2012/13 Forecast Max Demand (MVA)</th>
<th>2013/14 Forecast Max Demand (MVA)</th>
<th>2014/15 Forecast Max Demand (MVA)</th>
<th>2015/16 Forecast Max Demand (MVA)</th>
<th>2016/17 Forecast Max Demand (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>American River</td>
<td>3.0</td>
<td>3.9</td>
<td>0.0</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Am. River Reg.</td>
<td>10.0</td>
<td>12.5</td>
<td>4.0</td>
<td>7.4</td>
<td>7.7</td>
<td>8.0</td>
<td>8.4</td>
<td>8.8</td>
</tr>
<tr>
<td>Kingscote</td>
<td>6.25</td>
<td>7.0</td>
<td>0.0</td>
<td>4.5</td>
<td>4.7</td>
<td>5.0</td>
<td>5.3</td>
<td>5.6</td>
</tr>
<tr>
<td>MacGillivray</td>
<td>2x 2.0</td>
<td>2x 2.6</td>
<td>2x 1.5</td>
<td>2.0</td>
<td>2.0</td>
<td>2.1</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>MacG. Reg.</td>
<td>2.5</td>
<td>3.3</td>
<td>0.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.1</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Penneshaw</td>
<td>2x 2.0</td>
<td>2x 2.0</td>
<td>2x 0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Penn. PT Reg.</td>
<td>0.95</td>
<td>1.2</td>
<td>0.5</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>
### Table 3.2 – Kangaroo Island sub-transmission network (33 kV) capacities and forecast demand (SA Power Networks, 2012)

<table>
<thead>
<tr>
<th>Line From</th>
<th>To</th>
<th>30°C Rating (MVA)</th>
<th>Forecast 2012/13 MVA</th>
<th>Forecast 2013/14 MVA</th>
<th>Forecast 2014/15 MVA</th>
<th>Forecast 2015/16 MVA</th>
<th>Forecast 2016/17 MVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cape Jervis</td>
<td>Fisheries Creek</td>
<td>17.4</td>
<td>8.2</td>
<td>8.6</td>
<td>9.1</td>
<td>9.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Fisheries Creek</td>
<td>Cuttlefish Bay</td>
<td>10.0</td>
<td>8.2</td>
<td>8.6</td>
<td>9.1</td>
<td>9.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Cuttlefish Bay</td>
<td>Penneshaw</td>
<td>17.4</td>
<td>8.2</td>
<td>8.6</td>
<td>9.1</td>
<td>9.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Penneshaw</td>
<td>American River</td>
<td>17.4</td>
<td>7.2</td>
<td>7.6</td>
<td>8.0</td>
<td>8.4</td>
<td>8.8</td>
</tr>
<tr>
<td>American River</td>
<td>MacGillivray</td>
<td>13.2</td>
<td>6.5</td>
<td>6.9</td>
<td>7.2</td>
<td>7.6</td>
<td>8.0</td>
</tr>
<tr>
<td>MacGillivray</td>
<td>Kingscote</td>
<td>17.1</td>
<td>4.5</td>
<td>4.8</td>
<td>5.1</td>
<td>5.4</td>
<td>5.7</td>
</tr>
</tbody>
</table>

1. The published rating is based on a thermal limit or a limit required to maintain adequate clearances and does not take into account voltage limitations on the network which may further reduce the published rating.

2. Submarine Cable connection to the mainland, forecast to exceed capacity in 2016/17.

### 3.2.2 Distribution Network

The distribution network is continued inland by 156 km of 11 kV radial three-phase lines, extending along the populated areas on the eastern coastline and branching to the west from Kingscote to Smith’s Bay (Kangaroo Island Abalone) and from MacGillivray substation to Parndana (Timber Creek Sawmill), further dividing to supply the rural networks. Previous studies have investigated the potential for installing a large (5-10 MWₑ) biomass-fired base-load electricity generator at the Timber Creek mill, and it was concluded that the 11 kV network connection would be insufficient to support such a development. Oliphant (2009) and Ipsen (2011) have concluded that augmentation of the existing 11 kV network would be required, consisting of installing a 33 kV feeder to MacGillivray substation and associated transformer and control upgrades, with an estimated cost of $7 – 11 million.

Single-Wire Earth-Return (SWER) networks operating at 19 kV service the extremities of the island, with demand predominately along the north and south coasts west of Kingscote. The SWER networks are single-phase lines with only marginal capacity for improvement. Several large businesses as well as small communities are located on the island’s coastal regions and are particularly susceptible to power outages. Development of these communities and business is hampered by the lack of capacity and reliability on this network, which in turn, is curtailing economic growth for the region.

### 3.2.3 Distributed Generation

Historically, frequent loss of electricity has forced residents and businesses to compensate with petrol and diesel generators. In order to mitigate the risks of a network outage, a standby diesel generator plant operating 2x 2.5 MVA generators was installed at Kingscote. Additionally, 1.03 MVA of diesel generation is installed at KI Abalone, which is frequently dispatched by SA Power Networks to cope with high instantaneous loads. In total, 6.4 MVA of distributed generation has been surveyed, with likely uptake significantly higher.

It should be noted that despite the Australian Energy Regulator’s (AER) statement that existing generation on the island is sufficient to support a (brief) sub-transmission network failure, currently installed generators are insufficient to supply the recorded anytime maximum demand of 8.1 MVA. Additionally, operation of the generators is restricted to a maximum of two weeks due to maintenance considerations; a failure of the submarine cable would require in excess of three months to repair. AER has also indicated that a suitable solution to mitigating increasing demand on the island is the incremental installation of more diesel-powered generators.
3.3 Electricity Demand

Kangaroo Island is home to approximately 4,600 residents, living in 1,600 homes and operating 800 businesses. The majority of the population lives and works in the main centres on the island: Kingscote, Penneshaw, Parndana and American River. With the exception of Parndana, all centres are serviced by the 33 kV network.

Not accounted for in previous studies is the energy demand of the significant tourist numbers visiting the island each year. KI Council estimates that more than 180,000 tourists visit the island annually. Although annualising this figure would inaccurately predict the actual population at any one time, the effective population of KI is likely to be significantly higher than the current permanent resident population. This disproportionately skews the statistics on relative energy consumption per capita.

Wessex Consult in 2011 identified the largest instantaneous peak load of 8.1 MVA (7.4 MW) on 29 January 2011, which led to a significant outage (Davidson and Lee, 2011). The submarine cable supplying electricity to the island from the mainland has a rated capacity of 10 MVA, which is expected to be exceeded under demanding weather conditions.

3.3.1 Residential Sector

Approximately 70% of the island population live in the townships of Kingscote, Penneshaw, American River, Parndana and Cygnet River, all of which are serviced by three-phase electrical infrastructure. The remainder of the population are broadly distributed around the island and are serviced by SWER networks.

Household consumption has been estimated at approximately 8.0 MWh/y (Davidson & Lee, 2011), which is high compared with typical Australian household consumption. This is due to higher usage of electricity for thermal and space heating and cooking appliances compared to areas with a reticulated natural gas supply. Many remote households will also have higher energy consumption rates to operate utility loads such as agricultural buildings or equipment.

As many homes are located at the ends of SWER lines, security of supply is an important issue to address. Many of these residences currently operate standby diesel generators to address supply issues. Wessex Consult in 2009 evaluated average residential generator usage averaging 7.4 kVA for 74 hours per year. A centralised on-island energy generator would guard against undersea cable-related outages for these loads, but no improvement would be expected to current distribution network outages. Improving security of supply to remote residences would require upgrading the existing electricity distribution infrastructure at considerable cost.

3.3.2 Commercial Sector

Kangaroo Island currently hosts approximately 800 businesses, the largest of which are discussed in the following section. For small businesses, electrical demand is similar to residential demand, with a different load profile (a higher proportion of the electricity used happens during business hours). Energy supply and security issues are much the same as the residential sector, but with significant consequences to island productivity. In some cases, electricity supply concerns have prevented investment in new businesses (SAEDB, 2011). This is of particular concern for remotely located luxury accommodation, which also trade on a ‘clean-green’ brand, and yet rely heavily on back-up fossil fuel generation for their power supply. Most medium sized businesses (for example, between 30 and 200 kVA load) are located in areas supported by the three-phase sub-transmission network.
Again, upgrading of SWER networks generally is prohibitively costly, especially in the case of large businesses that would add significant load to the network should they wish to expand their operations. Servicing these electrical demands with renewable energy requires a novel solution utilising on-island resources.

3.3.3 Industrial Sector

KI hosts niche industries which take advantage of the unique natural resources of the island. In terms of electrical demand, the major industrial load centres are the Timber Creek sawmill located 20km east of Parndana, and the KI Abalone farms located at Smith’s Bay, approximately 20km northwest of Kingscote.

Both load centres are supported by multi-MVA diesel generation assets, due to the weakness of the distribution network. As an example, the KI Abalone farm’s circulation pumps are not started on grid electricity as the high starting current required causes under-voltage trips on the rest of the network. The demand from both centres is relatively flat, suitable for matching to a large base-load installation.

3.3.4 Demand Side Management

Understanding that any potential bioenergy solution is likely to have significant associated costs and lead times, demand side management (DSM) provides an interim means of mitigating the risks of failed electricity infrastructure. DSM describes measures taken to curtail electrical load at the point of demand, either by procedural or process control changes.

As demonstrated in the load duration curve below, Kangaroo Island’s average load is 4.3 MVA, while its peak load is in excess of 8.1 MVA. The maximum load was recorded just prior to diesel generation being dispatched to reduce the load on the electricity network. The peak loads occur for a very small proportion of the year, with loads reaching up to 5.3 MVA for 90% of the time.

![Kangaroo Island MVA Demand Duration](image)

Figure 3.2 – Kangaroo Island load duration curve (Davidson and Lee, 2011)
Figure 3.3 – Kangaroo Island daily demand profile for 29 Jan 2011 (Davidson and Lee, 2011)

SA Power Networks (previously ETSA) is the Distribution Network Service Provider (DNSP) for the electricity infrastructure throughout South Australia. The Australian Energy Regulator controls the pricing mechanisms used by the DNSP. Under the regulations of the Electricity Act 1996 and Electricity Pricing Order, the pricing mechanisms in use ensure that residents of Kangaroo Island are not unduly burdened by dint of being residents at the extremity of the SA electricity network. Neither does the pricing incentivise customers engaging in demand side management opportunities, which would be particularly beneficial to controlling the Kangaroo Island load. Currently network charges for small consumers are applied on a per-kWh basis, which does not incentivise load management at all. For larger customers above 75kVA, demand charges (per-kVA) are applied. Unfortunately, the charges are applied such that the majority of the charge is applied to the initial load, rather than the subsequent load. A better practice (with a view to DSM) would be to increase charges incrementally with more load used. This would also help to justify large customer investment in distributed generation, beyond the current energy security requirement. Even more so, scheduled periods of high demand which are notified to large consumers and for which a premium is charged, have been shown to effectively manage peak demand in other jurisdictions.

Some DSM opportunities that have been identified throughout this investigation include:

- Rescheduling J-tariff hot water heater loads – peak demand is avoided by regulating the number of hot water heaters being automatically switched on at any one time
- Installing variable speed drives or soft starts on large motors (e.g. at KI Abalone) to prevent high starting currents causing out-of-code events
- (Potentially) calibrating building management systems of large resorts to manage switching of air conditioning loads

3.4 Thermal Energy Demand

Utilisation of the thermal energy by-product is crucial to improving the economic performance of a bioenergy system. Most bioenergy plants currently installed make use of biomass residues to provide energy to a conversion process, for example, combustion of wood residues provide heat to drying kilns at
a sawmill. This also applies to dedicated bioenergy plants where biomass is combusted primarily to generate electricity; the heat from the process can then be used elsewhere. Residual heat can also be used in absorption chillers for refrigeration loads. Chapter 7 discusses biomass to energy conversion technologies in more detail.

On Kangaroo Island, there are few large heat sinks or refrigeration loads, owing to the scarcity of large industry. The following major thermal energy users have been identified:

- **Timber Creek Sawmill**: Thermal loads for the sawmill have not been identified but based on an annual production of approximately 50,000m³ sawn timber, a continuous 4 MWt load is expected
- **Kangaroo Island Abalone (potential)**: KI Abalone has expressed an interest in utilising low grade heat to increase the temperature of the water used to grow the abalone for increased production. They also maintain a 110kW_e (approximately 300 - 400kW_th) of refrigeration load which could be serviced using low grade heat

### 3.4.1 Potential Thermal Loads

Although there are only few thermal energy loads on the island at present, introduction of a bioenergy plant of some kind could supply heat (or cooling) as a by-product of the electricity generation process. In this case, many new industries could potentially arise to take advantage of this low-cost energy. Figure 3.4 below shows a summary diagram of the potential uses for low-grade heat. Note that the exhaust from a steam-driven electricity generator could potentially be considerably hotter than 150°C and therefore be used for other applications.

![Figure 3.4 – Summary diagram of potential low-grade heat uses, versus temperature required.](image)
3.4.2 Thermal Desalination

Low temperature thermal desalination is a promising use of residual heat that may have a positive impact on the island’s water supply in general and aquaculture industry in particular. Currently water supply on the island is unconstrained, due to two relatively mild summer seasons. However, during the recent extended drought SA Water proposed increasing the potable water storage on the island. Following conflicts to this proposal during the public consultation process, installing package desalination units (at considerable operating cost) was mooted as a potential solution.

Installing additional desalination capacity has significant potential benefits to both the island’s aquaculture industry, and current potable water supply to Kingscote and environs (potentially including other townships currently not served by mains water) which will become constrained with any temporary or permanent population growth. In addition the forestry plantations at the western end of the island utilise a significant quantity of water that would otherwise be used for agriculture or irrigation. A possible economic by-product of the process could be isolation of valuable minerals such as lithium from the concentrated sea water (bitterns).

Typical desalination processes utilise reverse osmosis processes for removing salt from water. Despite requiring high pressure pumping, operating the process is energy efficient, requiring only around 2.5 kWh/m³ (Tonner, 2008). Thermal desalination processes require much higher energy usage, but when most of the energy required is ‘free’ heat, thermal desalination is a comparatively low-cost method of producing clean water. This is especially the case on KI, as the high cost of electricity would negatively impact reverse osmosis desalination far more than thermal desalination, which could be conducted in parallel with power generation operations utilising freely available waste heat.

The technology used is similar to that used for concentrating milk or fruit juices, which draw progressively higher vacuums in multiple stages (“effects”) and apply low temperature heating to evaporate water. Heat recovery through the process improves the overall energy efficiency. Figure 3.5 below demonstrates the energy flows in the thermal desalination process.

![Energy flow schematic for thermal desalination process](image)

Depending on the technology used, a combined power plant-thermal desalination plant can produce 450 – 1300 m³ per day per megawatt. Table 3.3 gives a typical range of production capacities for various power generation and thermal desalination technologies (multi-stage flash (MSF) and multiple effect...
distillation (MED)). A comprehensive discussion on desalination technology can be found in the report by URS (2002).

Table 3.3 – Potential water production per megawatt electricity installed

<table>
<thead>
<tr>
<th>Power Generation Method</th>
<th>Water Production (MSF) m³/day per MWₑ</th>
<th>Water Production (MED) m³/day per MWₑ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back-pressure steam turbine</td>
<td>910</td>
<td>1,300</td>
</tr>
<tr>
<td>Extraction steam turbine</td>
<td>450</td>
<td>650</td>
</tr>
</tbody>
</table>

In terms of cost, MED technology capital costs are reported at approximately AU2011 $3,200 - $5,000 /m³/day (compared with reverse osmosis $2,000 - $3,200 /m³/day)$¹, but with approximately 70% lower operating costs. (URS, 2002)

It is important to note that a central bioenergy generator will have a high cooling requirement. Thermal desalination may be a viable option order to provide sufficient boiler water and cooling water to a large power plant.

¹ Accounting for inflation
4 Current Biomass Resources

4.1 Existing Plantations

Significant plantation forestry exists on Kangaroo Island. A series of extenuating circumstances in recent times has prevented full development of the forestry product potential, which has led to several studies considering the possibility of using the forestry resources for large-scale power generation.

Recent developments in the wood chip and log markets have confirmed that the Eucalyptus and Pine plantations on the island are effectively valueless, and RuralAus has elaborated recently that the Timber Creek Sawmill operates at a loss (RuralAus, 2012). Consequently, there is significant opportunity for use of the existing plantation forests in some bioenergy process.

Table 4.1 summarises the vital statistics for the current plantation forestry resource on Kangaroo Island (Silva Systems, 2011). In total, approximately 20,000ha are planted in forestry, consisting of 4,000ha of Pine, 15,000ha of *E. globulus* and *nitens*, and the balance unspecified agricultural outcrops. Assuming the current plantations remain in place, the total predicted biomass yield from the current plantation area is 175,000 green tonnes per annum.

N.B.: Herein, energy content is typically expressed in gigajoules (GJ). This amount of energy is equal to approximately 278kWh, or approximately 7 days of typical KI household energy consumption.

![Image of Eucalyptus stems, Kelly Hills Plantation P2005](image)

Figure 4.1 – Images of Eucalyptus stems, Kelly Hills Plantation P2005
Table 4.1 – Current plantation forestry statistics and yield potential (Silva Systems, 2011)

<table>
<thead>
<tr>
<th></th>
<th>P. radiata</th>
<th>E. globulus</th>
<th>E. nitens</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantation Area</td>
<td>ha</td>
<td>4,142</td>
<td>14,900</td>
<td>631</td>
</tr>
<tr>
<td>Volume Yield</td>
<td>m³/ha/y</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Age of Availability</td>
<td>years</td>
<td>20 - 30</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Biomass Density</td>
<td>kg/m³</td>
<td>450</td>
<td>530</td>
<td>480</td>
</tr>
<tr>
<td>Mass Yield (green)</td>
<td>tonnes/y</td>
<td>34,000</td>
<td>136,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Calorific Value</td>
<td>GJ/tonne</td>
<td>10.5</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Energy Available</td>
<td>GJ/y</td>
<td>357,000</td>
<td>1,292,000</td>
<td>60,000</td>
</tr>
</tbody>
</table>

There has been considerable interest expressed in clearing the forestry land outright for more productive uses such as niche market cropping and agriculture. Indeed, on the financial collapse of the previous owner of the *Eucalyptus* forestry land, threats were made by a group of local farmers to torch the trees to return the land to agriculture immediately (ABC, 2010). RuralAus estimated in a 2012 financial report (RuralAus Investments, 2012) that the RuralAus holdings on the island, consisting of 997ha of *E. globulus* and *nitens* plantations, would yield a volume of over 324,000m³ of wood; a similar calculation as that made in Table 4.1 therefore predicts that 2.4 million green tonnes of wood are currently available, not including the pine plantations. However, any investment now in a biomass energy solution for the island is likely to be contingent on securing a long-term biomass supply; simply clearing the forests in their entirety does not support this.

In the same report, RuralAus has declared their intent to further investigate the possibility of utilising the timber for electricity generation, citing the fundamental difficulty of connecting the proposed power plant to the deficient electricity distribution infrastructure on the island.

### 4.2 Other Biomass Residues

In comparison to the significant plantation forestry resources on the island, other biomass resources make up relatively small volumes, as detailed in Table 4.2 below. Sawmill residues account for a significant fraction of the total residue volume; however were the sawmill to be decommissioned in favour of a bioenergy plant this resource would not be available. Currently the resource provides thermal fuel to the sawmill processes. Cropping residues are the other major non-forestry biomass resource, consisting predominately of stubble from wheat, oats, canola and hay. Sawmill and cropping residues are located near the centre of the island (Timber Creek Sawmill and KI Pure Grain) while municipal wastes are concentrated in Kingscote.

Table 4.2 – Biomass residue volumes

<table>
<thead>
<tr>
<th>Residue</th>
<th>Indicative C.V. GJ/tonne</th>
<th>Estimated Volume (green tonnes/y)</th>
<th>Energy Available (GJ/y)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sawmill Residues</td>
<td>18 - 20</td>
<td>30,700</td>
<td>322,000</td>
<td>Silva Systems, 2011</td>
</tr>
<tr>
<td>Cropping residues</td>
<td>18 - 20</td>
<td>16,000 - 32,000</td>
<td>230,000 - 460,000</td>
<td>Silva Systems, 2011</td>
</tr>
<tr>
<td>Municipal Wood Waste</td>
<td>16 - 18</td>
<td>1,500</td>
<td>15,000</td>
<td>Silva Systems, 2011</td>
</tr>
<tr>
<td>Green Waste / Compost</td>
<td>5 - 10</td>
<td>2,600</td>
<td>21,000</td>
<td>KIC, 2012</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>50,700 - 66,700</td>
<td>598,000 - 828,000</td>
<td></td>
</tr>
</tbody>
</table>
Agriculture other than cropping is present on the island in the form of native mallee Eucalyptus used for oil distillation, and approximately 200ha of grapes are planted for viticulture. Both crops generate minor quantities of biomass residues, and while they would no doubt be suitable for use in appropriate conversion technologies, their volumes are insignificant in influencing what technologies will be implemented. Similarly, with the lack of an abattoir or dairy plant, there is no significant concentration of animal wastes for collection and energy recovery (KIC, 2012). Information on quantities of non-renewable calorific wastes such as tyres, paper, cardboard etc. is still forthcoming at the time of writing.
5 Future Biomass Resource - Potential

5.1 Scope

With a significant land resource and favourable climate, Kangaroo Island is well suited to cultivation of energy crops for domestic use. As discussed in the previous section, currently 20,000 ha of land are planted in valueless forestry which presents a compelling bioenergy opportunity. Long term, consideration needs to be given to using this land either for agricultural purposes which would grow the local economy, or using it to grow a domestic energy resource, thereby offsetting the already-extravagant and increasing costs of maintaining the current electricity and fuel supplies on the Island.

This Section reviews the bioenergy cropping options available, within the restrictions of Kangaroo Island’s protected ecosystem which supports numerous endemic species of flora and fauna, and upon which niche agriculture is reliant.

5.2 Climate & Environmental Considerations

5.2.1 Climate

Kangaroo Island’s climate is temperate with lower summer and winter averages compared to the rest of South Australia. Rainfall is relatively low at 485mm on average annually, compared to an Australia-wide median value of 860mm, however rainfall evaporation is lower than the Australian median. Table 5.1 illustrates some comparative climate statistics between Kangaroo Island and Adelaide.

Table 5.1 – Climate statistics for Adelaide and Kangaroo Island

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adelaide</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean max Temp °C</td>
<td>28.1</td>
<td>28.1</td>
<td>25.4</td>
<td>22.2</td>
<td>18.5</td>
<td>15.9</td>
<td>14.9</td>
<td>15.9</td>
<td>18.1</td>
<td>21</td>
<td>23.9</td>
<td>25.7</td>
<td>21.5</td>
</tr>
<tr>
<td>Mean min Temp °C</td>
<td>16</td>
<td>16</td>
<td>14.4</td>
<td>11.8</td>
<td>9.5</td>
<td>7.5</td>
<td>7</td>
<td>7</td>
<td>7.5</td>
<td>8.9</td>
<td>10.6</td>
<td>12.8</td>
<td>11.4</td>
</tr>
<tr>
<td>Mean Rainfall mm</td>
<td>17.9</td>
<td>18.2</td>
<td>22.3</td>
<td>35.2</td>
<td>53.9</td>
<td>56.3</td>
<td>58.8</td>
<td>50.9</td>
<td>45.6</td>
<td>37.5</td>
<td>29.5</td>
<td>24.3</td>
<td>446.3</td>
</tr>
<tr>
<td><strong>KI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean max Temp °C</td>
<td>26.5</td>
<td>26.5</td>
<td>24.3</td>
<td>21.5</td>
<td>18.5</td>
<td>16.1</td>
<td>15.4</td>
<td>16.1</td>
<td>17.8</td>
<td>19.9</td>
<td>22.9</td>
<td>24.8</td>
<td>20.9</td>
</tr>
<tr>
<td>Mean min Temp °C</td>
<td>13.2</td>
<td>13.5</td>
<td>11.1</td>
<td>8.6</td>
<td>7</td>
<td>6.7</td>
<td>5.9</td>
<td>6.7</td>
<td>8.4</td>
<td>7.1</td>
<td>9.7</td>
<td>10.9</td>
<td>8.9</td>
</tr>
<tr>
<td>Mean Rainfall mm</td>
<td>14.1</td>
<td>17.1</td>
<td>28</td>
<td>26.3</td>
<td>46</td>
<td>63.5</td>
<td>63.2</td>
<td>56.6</td>
<td>45.3</td>
<td>30.5</td>
<td>23.3</td>
<td>18.2</td>
<td>437.2</td>
</tr>
</tbody>
</table>

5.2.2 Ecology

The unique ecosystem on Kangaroo Island is fundamental to its continued success as a niche agricultural exporter; consequently, adhering to the ecological limits currently in place is a defining stipulation of any potential bioenergy crop. Currently 891 species of native plants and 46 endemic species are found only on Kangaroo Island (KI Visitor Information Centre, 2012). Invasive weeds that would flourish and force out these native species are not permitted.

5.2.3 Soil Types

Kangaroo Island consists predominately of flat to undulating plateau of ironstone and limestone gravels. The majority of the soil is acidic and slightly acidic to neutral with variations around the periphery of the
island. The major soil types are reported from the KI Soil Conservation Board (2000), with the major constituents being (in order of extent):

- **Gosse-Seddon Plateau**: Flat to undulating plateau regions with moderate to steep slopes around margins. Predominately ironstone gravels acidic and sandy soils (laterite or lateritic), some quartz outcrops.

- **Menzies Plains**: Flat to gently undulating land. Clay and sand with limestone with some basalt and ironstone gravel; sandy-loam to loam over clay – mix of acid, neutral and alkaline soils

- **MacGillivray Plains**: Flat to gently undulating land. Mixture of soil types – dune calcarenite, limestone, clay and ironstone gravels. Area contains swampy and lunette area and many salt lagoons that receive their water from higher land.

- **Dudley-Haines Plateau**: Flat to undulating plateau regions with moderate to steep slopes around margins. A complex pattern of ironstone plateau remnants and Cambrian bedrock.

Overall the soil condition is good compared with the Australia-wide median values, with higher levels of net primary production, plant carbon and litter and soil carbon. Landscape nutrients are generally at higher levels than the Australian median with total Nitrogen 47% higher and total Phosphorous 36% higher (ANRA, 2012).

### 5.3 Potential for Energy Crops

Numerous companies and organisations all over the world have investigated cultivation of crops for bioenergy, from both a technological and an economic standpoint. The principal motivators for these studies have been energy security and climate change mitigation through displacement of fossil fuels. Some successful and noteworthy instances of bioenergy cropping have been replacement of transport fuels in Brasil and the United States with sugarcane and corn ethanol, and the use of tallow, canola and other oils for biodiesel.

Energy crops are generally classified as woody, oilseed or herbaceous plants. Woody crops are generally better suited to thermochemical conversion processes (such as combustion or gasification), whereas herbaceous plants with high carbohydrate content are better suited for biological conversion to other chemicals or biogas. Oilseed crops in a bioenergy context are cultivated specifically for the purposes of biodiesel production.

Common herbaceous crops currently grown on KI have a high export value and it is unlikely these would be used for energy cropping. In general, herbaceous crops for thermal fuel offer poor return on investment due to the high opportunity costs and cost of harvesting. Cultivation for conversion of herbaceous crops into bioethanol is inappropriate for KI energy needs, as the majority of installed generation plant utilises diesel. These have been excluded from further analysis.

#### 5.3.1 Relevant Cropping Options

As discussed above, bioenergy crops can be distinguished by their intended end-use; woody biomass crops are easily combusted for electricity generation, whereas grassy, herbaceous crops are more suited for biological conversion to liquid fuels or biogas.

Few of the ‘typical’ energy crops in use around the world are suitable for use on Kangaroo Island, owing to the Island’s unique and protected ecosystem. Tables 5.2 and 5.3 below summarise the potential of the major bioenergy cropping species currently commercialised or under development. Note that *Pongamia* has not been considered as it is still in the early stages of development and oil yields are not yet commercially viable (Klein-Marcuschamer, 2012).
Costs of Bioenergy Crops

In most analyses the cost of the bioenergy crop being harvested is the key determinant of the profitability of the project. In general, the harvesting costs are highly variable due to the wide range of parameters being investigated. Land cost, type of harvesting equipment, geography of the land, condition of the road transport network, weather conditions and other factors affect significantly the cost of harvested biomass. An excellent discussion on the topic is given in Stucley et al, 2004, which identified a scenario in Nelson, New Zealand whereby the delivered cost of forestry residues varied more than 100% depending on the method and equipment used. From this report, some indicative costs are given below.

Table 5.2 – Indicative delivered costs for biomass resources (Stucley, 2004)

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Delivered Cost [$/green tonne]</th>
<th>Delivered Cost [$/GJ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood process residues</td>
<td>$0 - $1</td>
<td>$0 - $0.2</td>
</tr>
<tr>
<td>Forest residues from landing</td>
<td>$10 - $45</td>
<td>$2.00 - $3.20</td>
</tr>
<tr>
<td>Short Cycle Crops</td>
<td>$45 - $90</td>
<td>$4.20 - $6.30</td>
</tr>
<tr>
<td>Crop Residues</td>
<td>$50 - $110</td>
<td>$4.80 - $8.00</td>
</tr>
</tbody>
</table>

Figure 5.1 – Chart showing comparative costs of delivered fuel from harvesting residues from forest arisings from seven different systems (Stucley, 2004)
### Table 5.3 - Summary of Woody Biomass Energy Potential

<table>
<thead>
<tr>
<th>Woody species</th>
<th>Annual Yield m³/ha</th>
<th>Yearly GJ/ha</th>
<th>Suitability - ecology</th>
<th>Suitability - climate</th>
<th>Level of Development</th>
<th>Harvest Cost</th>
<th>Overall Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eucalyptus globulus</td>
<td>18</td>
<td>121</td>
<td>Grown on KI</td>
<td>Good</td>
<td>Developed</td>
<td>Low</td>
<td>Good</td>
</tr>
<tr>
<td>Eucalyptus nitens</td>
<td>18</td>
<td>108</td>
<td>Grown on KI</td>
<td>Good</td>
<td>Developed</td>
<td>Low</td>
<td>Good</td>
</tr>
<tr>
<td>Mallee eucalypts</td>
<td>18</td>
<td>100 - 120</td>
<td>Grown on KI (cnerifolia)</td>
<td>Good</td>
<td>Developed</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>Pinus radiata</td>
<td>18</td>
<td>83</td>
<td>Grown on KI</td>
<td>Good</td>
<td>Developed</td>
<td>Low</td>
<td>Good</td>
</tr>
<tr>
<td>Salix (Willow)</td>
<td>26</td>
<td>156 - 182</td>
<td>Invasive Weed</td>
<td></td>
<td></td>
<td></td>
<td>Unsuitable</td>
</tr>
</tbody>
</table>

### Table 5.4 - Summary of Oil Species Energy Potential

<table>
<thead>
<tr>
<th>Oil species</th>
<th>Annual Yield L/ha</th>
<th>Yearly GJ/ha</th>
<th>Ha required / 1,000L diesel eq. ¹</th>
<th>Approx. value $/ha ²</th>
<th>Suitability - ecology</th>
<th>Suitability - climate</th>
<th>Level of Development</th>
<th>Harvest Cost</th>
<th>Overall Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapeseed (canola)</td>
<td>800 - 1200</td>
<td>27 - 41</td>
<td>1.1</td>
<td>$ 1,600</td>
<td>Grown on KI</td>
<td>Good</td>
<td>Developed</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Castor</td>
<td>1400</td>
<td>47</td>
<td>0.8</td>
<td>$ 2,300</td>
<td>Invasive Weed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td>2700</td>
<td>81</td>
<td>0.4</td>
<td>$ 4,300</td>
<td>Foreign to KI</td>
<td>Unsuitable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cottonseed</td>
<td>300</td>
<td>9 - 12</td>
<td>3.6</td>
<td>$ 500</td>
<td>Foreign to KI</td>
<td>Moderate</td>
<td>Developed</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Ground Nut</td>
<td>1000</td>
<td>34</td>
<td>1.1</td>
<td>$ 1,600</td>
<td>Previously trialled</td>
<td>Unsuitable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linseed</td>
<td>480</td>
<td>18</td>
<td>2.3</td>
<td>$ 800</td>
<td>Currently trialled</td>
<td>Moderate</td>
<td>Developing</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Mustard</td>
<td>570</td>
<td>17 - 23</td>
<td>1.9</td>
<td>$ 1,000</td>
<td>Grown in SA</td>
<td>Good</td>
<td>Developing</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Palm</td>
<td>6000</td>
<td>180 - 240</td>
<td>0.2</td>
<td>$ 9,600</td>
<td>Foreign to KI</td>
<td>Unsuitable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sesame</td>
<td>700</td>
<td>21 - 28</td>
<td>1.6</td>
<td>$ 1,200</td>
<td>Foreign to KI</td>
<td>Moderate</td>
<td>Developed</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Soybean</td>
<td>440</td>
<td>15</td>
<td>2.5</td>
<td>$ 700</td>
<td>Foreign to KI</td>
<td>Moderate</td>
<td>Developed</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Sunflower</td>
<td>950</td>
<td>32</td>
<td>1.1</td>
<td>$ 1,600</td>
<td>Grown in SA</td>
<td>Good</td>
<td>Developed</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

¹ Hectares required per 1,000L of mineral diesel equivalent.
² Based on a retail diesel cost of $1.73/L, as at October 2012
6 Energy Carriers other than Electricity

6.1 Definitions

As discussed in Chapter 3, the current electricity infrastructure on Kangaroo Island is nearing capacity, with augmentation of the sub-transmission and distribution networks prohibitively expensive in most circumstances. Distributed electricity generation utilising biomass energy offers an alternative to conventional transmission of centrally-generated electricity. A number of biomass densification and refinement options exist which could offer an economic solution to the energy transmission problem. Each option has intrinsic capital and operating costs which are balanced by the reduced biomass transport costs. A full feasibility study is required to investigate these costs in detail, and will be recommended for the most promising densification / refinement technologies.

This chapter considers the relevant bioenergy carrier options available to Kangaroo Island and demonstrates the relative merits of each. As a baseline scenario, harvested *Eucalyptus / Pinus* logs are considered as an energy carrier for a potential central biomass power plant.

6.2 Baseline Scenario – Fuel Logs

The most conventional means of generating electricity from biomass involves the combustion of hogged fuel logs to produce steam, which in turn operates a steam turbine coupled to a generator, producing electricity. This scenario has been under investigation for the Timber Creek Sawmill for some time and is currently being revisited by Rural Aus. For the sake of the argument, a nominal plant output of 5.0 MWₑ has been considered as a basis.

A simple calculation utilising common conversion parameters can be used to determine the extent of the transportation required to fuel the power plant. Table 6.1 below summarises the calculation. In conclusion, approximately 71,000 tonnes of green wood is required to fire the 5.0 MWₑ power plant, requiring 54 log-trailer movements (minimum) per week from the plantation to the plant.
Table 6.1 – Summary Calculation of Fuel Log requirements for 5.0 MW_e power plant

<table>
<thead>
<tr>
<th>Fuel Summary Table</th>
<th>Logs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Moisture Content</td>
<td>50%</td>
</tr>
<tr>
<td>Estimated plant efficiency</td>
<td>25%</td>
</tr>
<tr>
<td>Fuel input MWth</td>
<td>20</td>
</tr>
<tr>
<td>Annual fuel requirement GJ</td>
<td>567,648</td>
</tr>
<tr>
<td>Gross calorific value GJ/tonne</td>
<td>8.0</td>
</tr>
<tr>
<td>Annual fuel requirement tonne</td>
<td>70,956</td>
</tr>
<tr>
<td>Bulk density kg/m³</td>
<td>700</td>
</tr>
<tr>
<td>Annual fuel requirement m³</td>
<td>101,366</td>
</tr>
<tr>
<td>Weekly trailer movements # trailer units</td>
<td>2,490</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Bulk density from Sims (2002)

6.3 Processed Wood Fuels

From the table above, it is clear that locally-produced electricity using fuel logs will take a significant toll on KI road infrastructure. A number of energy-densification options exist which can reduce the road transport requirement while still delivering the required amount of energy to the power plant. Each option has an associated capital and operating cost which is balanced against the reduced road transport costs.

6.3.1 Wood Chips

Chipping logs at the forest landing improves handling of the biomass and in some cases allows some drying to take place before transport. When cut, “green” logs have a moisture content of 55% – 60% wet basis, (w.b.). Logs also take a considerable time to dry in air. By chipping or ‘hogging’ the logs and then storing the chips to air-dry over some months, the moisture content of the chip can be reduced to approximately 20% w.b. This means 35% – 40% of the original biomass does not need transporting.

Although the mass has been significantly reduced in this scenario, chipping also reduces the bulk density significantly. While a standard semi-trailer rig is limited to 42.5 tonnes (DTEI, 2006), its volumetric capacity is approximately 95m³. Because of the low bulk density of chips, in this case the total load is volume-constrained. Table 6.2 shows the total transport requirements of green and dry chip compared to the base-case.

While wood chips are generally more suitable for centralised generation, with the appropriate technology chips could also be a suitable fuel source for small-scale gasification-based distributed generation. Wood chips are highly susceptible to moisture and must be stored in a water-proof environment for adequate conversion efficiency. Storage of wood chips is a critical design parameter, as moisture ingress can cause the fuel to be rendered unsuitable for processing and in extreme cases, can lead to spontaneous heating and combustion.
Table 6.2 – Summary calculation of wood chip requirements for 5.0 MW_e

<table>
<thead>
<tr>
<th>Fuel Summary Table</th>
<th>Logs</th>
<th>Wood chips (green)</th>
<th>Wood Chips (air dried)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Moisture Content</td>
<td>50%</td>
<td>50%</td>
<td>20%</td>
</tr>
<tr>
<td>Estimated plant efficiency</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Fuel input</td>
<td>MWth</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Annual fuel requirement</td>
<td>GJ</td>
<td>567,648</td>
<td>567,648</td>
</tr>
<tr>
<td>Gross calorific value</td>
<td>GJ/tonne</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Annual fuel requirement</td>
<td>tonne</td>
<td>70,956</td>
<td>70,956</td>
</tr>
<tr>
<td>Bulk density</td>
<td>kg/m³</td>
<td>700</td>
<td>325</td>
</tr>
<tr>
<td>Annual fuel requirement</td>
<td>m³</td>
<td>101,366</td>
<td>218,326</td>
</tr>
<tr>
<td># trailer units</td>
<td></td>
<td>2,490</td>
<td>2,799</td>
</tr>
<tr>
<td>Weekly trailer movements</td>
<td># trailer units</td>
<td>54</td>
<td>60</td>
</tr>
</tbody>
</table>

6.3.2 Densified Wood Products

Use of logs for biomass fuel frequently excludes significant volumes of stems which are removed for transport. Branches, stumps, leaves and tops are shed and typically left on the forest floor to decay. In forestry-intensive countries such as New Zealand, densification plants have been built that exploit the forestry residues for the production of high value products such as wood pellets and briquettes. These fuels, which are produced to a constant standard, are typically used as substitute heating fuel in domestic and commercial boiler units.

Densification also improves biomass transportability for potential small-scale electricity generators. As a standardised wood product, wood pellets and briquettes are more manageable than wood chips for smaller installations. Like wood chips, densified products are particularly vulnerable to moisture, and must be stored appropriately.

Table 6.3 shows the summary energy transport calculation for densified wood products. Although low volume, the mass limit for semi-trailers prevents full realisation of the transport efficiencies of highly dense fuels.

Figure 6.1 – Sawdust Extruder for Briquetting (Andritz, 2012)
Table 6.3 – Summary calculation of densified wood requirements for 5.0 MW<sub>e</sub> *

<table>
<thead>
<tr>
<th>Fuel Summary Table</th>
<th>Logs</th>
<th>Wood Pellets</th>
<th>Wood Briquettes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Moisture Content</td>
<td>50%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Estimated plant efficiency</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Fuel input MWh</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Annual fuel requirement GJ</td>
<td>567,648</td>
<td>567,648</td>
<td>567,648</td>
</tr>
<tr>
<td>Gross calorific value GJ/tonne</td>
<td>8.0</td>
<td>18.4</td>
<td>18.4</td>
</tr>
<tr>
<td>Annual fuel requirement tonne</td>
<td>70,956</td>
<td>30,850</td>
<td>30,850</td>
</tr>
<tr>
<td>Bulk density kg/m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>700</td>
<td>675</td>
<td>1,050</td>
</tr>
<tr>
<td>Annual fuel requirement m&lt;sup&gt;3&lt;/sup&gt;</td>
<td>101,366</td>
<td>45,704</td>
<td>29,381</td>
</tr>
<tr>
<td># trailer units</td>
<td>2,490</td>
<td>1,164</td>
<td>1,164</td>
</tr>
<tr>
<td>Weekly trailer movements # trailer units</td>
<td>54</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

* Note that the number of trailer movements are the same for both Pellets and Briquettes despite having different bulk densities, due to the weight limit of the trailer being reached before the volume limit. Were the maximum volume of the trailer used, the gross vehicle mass would exceed road transport regulations.

6.3.3 Torrefied Wood

Torrefaction is a relatively new technology applied to biomass energy. When heated to approximately 300°C for 1 – 2 hours (depending on the type of biomass) the intrinsic moisture is completely driven off and the physical structure of woody biomass fundamentally changes. Torrefied wood has approximately 90% of the original fuel content of the wood, but only half as much mass, making it superbly energy dense and a comparable fuel to coal.

The torrefaction process also improves the handling of the biomass fuel, making it much easier to crush due to weakening of the lignin binder in raw wood, and also improves its water-fastness, making it far more durable during transport and storage. Toxicity is a concern, however this risk would likely be minimised by reducing physical handling requirements in the design of a new plant. Torrefied wood also has a spontaneous heating/combustion risk, as is the case with many wood fuel types.

Despite clear advantages over unprocessed wood as a fuel, as a relatively new process, currently no commercially operating torrefaction plants exist. Technical difficulties have plagued torrefied wood plants, which are very susceptible to feed stock condition. The process itself is more suited to supplying biomass to a large-scale centralised plant due to handling requirements; in fact, previous studies have determined that at transport distances less than 125km, wood chips are a more economical option (Scion, 2012).
### 6.3.4 Refined Fuels

At the leading edge of current biomass energy technology is the development of processes for the production of refined liquid and gaseous fuels (Biofuels Digest, 2012). Some of these processes are familiar, such as the generation of biodiesel from oilseed rape or tallow; others, such as the Fischer-Tropsch and Mobil processes, have been applied to fossil fuels for decades, but only recently to biomass. Cellulosic ethanol is a rapidly emerging technology which converts woody feed stocks into bioethanol via a biological process.

**Biodiesel**

Biodiesel is a well-established fossil fuel substitute, produced by esterification of long-chain hydrocarbons such as rape oil (Canola) or tallow. It is not applicable to woody biomass, but may in the future constitute a significant part of the island’s energy supply, especially given the extensive use of diesel generator sets, which likely have “drop-in” biodiesel capability.

**Bioethanol**

Ethanol has been produced for millennia through the fermentation and distillation of all manner of crops. Pioneered by Brazil, ethanol from sugarcane has been refined and blended with petrol as a fossil-fuel substitute in spark-ignition engines. Bioethanol from corn has recently become popular in Australia and the United States, but has triggered global backlash from the widespread perception of biofuels competing with food production. As with biodiesel, bioethanol produced by this method may one day be compatible with the island’s energy roadmap, but does not address the use of the current plantation forests. Recently cellulosic ethanol (ethanol from woody biomass) technologies have been developed, but are currently uncommercialised.

**Fischer-Tropsch Diesel (“Green Diesel”)**

Fischer-Tropsch diesel has been produced for several decades from coal, particularly in areas where liquid fossil fuels were scarce such as Germany in the 1940s and South Africa in the latter half of the 20th century. In the last 20 years there has been significant research worldwide into application of the Fischer-Tropsch process to woody biomass, but to date no dedicated biomass-to-FT diesel plant has been commercialised. After distillation and refinement, green diesel has the potential to be a drop-in substitute for mineral diesel in existing engines.

---

Table 6.4 – Summary calculation of torrefied wood requirements for 5.0 MW<sub>e</sub>

<table>
<thead>
<tr>
<th>Fuel Summary Table</th>
<th>Logs</th>
<th>Torrefied wood</th>
<th>Charcoal Briquettes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Moisture Content</td>
<td>50%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Estimated plant efficiency</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Fuel input</td>
<td>MWth</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Annual fuel requirement</td>
<td>GJ</td>
<td>567,648</td>
<td>567,648</td>
</tr>
<tr>
<td>Gross calorific value</td>
<td>GJ/tonne</td>
<td>8.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Annual fuel requirement</td>
<td>tonne</td>
<td>70,956</td>
<td>23,652</td>
</tr>
<tr>
<td>Bulk density</td>
<td>kg/m³</td>
<td>700</td>
<td>850</td>
</tr>
<tr>
<td>Annual fuel requirement</td>
<td>m³</td>
<td>101,366</td>
<td>27,826</td>
</tr>
<tr>
<td># trailer units</td>
<td></td>
<td>2,490</td>
<td>893</td>
</tr>
<tr>
<td>Weekly trailer movements</td>
<td># trailer units</td>
<td>54</td>
<td>20</td>
</tr>
</tbody>
</table>

---

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**Methanol, Di-methyl ether (DME) and Synthetic Gasoline**

Like FT diesel, the Mobil process is a well-developed method for the generation of methanol, and subsequently synthetic gasoline, from natural gas. Like FT diesel, the technology relies on first converting the raw fuel into synthesis gas, a mixture of carbon monoxide and hydrogen. Although not yet applied to biomass, a similar method of producing methanol and other alcohols from carbonaceous municipal solid waste (MSW) utilising bioreactors is in the midst of commercialisation at multiple locations in North America (Stucley, 2012). Bioreactors are also in use converting synthesis gas into alcohols at steel mills in New Zealand (Williamson, 2012). Like bioethanol from corn, it is only suitable for use in spark-ignition engines.

**Synthetic Natural Gas (“Bio-SNG”)**

Bio-SNG has been developed in Europe from gasification processes as an alternative to liquid fuels. From the synthesis gas generated in the biomass gasification process, methane is produced in downstream reactors and fed into the existing natural gas infrastructure. The technology is currently being demonstrated at commercial scale in Europe which strongly motivates development of renewable energy alternatives to fossil fuels (Rauch, 2011). The technology could also form the basis of a road-mobile compressed natural gas (CNG) infrastructure, which is undergoing resurgence in many countries and has been utilised throughout Australia and New Zealand in favourable economic conditions. CNG can be used in most diesel engines with minimal conversion, but with an accompanying de-rating.

In general, refined fuels offer significant advantages for both energy transport and energy storage over solid fuel options. Significant research worldwide is currently devoted to improving the economics of biomass-derived refined fuels for general usage. In places with energy supply constraints like Kangaroo Island, it is likely that the current economics will be favourable compared with fossil fuels, and the improvement in energy security will favour the economic balance.

Table 6.5 below demonstrates the comparative transport requirements of fuel logs with diesel and compressed natural gas. The calculation does not consider the transport requirements between the biomass resource (forestry plantations) and the refining plant.

| Table 6.5 – Summary calculation of refined fuel requirements for 5.0 MW<sub>e</sub> |
|-----------------------------------|-----------------|-----------------|-----------------|
| **Fuel Summary Table**            | **Logs**        | **Diesel / Biodiesel** | **Compressed Natural Gas** |
| Fuel Moisture Content             | 50%             | 0%               | 0%              |
| Estimated plant efficiency        | 25%             | 35%              | 35%             |
| Fuel input                        | 20 MWh          | 14               | 14              |
| Annual fuel requirement GJ        | 567,648         | 405,463          | 405,463         |
| Gross calorific value GJ/tonne    | 8.0             | 45.6             | 52.8            |
| Annual fuel requirement tonne     | 70,956          | 8,892            | 7,675           |
| Bulk density kg/m³                | 700             | 840              | 174             |
| Annual fuel requirement m³        | 101,366         | 10,586           | 44,108          |
| # trailer units                   | 2,490           | 399              | 855             |
| Weekly trailer movements         | 54              | 9                | 19              |
7 Biomass Conversion Technologies

Conversion of biomass to energy takes place either through a ‘thermo-chemical’ or a ‘bio-chemical’ pathway. Thermal conversion of biomass to energy is arguably the first “technology” to be developed by humans. Thermal technology for bioenergy can be broadly classified into three sub-groups: gasification, combustion, and pyrolysis. Examples of bio-chemical conversion include anaerobic digestion or fermentation to bioethanol fuel.

Thermal processes for electricity generation from a fuel source (including biomass sources) also offer the possibility of utilising both the heat and electrical outputs from the process. This is termed “cogeneration”, or Combined Heat and Power (CHP) production, and is more formally defined as “the simultaneous production of two energy sources; electrical (or mechanical) and thermal, from the same system”. In “tri-generation”, heat produced from the cogeneration plant is additionally used to produce cooling, via an absorption refrigeration cycle.

As a good starting reference guide for thermal bioenergy plant configurations, and representative biomass requirements, the table below shows some basic performance parameters.

<table>
<thead>
<tr>
<th>Size</th>
<th>Properties served</th>
<th>Annual fuel demand</th>
<th>Vehicle movements</th>
<th>Conversion technology</th>
<th>Physical size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic heating (15kW)</td>
<td>Family dwelling</td>
<td>3 - 5 odt wood</td>
<td>2 - 3 tractor loads /y</td>
<td>Boiler or wood burner</td>
<td>Large suitcase</td>
</tr>
<tr>
<td>Small business heating (350kW)</td>
<td>School or small factory</td>
<td>80 – 120 odt wood or straw</td>
<td>40 tractor loads /y</td>
<td>Boiler or straw burner and fans</td>
<td>Garage for one car</td>
</tr>
<tr>
<td>Small electricity generating plant (250kWe)</td>
<td>200 – 300 houses or small industry</td>
<td>1500 – 2000 odt wood or straw</td>
<td>6 x 20t trucks / week</td>
<td>IC* engine or gasifier</td>
<td>Small barn</td>
</tr>
<tr>
<td>Medium electricity generating plant (5MWe)</td>
<td>4000–6000 houses or small industrial estate</td>
<td>20 – 30,000 odt of range of biomass fuels</td>
<td>50 x 38t trucks / week</td>
<td>IC engine or steam turbine or gasifier</td>
<td>Petrol service station</td>
</tr>
<tr>
<td>Large electricity generating plant (30MWe)</td>
<td>25-35000 house or industrial estate</td>
<td>120-140,000 odt using dry biomass fuels</td>
<td>250 x 38t trucks / week</td>
<td>Steam turbine or gas turbine or combined cycle</td>
<td>Large church</td>
</tr>
<tr>
<td>Combined cycle gas turbine or coal-fired station (500MWe)</td>
<td>500,000 houses or large industrial site</td>
<td>800 Mm3 gas or 1Mt coal</td>
<td>Pipeline Or 900 x 38t trucks / week equiv</td>
<td>Gas turbine and / or steam turbine</td>
<td>Large barn or Sydney Opera House</td>
</tr>
</tbody>
</table>

Figure 7.1 - Typical scales of various thermochemical conversion technologies (Stucley, 2004)
7.1 Combustion

Combustion is the burning of fuel in excess air to produce heat. The main technical advantage of a combustion process in the biomass power-plant context is that it is generally more fuel-flexible than a gasification process.

There are many types of processes that are driven by the heat from a combustion system in order to generate electricity. Steam Rankine Cycle and Organic Rankine Cycle are two generation cycles most commonly associated with power generation.

**Furnaces and Boilers Suitable for Ground Biomass**

Forestry residues and by-products, as well as demolition wood waste and agricultural wastes, are all forms of biomass that have been successfully fired in systems for heat and/or power generation. In the context of the current project, wood-fired systems operating either on chipped, ground or shredded wood are common in many countries. Heat from the furnace is normally used to raise steam (for industrial uses), heat water (for industrial or district heat uses) or heat a thermal oil heat transfer fluid.

Furnaces normally range from 0.1 to 30 MWth in size. Via a system of primary and secondary air feed points and an appropriate furnace grate mechanism; modern furnaces usually achieve efficient and very clean combustion and can tolerate a range of feedstock sizes and moisture contents. The standard biomass boiler site arrangement normally includes a 3 to 4 week stockpile of appropriately sized fuel.

In larger installations the flue gases produced by the furnace are normally scrubbed by cyclone and electrostatic precipitators to remove ash and particulates. Ash is collected both from the flue gas (“fly ash”) and from the bottom of the furnace (“bottom ash”). There are no other key waste products from the process.

Biomass furnaces of a relevant size range to cover Kangaroo Island’s potential needs are a commercially mature technology in widespread use throughout the world.

**Steam Rankine Cycle**

The steam Rankine cycle is the most commonly found thermodynamic cycle in power plants, especially at the large scale. The simplified Rankine cycle is illustrated in the figure below.

![Figure 7.2 - Simple steam Rankine cycle](image)
The basic cycle involves 4 stages:

- **Stage 1**: Water is pumped at high pressure to the boiler for heating.
- **Stage 2**: The boiler turns the water to steam and it enters the turbine at high temperature and pressure where it expands as it passes through the turbine causing the turbine to spin (thus providing mechanical energy to drive the generator for electricity production).
- **Stage 3**: The low pressure steam exiting the turbine then enters the condenser where it is cooled and turns back to liquid water, which draws the vacuum that enables the turbine to function. Heat recovered from the condenser can be exported to a process.
- **Stage 4**: Exiting the condenser, the water returns to the pump to repeat the cycle.

**Organic Rankine Cycle**

An Organic Rankine Cycle (ORC) process is similar to the conventional Rankine process except that an organic working fluid with favourable thermodynamic properties is used in an ORC instead of water. The two most common fluids used in commercial systems are iso-pentane and silicone oil. The main advantage of choosing an ORC is that for a power plant with lower than 5 MWe output, it can have significantly lower operating costs. As it works at much lower pressures and temperatures than a steam plant (typically at or below 10 atmospheres and 300°C), it is not governed by the same level of stringent regulations for operation and maintenance requirements (in particular, attendance of personnel). When optimised for electricity generation, efficiencies are typically up to 24% (CEC, 2010)

![Figure 7.2 - An ORC trigeneration process with wood as feedstock (adapted from Stadtwärme Lienz (2009))](image-url)
In a biomass-fired ORC system, thermal oil is used as the heat carrier to transfer the heat from the combustion system to the ORC working fluid. Advantages of using thermal oil as the transfer medium include (Duvia and Gaia, 2002):

- Low boiler pressure;
- Large inertia and insensitivity to load changes;
- Simple and safe operation and control; and
- The adopted temperature (~300°C) for the hot side ensures a very long life of the oil.

Biomass-fired ORC systems are in relatively widespread use in a number of European countries and are considered to be technically and commercially mature technology. Since the ORC process is a closed cycle, and therefore virtually no losses of the working fluid occur, the operating costs are low. Only moderate consumption-based costs (electricity, lubricants) and maintenance costs are incurred. The usual lifetime of ORC units is greater than twenty years, as has been demonstrated by geothermal applications. The silicone oil used as working medium has the same lifetime as the ORC since it does not undergo any appreciable ageing (Vos et al, 2005).

### 7.2 Gasification

Gasification plants are of most benefit where the biomass feedstock properties (especially shape, size and reactivity) can be carefully controlled to suit the process, so a high quality gas suitable for engine or gas turbine use can be reliably generated.

The basic process involves the thermal decomposition of the biomass into a fuel gas known as “producer gas” or “wood gas” in a reactor called the “gasifier” or “gas producer”. This is a high temperature process and a variety of system configurations have been developed to enable this conversion to be undertaken on the majority of solid (and some liquid) fuel feed stocks. Depending on the gasification medium, the product gas has a calorific value of 5 – 18 MJ/Nm³ (compared to natural gas with a calorific value of 41 MJ/Nm³).

The fuel gas is typically converted to work using a conventional piston engine, or in some cases, a gas turbine. The engine or turbine then drives a generator to produce electrical output. Heat is available as a by-product of both the gas making step (i.e. from the gasifier) as well as from the engine (exhaust or water jacket heat).
Figure 7.3 - Schematic representation of a gasification process (adapted from NAPE, 2008)

The integration of wood gasifiers with gas engines is not necessarily trouble-free. In most cases, gasifiers coupled with gas engines are based on the downdraft principle because of the relatively low tar production (BTG, 2005). At the larger scale, fluidized bed gasifiers have been demonstrated incorporating extensive gas clean-up trains. Most technical problems with such plant can be traced to feedstock issues.

Gasifiers can also be used simply to produce a crude gas which is then burned in a combustion chamber, in a process also known as “two-stage combustion”. In this instance, gas quality can be lower as it is not passing through complex machinery. A thermodynamic cycle (as previously discussed) is then used to produce the electrical output.

**Feedstock Requirements**

The feedstock size for gasifiers varies depending on the type of gasifier. The feedstock size for downdraft gasifiers is usually around 20-100 mm. Large-scale plant based on fluid bed gasifier technology take in chips, and entrained flow gasifiers usually require feedstock size to be less than 1 mm (BTG, 2005).

One of the major constraints in employing gasification processes for this project is the shape, size and form of the feedstock to be used, as many gasifier types require almost uniform physical structure and small size of feedstock. It is important to note that the more commercially mature fixed bed gasifiers will in general not operate successfully on ground or shredded feedstock.

**Other Products**

Gasification is a primary process for the production of liquid fuels and synthetic natural gas from biomass. At the large scale this is typically accomplished through the use of fluidized bed designs which promote rapid heat transfer to the biomass feedstock, preventing the formation of tars and other impurities which contaminate the producer gas stream.

**7.2.1 Pyrolysis**

Pyrolysis is an emerging technological area in relation to biomass and in simple terms consists of the controlled heating of the feedstock in a low or zero-oxygen environment such that all the volatile matter is driven out of the material, leaving behind a solid residue (char) and producing a combination of energy-rich gases and liquids.

Pyrolysis is not usually considered first and foremost as an energy production process, but is more often applied where the physical products (either the char or the volatile gases/liquids) are the desirable products. Pyrolysis processes have been used as a first-stage in the production of synthetic liquid fuels.
(the crude liquids then being subject to an extensive series of further processing steps) from coal or biomass, and more recently the approach has been getting attention as a means of producing “biochar” – a form of biomass-derived charcoal for use in soil amendment.

Pyrolysis processes are characterised by the speed at which the biomass feedstock is heated, which leads to a vastly different product set. “Slow” pyrolysis processes favour the production of biochar and producer gas at the expense of bio-oil, whereas fast pyrolysis processes produce far higher quantities of bio-oil. Due to the high oxygen content of biomass fuel, the crude bio-oil produced is unlike mineral crude oil, with high water and acidic fractions. Bio-oil can be refined however into suitable diesel and petrol substitutes, usually at a high energy cost.

![Image](image.png)

**Figure 7.4** – The production of the solid fraction biochar from a slow pyrolysis process can result in a net removal of carbon from the atmosphere (Sohi, 2009)

Pyrolysis processes for energy production are not commercially mature, but may offer a future pathway for the production of heat, power and potentially other high-value chemical products as well as liquid fuels.

### 7.2.2 Anaerobic Digestion

The anaerobic digestion process involves the use of microorganisms for the conversion of biodegradable biomass material into energy, in the form of methane gas and a stable sludge. Anaerobic digestion can occur under controlled conditions in specially designed vessels (reactors), semi-controlled conditions such as in a landfill, or under uncontrolled conditions. The methane-rich gas produced in the process may then be scrubbed to remove minor contaminants and passed to an internal combustion engine to generate motive or electrical power.

Anaerobic digestion requires wet feed stocks and is thus best applied to wet wastes, e.g. food wastes, manures and other putrescible matter. The process is often considered more for its benefit as a waste management system, with the energy in the gas stream being an added benefit. Most commonly, digesters are found at the larger wastewater treatment plants and some intensive animal farming operations where large quantities of manure are produced. Landfill gas is also produced via anaerobic digestion processes occurring within the landfill itself.
7.3 Comparative Technology Costs and Maturity

A good summary comparing the ranges of expected costs for different forms of generation including bioenergy technologies is provided in the following Figures. The broad range of LCOE provided for biomass electricity reflects the variety of technology and feedstock types that may be employed, as well as the broad range of scales on which bioenergy can be applied.

As can be seen in the charts below, biomass electricity can be generated at comparable cost to wind electricity, when using more mature technology. The viability of biomass over other renewable energy often depends on effective utilisation of the heat generated in the process. Feedstock supply costs are a key driver in the viability of bioenergy projects, and as these costs are highly variable, accurate cost information must be developed for the particular scenario under consideration. Significant economies of scale are present in bioenergy projects, such that larger plants can typically produce energy at lower cost, encouraging centralisation in areas which permit it.

For comparison, the levelised cost of electricity from a diesel generator on the island, assuming no capital cost (equipment already purchased) and a typical engine efficiency of 35% is approximately 41 ¢/kWh (including taxes and duties, and discounting the tax rebate of 31.9¢/L available for stationary generation (ATO, 2012)). The chart below gives renewable energy costs excluding taxes and duties.

Figure 7.5 – Range in recent LCOE for commercially available renewable energy technologies in comparison to recent non-renewable energy costs. Technology subcategories and discount rates were aggregated. These values do not include interest, taxes, depreciation or amortisation (adapted from Edenhofer et al, 2012)
Figure 7.6 – Typical recent bioenergy LCOE at a 7% discount rate, calculated over a year of feedstock costs, which differ between technologies. These costs do not include interest, taxes, depreciation and amortisation (Edenhofer et al, 2012)

Figure 7.7 – Recent bioenergy plant costs reported as LCOE at 10% discounted rate (IRENA, 2012)
The figure below provides a recent assessment of the level of technical maturity of a variety of bioenergy processes, indicating combustion processes as generally more established than gasification. Biogas systems are also commercially mature, although secondary gas upgrading schemes are not so well established.

<table>
<thead>
<tr>
<th>Type of Plant</th>
<th>Type of Product</th>
<th>Stage of Development of Process for Product(s) or System(s)</th>
<th>Basic and Applied R&amp;D</th>
<th>Demonstration</th>
<th>Early Commercial</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Densified Biomass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charcoal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Heat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Moisture Lignocellulosic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power or CHP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet Waste</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Figure 7.7 – Stages of development of bioenergy: thermochemical (orange), and biochemical (blue), and for heat and power (Edendorfer et al, 2012)

### 7.4 Greenhouse Gas Emissions Impact

All bioenergy technologies discussed above offer significant environmental benefits over the status quo, especially in terms of greenhouse gas emissions. The DCCEE (2010) has published the National Greenhouse Accounts Factors which give an indication of the emissions intensity for various fuels. In South Australia, the emissions intensity for electricity (averaged across the state) is 720 gCO₂-e/kWhₑ by coincidence the same figure is calculated for electricity generated from a diesel generator set (disregarding the emissions associated with refining and transporting the fuel).

Emissions are incurred in bioenergy projects predominately from the fuel used to grow, harvest and transport the bioenergy crop, but on a per-kWhₑ basis these emissions are far lower than alternative sources of electricity. The International Energy Agency’s Task 38 has been established to evaluate the life-cycle greenhouse gas emissions from bioenergy. A summary of a UK Department of Trade and
Industry study in support of Task 38 activities has established that the greenhouse gas emissions from bioenergy systems are typically in the range of 10 to 50 gCO₂-e/kWh. Results of greenhouse gas emissions from selected renewable energy systems have been reproduced below from Stucley (2004).

<table>
<thead>
<tr>
<th>Technology</th>
<th>g/kWh CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal: Best Practice</td>
<td>955</td>
</tr>
<tr>
<td>Natural gas: in combined cycle plant</td>
<td>446</td>
</tr>
<tr>
<td>Onshore wind</td>
<td>9</td>
</tr>
<tr>
<td>Hydro - existing large</td>
<td>32</td>
</tr>
<tr>
<td>Hydro – small-scale</td>
<td>5</td>
</tr>
<tr>
<td>Decentralised photovoltaic (PV) - retrofit</td>
<td>160</td>
</tr>
<tr>
<td>Decentralised PV – new houses</td>
<td>178</td>
</tr>
<tr>
<td>Decentralised PV – new commercial</td>
<td>154</td>
</tr>
<tr>
<td>Bioenergy – poultry litter - gasification</td>
<td>8</td>
</tr>
<tr>
<td>Bioenergy – poultry litter – steam cycle</td>
<td>10</td>
</tr>
<tr>
<td>Bioenergy – straw – steam cycle</td>
<td>13</td>
</tr>
<tr>
<td>Bioenergy – straw - pyrolysis</td>
<td>11</td>
</tr>
<tr>
<td>Bioenergy – energy crops - gasification</td>
<td>14</td>
</tr>
<tr>
<td>Bioenergy – Forestry residues – steam cycle</td>
<td>29</td>
</tr>
<tr>
<td>Bioenergy – Forestry residues - gasification</td>
<td>24</td>
</tr>
<tr>
<td>Bioenergy – animal slurry – anaerobic digestion</td>
<td>31</td>
</tr>
<tr>
<td>MSW incineration</td>
<td>364</td>
</tr>
<tr>
<td>Landfill gas</td>
<td>49</td>
</tr>
<tr>
<td>Sewage gas</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 7.8 – Life cycle carbon dioxide equivalent emissions for various technologies. Note current greenhouse gas emissions from electricity in South Australia is 720 gCO₂-e/kWh (Stucley, 2004)

For Phase 2 of this investigation, the greenhouse gas emissions intensity of the proposed bioenergy solutions will be estimated based on the relevant emissions factors.
8 Discussion and Recommendations

8.1 Existing Infrastructure

The precipitating factor in the bioenergy assessment has been recognition of the unreliability of the electricity network on Kangaroo Island. Further development of island industry and tourism is contingent upon improved energy security. Previous attempts to improve this security, specifically by application for funding for a second undersea cable and improvement of the on-island sub-transmission network, have gone unheeded. To compound the problem, the distribution network on the island consists mostly of single-wire earth return lines, which will not accept any significant increases in load.

Installation of local generation and distributed generation options would provide relief to the security of supply situation. Although 6 MVA of back-up diesel generators have been installed in Kingscote, these are only suitable for short-term operation; as an undersea cable outage would take in excess of three months to repair, such an outage would be crippling to island industry and tourism.

An on-island central generator, perhaps fuelled with domestic biomass at low cost, is an obvious solution to the fragility of the undersea cable electricity supply. There are some drawbacks to a centralised solution, such as:

- A biomass power plant generally only functions as a base-load plant, so another supply of electricity must be maintained which can follow peaks in the load (either fast-response diesel generators or mainland electricity supply).
- A central generator will only alleviate security of supply issues; with the current state of the distribution network, no new loads could be brought online in remote areas. This curtails development, particularly of luxury resorts.

8.1.1 Recommendations for Phase 2 Study

- Accurate evaluation of the costs of improving the sub-transmission and distribution networks on the island will be a critical factor in determining the cost effectiveness of any on-Island energy solution. This will be achieved through consultation with SA Power Networks and discussion with electrical engineering consultants.
- Identification of potential thermal energy loads will shape the prioritisation of the various bioenergy options discussed below.

8.2 Biomass Energy Supply

Kangaroo Island is ideally placed to implement a bioenergy-based solution to alleviate security-of-supply issues. Due to an unfortunate series of events, the island currently has available to it approximately 2.4million tonnes of green *Eucalyptus* and *Pinus radiata* wood, sufficient to supply a 10 MW<sub>e</sub> generator for approximately 17 years. Harvesting of this timber will free up approximately 19,000 ha of land, much of which is highly fertile and desirable for agricultural development.

Cropping residues and organic municipal solid wastes are of insufficient quantity and quality by themselves to support an anaerobic digester or biomass-fired generator; therefore a potential bioenergy
solution will require some land to be set aside to maintain fuel supply. Many biomass options have been investigated for energy purposes, but due to the unique and protected ecology on Kangaroo Island only a few of these options are suitable. Existing crops of *Eucalyptus globulus* and *nitens* and *Pinus radiata* would provide suitable fuel to a thermal energy solution involving, for example, combustion and gasification.

Cultivating forestry for bioenergy is not without its own risks which affect security of supply. A potential bushfire through the island could devastate the supply of woody biomass, leaving a plant without return on investment and potentially the island once again without a secure electricity supply. However, maintaining cultivation of the present forestry resource and managing the bushfire risk through de-fuelling (and thereby providing fuel to a biomass electricity generator) could be an acceptable risk management tool. Maintaining the forestry plantations at sufficient distance from one another would also help to ensure security of supply for a bioenergy plant.

Oil crops such as rapeseed (canola) or sunflower could be used to generate biodiesel, but typically have much higher harvesting costs than woody biomass. Herbaceous crops, such as grasses, can be used for generation of alcohol-based biofuels. These have been discounted given the unsuitability of alcohol biofuels for island energy generation.

### 8.2.1 Recommendations for Phase 2 Study

- The extent of the fertile land currently planted in forestry must be determined to evaluate the availability of poorer-quality land suitable to support a potential bioenergy solution on the island. For the Phase 2 study, it will be assumed that sufficient bioenergy cropping land will become available following depletion of the current woody biomass stock.
- The suitability of various energy crops must be verified with Kangaroo Island natural resource managers.
- To reduce costs, bioenergy and biofuel options should be developed which are suitable for use in existing island energy generators. The potential for retrofitting existing diesel generation assets to accommodate biofuels, biogas or wood synthesis gas should be investigated.

### 8.3 Alternatives to Centralised Generation

As mentioned previously, centralised generation will do little to combat energy transmission to remote areas serviced by SWER lines. Currently a significant portion of remote users, including large loads such as the Southern Ocean Lodge suffer security of supply problems and mitigate this risk by frequent operation of costly diesel generation assets. Any expansion of load in these areas is impossible without augmentation of the electricity network, which will come at significant cost.

Instead of augmenting the grid, bioenergy can offer alternative modes of energy transmission to a distributed electricity generator. As discussed in Section 6, bioenergy carriers encompass a diversity of energy intensity and technological maturity, from wood chips to highly refined biofuels. All bioenergy carriers require some investment in centralised plant to support creation of an energy product which must then be distributed to the end user (usually by road). For instance, a large bioenergy plant at Timber Creek mill would require significant augmentation to the electrical grid in order to generate electricity for remote customers; alternatively, an energy densification plant at the same site would require significant freighting to deliver the bioenergy product to the end user. Thus, considering bioenergy carriers over augmentation of the electricity network is a simple economic trade-off between the costs of maintenance of the electricity network and costs of maintenance of the road network.
Bioenergy Resource Analysis and Technology Feasibility Study

Analysis and selection of a potential bioenergy carrier goes hand-in-hand with selection of a bioenergy technology solution. Recommendations for both will be discussed in the next section.

8.4 Bioenergy Technology Solutions

A number of potential bioenergy solutions have been identified in the course of this initial investigation. All expand on the numerous studies undertaken detailing the feasibility of some centralised bioenergy generation option.

8.4.1 Central Generator + Distributed Gasification

It is recognised that a central generator on the island would significantly benefit the current energy security situation, recognising that by itself it is unlikely to alleviate problems with supplying peak loads or increasing electricity supply to new loads at the ends of the existing network. Additionally, a central biomass power plant would generate significant thermal energy which may not be able to be utilised unless paired with a new thermal demand.

It is proposed therefore to pair the biomass power plant with a densification plant producing wood pellets or briquettes. Such densification plants have a significant heat use for drying the green biomass. Wood pellets by themselves are a marketable product with significant international demand (in Europe, thus with a high transport cost component). However, densification of woody residues also enables uptake of domestic-scale wood gasifiers, which are a commercial-off-the-shelf technology used in remote locations around the world. This would offset the requirement for diesel and provide a significantly cheaper electricity solution for residences and businesses which are vulnerable to grid outages.

A possible ownership model would be to enable a domestic (KI-based) enterprise to lease a fleet of wood gasifiers to customers requiring back-up electricity. Many residential/small commercial-scale gasification options exist which utilise wood chips or briquettes as fuel, which is required to conform to a strict standard to enable ease of operation. For security of supply the operation would be vertically integrated, supplying both fuel and maintenance services to customers. As larger energy plant typically requires higher levels of maintenance and supervision, it is recommended for larger remote customers (>30 kVA) such as Southern Ocean Lodge or a new resort development to engage a suitable consultant on an individual basis to determine the most cost-effective electricity supply option. A possible distributed generation option in this case is use of the densified fuel in a combustion/ORC plant.

The drawback of this model is that significant diesel generation assets already exist on the island. It is feasible that the gasifier company would be able to retrofit these assets to accommodate wood gas or even dual-fuel supply; however conversion to wood-gas usually entails significant de-rating of the engine.
8.4.2 Central Generation + Bio-SNG

As noted above, central generation is a requirement on the island for energy security. The established technology solution for this case would be utilising a boiler to raise steam, to drive a turbine generator set.

An alternative technology that has been demonstrated in Europe for 12 years is large-scale biomass gasification, utilising fluidised bed technology (Rauch, 2011). Steam gasification of woody biomass produces a medium calorific value gas which can be used in gas engines to generate electricity. Although not yet commercial, both fluidised bed and gas engine technology is well established, and gas engines offer operating cost benefits over steam turbines.

The producer gas that is generated can also be up-rated to a natural gas substitute (Bio-SNG). Compressed Natural Gas (CNG) is a well-developed energy carrier typically used as automotive fuel, but also as substitute fuel in diesel generators. It is proposed that a central biomass plant gasifying biomass to producer gas, then up-rated the gas to bio-SNG could supply both electricity to the grid and, indirectly, to remote customers using their existing (albeit de-rated) diesel generator sets. Depending on location of the plant, distribution of the gas could be by road-going tanker or high-pressure gas pipeline. Additional potential benefits are:

- Rapid response to peak grid demand, whereby stored Bio-SNG is used in additional engine generators directly at the plant
- Utilisation of the Bio-SNG for automotive transport, reducing the island’s overall reliance on fossil fuels
Such an option presents significant technological risks. Installing such a plant on KI would come at high cost and require expert supervision, perhaps through partnership with an expert commercial engineering enterprise. An example of an operational Bio-SNG plant is in Güssing, Austria. Although this plant has been operating for 12 years, a “commercial” unit does not yet exist. Its electrical generation capacity is 2.5 MW, therefore a similar plant on KI would probably be a larger scale facility. For economic benefit, the plant’s use of waste heat would have to be highly integrated, perhaps through use of ORC generators, which would come at additional cost. The Güssing plant has had a significant effect on the economy of the region, creating employment in a region desperately needing it, while concurrently reducing energy costs.

8.4.3 Integrated Biorefinery

With the significant volumes of low-cost biomass fuel available, the opportunity exists to establish a leading edge technology demonstration plant utilising fast pyrolysis or enzymatic technology. Utilising cutting-edge technology, low-volume, high-value chemicals can be produced which heretofore could only be obtained by refining mineral oil. Energy streams such as electricity and heat can be produced as either primary or co-products. The market potential for “green” chemicals is well established and may suit Kangaroo Island’s overall brand.

The most prominent example of fast pyrolysis technology in Australia is the Verve Energy Integrated Wood Processing demonstration plant in Narrogin, WA. Mallee Eucalypts have been planted in Western Australia in great numbers to alleviate soil salinity issues. The IWP plant converts 20,000 tonnes of Mallee per year into electricity (1 MW output), distilled eucalyptus oil and activated carbon. The plant has been operating since 2005 (Engineers Australia, 2011).

Depending on the feedstock and conversion technology, integrated biorefineries can produce a number of high-value compounds and electricity. Catalytic hydrothermal processing is being used by companies such as Licella to generate bio-crude oil from woody residues, which are further refined to liquid fuels, jet fuel and heavier compounds (Licella, 2012). Enzymatic processing of biomass (to date mainly used for the production of ethanol) has been improved so that a variety of chemical raw materials can be produced, most notably succinic acid which is a precursor to “green” plastics and polyesters.

The World Economic Forum produced in 2010 an excellent document on the global potential for biorefineries and bioproducts; it was estimated that the global economic potential for “green” bulk chemicals and bioplastics was US$10-15 billion (as well as US$80 billion for biofuels and US$65 billion for power and heat) (King and Hagen, 2010). In general, the aim of the biorefinery concept is to produce the highest-value product available. This is consistent with the economic practices of existing businesses.
on the island which produce high-value products in low volumes, thereby mitigating the increased transport costs associated with getting the products off the island. Figure 8.3 shows a representative chart of the kinds of chemicals that can be potentially produced from woody biomass with comparative market size and values.

![Figure 8.3 – Market size and values of potential woody biorefinery products (Taylor, no date)](image)

Significant technical feasibility analysis would be required to establish a compelling business case for a plant of this type over and above the conventional combustion-Rankine cycle plant. Similarly, the engineering design requirements would be significantly more involved and higher risk. As an example of the lead times involved, the timeframe from inception to commissioning was over five years.

### 8.4.4 Recommendations for Phase 2 Study

- Verification and validation of the results of the centralised generation studies will form a suitable base-line for comparison of other technology/energy carrier options.
- Preliminary feasibility analysis for each of the three scenarios identified above (subsections 8.4.1 – 8.4.3) should be conducted to establish budget costs, net present values and identify technical issues.
- Coordination of the Phase 2 study with the intentions of RuralAus is fundamental to the success of the overall mission.
9 Conclusions

The purpose of this study was to develop an understanding of the bioenergy potential on Kangaroo Island, firstly by evaluating the current and future bioenergy feedstock potential and secondly by identifying the conversion technology options available. Matching the available bioenergy resources on the island with suitable conversion technologies has led to a shortlist of viable candidates for techno-economic feasibility analysis, to be completed as Phase 2 of this study.

Recommendations identified from the Phase 1 analysis are as follows:

**Demand-side Management**

In the short term, electricity demand on the island should be managed through proactive implementation of opportunities to curtail peak loads, thus improving the security of the current electricity supply to the island. Some suggestions include:

- Rescheduling J-tariff hot water heater loads – peak demand is avoided by regulating the number of hot water heaters being automatically switched on at any one time
- Installing variable speed drives or soft starts on large motors (e.g. at KI Abalone) to prevent high starting currents causing out-of-code events
- (Potentially) calibrating building management systems of large resorts to manage switching of air conditioning loads

**Current and Future Biomass Supply**

Currently available biomass feed stocks in the form of forestry plantations represent the most cost effective and sustainable bioenergy resource option. Current concentrations of organic residues are insufficient by themselves to support a bioenergy investment, but could be added to the fuel mix if economically appropriate to do so. Other potential bioenergy crops have been discounted either due to the high cost of processing versus yields, or the poor compatibility of potential energy crops with the island’s ecosystem and biosecurity, or in the case of herbaceous crops, the unsuitability of the bioenergy product (alcohols) with the current energy infrastructure on the island.

**Candidate Process Technologies for In-depth Investigation (Phase 2)**

In addition to the central biomass-fired generator base-case, three alternative processing technologies have been identified:

- Incorporating a biomass densification plant (pellets or briquettes) with a central generator in order to support a new, distributed biomass gasification solution for remote areas
- Combining a central generator with a bio-synthetic natural gas plant to provide base-load electricity and alternative fuels for stationary and mobile piston engines (transport or electricity generation)
- Development of an integrated biorefinery to produce low-volume, high-value specialty chemicals as well as electrical and thermal energy, to increase return from the feed stock investment
10 Glossary and Nomenclature

CHP  Combined Heat and Power (also known as co-generation)
CNG  Compressed Natural Gas
DNSP Distribution Network Service Provider
DSM  Demand Side Management
ETSA  former acronym for the name of the South Australian distribution network service provider, now SA Power Networks
Ø   phi, symbol for Power Factor
GJ   GigaJoules – a unit of energy equal to ~278kWh
KI   Kangaroo Island
kV   kiloVolts – a unit of electrical potential
kWh  kilowatt-hours – a unit of energy. A Kangaroo Island household consumes approximately 8,000kWh per annum
LCOE Levelised Cost of Energy – the cost of energy required for a (renewable) generator to have a zero net present value over the lifetime of the plant
MVA  Mega Volt-Amperes – a unit of electricity describing the apparent power demand as opposed to the real power demand (MW). Apparent power = Real power / cos(Ø)
MW_e MegaWatts electric
MW_t MegaWatts thermal
MWh  MegaWatt-hours - a unit of energy equal to 3.6GJ
NEM  National Electricity Market
NPV  Net Present Value – the value of an investment at the present time accounting for discounted case flow
ORC  Organic Rankine Cycle
PV   Photovoltaic
SNG  Synthetic Natural Gas
SWER Single Wire Earth Return, a type of electricity transmission line
11 References


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Appendix A – Project Terms of Reference
Kangaroo Island Council

Bioenergy Resource Analysis and Technology Feasibility

Terms of Reference
**Terms of Reference**

Kangaroo Island Council are investigating alternate energy sources for the Island (which lies 16 km off the coast of South Australia). The Island is currently getting its power through a 10 MW / 33 KV undersea cable which is close to the end of its operating life and is the subject of a submission to the Australian Energy Regulator in 2015 for replacement with a new 66 KV cable and also the upgrade of the island distribution network backbone from 33 to 66 KV. We see this as vital infrastructure as it then becomes a potential export conduit for the Island for renewable energy generation into the national energy market in the future.

We need to create some growth opportunity between now and upgrade (between 2014 and 2018) for Island businesses. There is a large amount of 10-15 year old plantation eucalypt (blue gum) - around 15,000 ha worth planted originally under a tax advantageous managed investment scheme for wood chip but with no market, no processing facility and no deep water port - so essentially no value at this time. Contracts to purchase this timber from the investors are a clear possibility in the absence of any alternative market. Community waste is also shipped off the Island to recycling companies / landfill on the mainland incurring significant annual freight costs. In addition we have significant diesel / LPG consumption at a AUD $0.25/L premium to mainland supply (in terms of diesel for the pair of private ferries that service the Island, the primary producers and over 6MW of self-generation, gas for heating and vehicles etc).

The on-Island electricity distribution network is old and very “skinny” in terms of capacity - this makes large scale 1 MW+ power generation and injection into the grid problematical and very expensive in augmentation terms. Even with the proposed upgrade to the Island backbone there will be minimal positive effect on those outlying business / townships due to the lack of the capacity of the network to move this power out to consumers effectively.

As a result of this there is a need to investigate whether there is an economic case for gas or liquid fuel generation close to the biomass resource with decentralized "behind the meter" generation and retail sale in multiple locations where there is currently significant diesel powered own-generation or where existing primary production expansion opportunities are limited due to paucity / quality / security of supply.

As an additional factor, the cost of freight off the Island (and primary inputs onto the Island) for primary producers is a significant issue and Island producers are continually looking at adding value to their produce in order to mitigate the additional cost. It follows therefore that there may be opportunities for producers to look at alternative crops that could be grown on more marginal country that use less water than plantation timber that could become additional revenue streams. There are also compelling social reasons for cropping types that are more labour intensive than plantation timber - the ability to restore the estates currently under timber to active agriculture would drive employment back into the more remote areas of the Island with ensuing benefit to associated businesses, schools, Community groups etc.
A result of this study and other work running concurrently will be the creation of an energy road map for the Island - we need to understand what are the best options for the short and medium term that will potentially allow the Island to grow and we need to understand if biomass-to-energy should be an essential part of this roadmap.

The study is seen as being delivered in two phases:

**Phase 1:**
Characterise current and potential future biomass resources suitable for energy production and thermal energy needs on Kangaroo Island which may present particular economic niches; then based on the resource opportunity, energy type needs and technology availability, provide a short-list of technologies which potentially are a good fit and have achieved an appropriate level of maturity.

Steps involved would be:

1. **Current Biomass Resource - Assessment**
   Provide a comprehensive set of current biomass resource data for the Island. Combining information on plantations, agricultural residues (including stubbles and manures) and key biomass waste streams including ‘wet’ and ‘dry’ organic matter and the general composition of waste exported from the Island. Non-biomass wastes may be included in the inventory if they have potential compatibility with a bio-energy process (e.g. waste oils, tyres, paper, cardboard, plastics etc could be co-fired in some technologies without detrimental emissions). The intention is to provide an “asset register” of current biomass and waste resources for Kangaroo Island, indentifying approximate volumes, geographical spread, energy content and competing uses. The biomass resource assessments will include a summary table of resources, including projected costs at farm gate, estimated transport costs and any additional processing requirements.
   Note: a comprehensive assessment conducted in 2010 of the timber resources on the Island will be made available to prospective consultants. It is anticipated that this will reduce the volume of work in this step considerably.

2. **Future Biomass Resource - Potential**
   Provide a brief assessment of potential energy cropping opportunities for Kangaroo Island, including an assessment of current and developing bio-energy crops, their energy yield, and their suitability to the Island. These would include oil crops (e.g. canola) as well as short rotation coppice crops such as E. mallee, and grasses (Elephant grass etc). Consideration will be given to land availability and current use: any significant direct and indirect land use change likely to be associated with future bio-energy cropping will be noted. Whilst it is unlikely that most of these current and developing crops would be acceptable given the sensitive island ecology, it is worthwhile formally documenting these crops and their compatibility (or lack thereof) to record that they have been considered and a determination made.
The biomass resource assessments will include a summary table of resources, including projected costs at farm gate, estimated transport costs and any additional processing requirements.

3. **Heat Utilisation Opportunities**
As economic outcomes are often influenced by the ability to create value from thermal output, a consideration of current and possible heat uses on the Island will be made. These will also include any substantial refrigeration loads which could be serviced by a tri-generation process and the low temperature thermal desalination of water and treatment of brine to sea salt / range of finished products including minerals and fertiliser.

4. **Technology Shortlist**
The resource assessment outcomes will most probably exclude some potential bio-energy technologies on the basis of feedstock. Those that remain should be considered further, to the point where a go/no-go decision can be made in terms of some basic technology assessment criteria
- Reliable and proven in service
- Environmentally benign, with demonstrated Greenhouse gas (GHG) benefits
- Commercially available
- Can be fully supported with respect to maintenance and repair
- Suitable for the Kangaroo Island environment and potential grid constraints
- Literature data review based on Levelised Cost of Energy (LCOE) indicating LCOE being better than on-island diesel generation / costs of augmentation for mains power.

The above should include a range of high-grade energy options (only one of which is direct electricity production). Other possibilities, involving energy densification though conversion of available biomass feedstock's to liquid or gaseous fuels or densified solids (torrefaction, briquetting, pelletising etc) will be considered, as an alternative to the limitations imposed by the local electricity distribution grid. These alternative energy carrier methods will be considered in the context of other limitations, for example the road network and the extent to which heavy vehicles would be required for energy transport.

**Phase 2:**
Conclusions will be drawn in Phase 1, on which technology scenarios should proceed with a more detailed feasibility assessment of resource and technology combinations to suit the application contexts of:
- Centralised processing with power generation
- Centralised processing with commercial decentralised power generation
- Centralised processing with commercial and retail gas / liquid fuel opportunities.
The study should focus on the economic feasibility of establishing modular biomass processing plants with a power generation equivalent at the 1MWe module scale for better versatility on Kangaroo Island. The study should clearly identify the following:

- Review of commercially available biomass processing technologies, plant types, specification, cost and processing parameters.
- Commercially available direct storage and generation costs at plant site (assuming no augmentation costs) for base load “behind the meter” application - plant types, specifications, costs of purchase and operation.
- Commercially available decentralised storage and mobile / packet generation / combined heat and power generation for base load “behind the meter” applications - plant types, specification, costs of purchase and operation.
- Determine likely on-Island market opportunities for decentralised retail / wholesale opportunities for gas / liquid fuels

The feasibility assessment in Phase 2 would yield as key outputs, estimated capital costs ($/MWe), operating costs ($/MWe) and LCOE ($/MWe) for all relevant scenarios on specific case-by-case bases. From these, and an appropriate base case (e.g. diesel-based generation) the quality of the investment can be characterised in terms of Net Present Value (NPV) and Internal Rate of Return (IRR).

The analysis would also summarise other factors which may have a bearing on an investment decision:

- Sustainability considerations (embodied energy and carbon in plant and operations)
- Environmental impacts (noise, aesthetics, ecological impacts)
- Cultural sensitivities / heritage considerations
- OH&S
- Insurance
- Local employment opportunities - direct / indirect
- Expansion potential for local businesses known to be constrained by power / fuel costs
- Carbon tax/emissions trading implications
- Tourism potential

**Note:**
It is likely that the Phase 2 feasibility work will consider a variety of commercially available bio-energy systems based on the primary processes of combustion, gasification and pyrolysis, and, (depending on the identification of a suitable resource in Phase 1) anaerobic digestion and liquid bio-fuels from oil crops.

Excluding the combustion-based scenarios, which are typically limited to heat and electricity production only, the other primary processes may also involve secondary technologies to produce liquid or gaseous fuels instead of, or in addition to, heat and electricity. There are a number of secondary processing pathways by which liquid and gaseous fuels can be produced, and the assessment will consider only such processes identified as being at or very near commercial maturity (per Phase 1), and which
could conceivably be installed, commissioned, operated and maintained successfully on Kangaroo Island.

Solid fuel densification processes may also be considered as energy carrier mechanisms, if they offer further practical and economic alternatives. Decentralised mobile generation options may include gas repowering retrofit of existing diesel generator sets, as well as skid-mounted standalone small biomass generators (e.g. small units deployed under lease agreements with island-based service and maintenance). Unit selection would need to be aligned to load required – i.e. base load or top-up / stand-by generation.

Retail / wholesale opportunities for gas / liquid fuels would include drop-in liquid biofuels as a diesel replacement for existing generation plant, and potentially upgraded biogas and SNG (synthetic natural gas) as a general power / heating fuel alternative, if technologically feasible.

**Timing**

Kangaroo Island Council would like to proceed with this work as soon as possible as the work will inform other activities that are running concurrently. It is anticipated that work could be completed within eight – ten weeks of acceptance of the proposal.

**Reporting**

The Kangaroo Island Council representative for reporting purposes will be the Chief Executive Officer.

**Preparation of program for delivery of services**

Within two weeks of signed agreement.

**Progress Reports**

- Week 4/6 Phase 1 report – written report and verbal debrief
- Week 8/10 Phase 2 report – written report and verbal debrief

**Payment & Terms**

- Purchase Order Issued - 30%
- Phase 1 Report & debrief - 35%
- Phase 2 Report & debrief - 35%

Accounts payable on 14 days terms

**Insurances**

- Public liability insurance shall be not less than $10,000,000
- Professional indemnity insurance shall be not less than $10,000,000

**Proposal Timing**

Proposal period closes 5pm 31st August 2012.

Proposals and queries to be addressed to:
Andrew C Boardman, Chief Executive Officer
Email: andrew.boardman@kicouncil.sa.gov.au ph: +61 (0) 448 868088
1 Phase 2 Objectives and Scope

Objective… to evaluate several possible bioenergy scenarios for KI in sufficient detail to refine costs and determine feasibility, against reference scenarios for local grid augmentation/upgrade and continued importation of fossil fuels for generator use. Ideally, with sufficient detail to provide a starting point for serious investment choices.

1.1 Baseline Analysis – Grid Augmentation and Fossil Fuel Imports

Analyse and discuss the “base case” for grid upgrade/augmentation, providing a review of projected costs if/where available from SAPN and the fundamental benefits/limitations of the KI grid (in particular, limited backbone west of Parndarna).

Provide a review of projected diesel costs, estimated market volume and corresponding electricity generation costs for standalone diesel systems at a range of scales. Provide baseline bottle gas (LPG) costs and market scale for reference against gas replacement options.

1.2 In-field Processing Options

Review of in-field processes for plantation harvesting, in-field chipping whole tree removal (etc) and land repatriation; pro’s and con’s. Status, prospects and costs for any in-field densification technologies; re-locatable “satellite” densification plants. Options for nutrient return, soil augmentation with char, avoiding temporary N lockout issue with windrows, operational issues such as self-heating of chip stockpiles.

1.3 Centralised Processing with Power Generation

Review and indicative costings for centralised biomass processing plant options at scale range to suit power station operations. Specific technology options for power generation from a centralised plant of 1 to 2 MWe scale (not too big otherwise may further jeopardise cable upgrade). Likely to be commercially mature combustion or gasification processes. Indicative costings to include a list of assumptions, likely capex, opex and resulting LCOE.
1.4 Centralised Processing with Centralised and Decentralised Power Generation

Alternative to the above incorporating increased fuel processing capacity to supply additional solid feedstock to smaller-scale power generation facilities located at remote load centres with grid constraints. Include a summary of generation technology options for the remote load centres (replace existing diesel generator with same output biomass generator; re-power and de-rate existing diesel generator using a substitute biomass-derived gas fuel – discuss pro’s and con’s of both options). Provide indicative remote generation costs vs diesel.

1.5 Centralised Processing and Generation with SNG Production and Distribution to Decentralised Generators

Alternative to previous option where, in addition to centralised power generation additional biomass is processed through to synthetic natural gas (SNG) for distribution to remote users. Include indicative costs for SNG and power from SNG-fuelled small generators and a consideration of the market opportunity for possible bottled gas (LPG) replacement.

1.6 Other Integration Options for Centralised Generation

Consideration of other processes which can value-add to the central processing + power plant scenario, in particular thermal desal, and biorefinery processes for liquid fuels and low volume high-value fine chemicals. Focus on the economic / project leverage benefits of a centralised processing hub with multiple production streams (get buy in from utilities and larger commercial entities). Basic economic projections suitable as a starting point for investors. Include the cost differential potential for liquid fuels (higher island fuel costs) and the potential if KI was able to negotiate a fuel tax exemption for P&E use of liquid / gas fuel on Island.

1.7 Analyses

Where appropriate in the above scenarios, NPV and IRR estimates will be made for the relevant investment decisions; eg large-scale central biomass power vs grid upgrade, and decentralised biomass generators (solid or gas fuelled) vs diesel gensets.
In addition to the economic outcomes, technology options reviewed in all the scenarios will be rated against the following factors:

- Sustainability considerations (embodied energy and carbon in plant and operations)
- Environmental impacts (noise, aesthetics, ecological impacts)
- Cultural sensitivities / heritage considerations
- OH&S
- Insurance
- Local employment
- Carbon tax/emissions trading implications
- Tourism potential