Kangaroo Island biomass generation plant precursor study: Summary report.

RuralAus INVESTMENTS

Prepared for:

RenewablesSA,

October, 2011.

Kangaroo Island biomass generation plant precursor study:

Summary report.

Prepared for:

RenewablesSA

By:

RuralAus
INVESTMENTS

October, 2011

Important disclaimer

The information contained in this document has been sourced from 5 separate sub-project studies and the resulting reports as prepared by the sub-project teams. Given that the purpose of a precursor study is to develop a range of information, the analysis presented in this document is indicative and best endeavours and should form the basis of subsequent analysis going forward.

Table of contents

Summary

Study introduction, objectives and methods

RuralAus has an opportunity to develop biomass based electricity generation capacity based on sawmill processing and plantation harvesting residues to significantly reduce reliance on onsite diesel- based generation capacity. While considering this option it became apparent that a much broader scenario existed to increase the generation capacity up to 10 MWe $_{\mathrm{NET}}$ and provide the surplus electricity into the KI grid to reduce local supply constraints and allow on-island economic growth. Recognising the benefit to the broader KI community and the State of South Australia, RenewablesSA awarded $254,520 (ex GST) in grant funding to the project from the Renewable Energy Fund and this was combined with $120,000 (ex GST) provided by RuralAus. The following is a summary of the outcome of 4 sub-projects completed under this combined funding arrangement.

Market access sub-project

The current electricity supply grid KI is via an aging and constrained submarine cable, placing the supply at risk due to potential catastrophic failure, and retarding local economic development. Based on current and projected KI gross demand and considering demand duration attributes, a 5 MWe$_{\mathrm{GROSS}}$ base-load biomass power-station (80%-90% run time) would be possible by 2013/14 freeing up current supply allowing economic development e.g. increased tourists and aquaculture. Once the created surplus capacity was allocated, a second tranche of 5 MWe$_{\mathrm{GROSS}}$ would be possible from 2015/16. A proportion of the proposed biomass capacity would be required to supply electricity to the sawmill, and it is suggested that load following diesel gensets (already at the sawmill) could be used to meet spikes in load due to mill operations. During non-operating hours, the power-station would supply all net electricity to the grid, and if required, minor quantities could be exported from KI to the Fleurieu Peninsula. Additional to the capital required to construct the power-station will be the need to connect the site to a suitable point in the KI grid and the capital required is unknown. Once connected, the resulting electricity must be sold and due to economies of scale and potential counter party risk, a power purchase agreement (PPA) with an appropriate retailer is suggested to be a suitable business model. The likely price paid to the power-station will be a residual of the fixed retail price paid by all South Australians regardless of location. The price paid is likely to match other renewable supplies and could be between $100 and $135/MWh (black electricity and any Renewable Energy Certificates - RECs claimed).

Biomass sub-project

Plants capture solar energy and CO_2 during photosynthesis and on combustion this energy is released to provide heat e.g. for electricity generation, and then if re-grown, the released CO_2 is biosequested. To ensure certainty, the Federal Government has placed a limit on eligible biomass which includes radiata pine plantation materials and sawmill processing residues, indicating that the proposed KI power-station should be able to claim RECs. The net energy available to generate electricity is the gross energy contained in the bone dry biomass, less the energy required to evaporate water from within the biomass. Depending on the biomass, ash will be produced and analysis has shown that on a per tonne of green biomass basis, leaves and needles result in greater ash on combustion than the other biomass components. To provide certainty to an investment in a biomass power-station, a secure feedstock supply must be available and the current level of sawmill residues plus the resulting harvest residues from clearfalling plantations to produce sawlogs equates to approximately 70,000 t_{GREEN}/y (adequate for approximately 5 MWe_{GROSS} of capacity) depending on the harvest residues recovered. Removal of all harvest residues has implications for site productivity and sustainability, and the replacement value of nutrient removal (based on the cost of nutrient replacement) was estimated to range from: radiata pine needles = \$28.00 /t_{GREEN} to eucalypt wood = \$1.50 /t_{GREEN}. The estimated cost of biomass recovery and delivery to the power-station ranged from \$24 to \$55 /t_{GREEN} depending on harvesting strategies and the materials recovered.

Technology sub-project

A range of technologies are available to convert biomass into energy, however given the isolation of KI, degree maturation and robustness was a critical determinate of a focus on combustion as an appropriate technology. Combustion technology includes fixed, travelling and fluidised bed grates on which the biomass is combusted with differences in capital cost and operating attributes which will require careful assessment in the final project design. The heat released on combustion converts water into steam in a boiler to drive turbines to create electricity. One variation is an Organic Rankine Cycle system where the boiler water is replaced by an organic liquid with enhanced operating attributes. Based on the analysis conducted capital costs ranged from \$4.6 to \$7.5 million / MWe_{NET} capacity, which would indicate a need for appropriate due diligence capital v operating costs, particularly with parasitic loads (internal power-station needs) reported as 12 to 21% of the gross generating capacity. Operating costs include biomass (modelled range 16,800 to 23,300 /MWe_{NET}/y) and water consumed by the boiler and in converting steam back to liquid in condensers (20.4 to 76.8 m^3/MWe_{NET}/day). A trade-off exists between the use of water cooled condensers (water and water pumping parasitic loads) and fan based systems, and in terms of KI, this is a mute point given the quality and quantity of water required for cooling towers: regardless, this issue will require careful attention in subsequent analysis. Potential atmospheric and particulate emissions will be driven by attenuation technology applied to the smoke stacks and the biomass combusted – reliance on plantation residues and sawmill processing residues is likely to be significantly less problematic compared to the introduction of municipal waste streams. Similarly, with plantation based biomass, there is unlikely to be ash disposal issues as the by-product may in fact be a resource.

Financial analysis sub-project

A financial analysis was conducted combining the results of the various sub-project into a single financial model. The model was populated with additional information provided by the consulting group undertaking the financial analysis where there were gaps in the information. A base-case scenario was prepared indicating that the cost of generating the electricity was greater than the likely revenues at the current point in time. When an analysis was conducted of the project cashflows out over time and the internal rate of return (IRR) was estimated to be a nominal 2.68% (with assumed inflation of 2.75%) due to assumed real increase in revenues (black electricity) above the impact of inflation. Sensitivity analysis was conducted of expenses and revenues to determine the main drivers of IRR based on percentage change in the assumption and the outcome IRR. CAPEX and biomass costs were found to be the most significant expense drivers, where as black electricity price and change in black electricity price were the most significant drivers of IRR. This is a significant outcome given that the CAPEX excluded any connection to the grid and that the biomass excluded any stumpage to the growers. In order the refine the analysis, more detailed design and costings are required.

Introduction

RuralAus Investments Limited (RuralAus) (RUR:ASX) has recently purchased an integrated plantation forestry asset on Kangaroo Island (KI) comprising 2,200 ha of *Pinus radiata* (radiata pine) plantations and a timber processing centre located near Parndana. The timber processing centre has the capacity to process approximately 50,000 m^3/y of plantation grown radiata pine saw logs to produce approximately 18,000 m^3/y of green and kiln dry timber. The site can also process approximately 13,000 m^3 of small radiata logs from thinnings into 12,000 m^3/y of treated pine round posts. The products are for the mainland market and the centre has the potential to employ 32 staff and 15 people would be employed by ancillary contractors providing harvesting, transport and general support services. The processing centre has a poor financial track record as managed by previous owners as a standalone entity and analysis indicated that in the past (onsite diesel generator) electricity costs placed significant pressure on profitability. Even though connected to the KI electricity grid network, limitations in electricity availability and reliability dictated the need for diesel based onsite generation capacity.

Comment *The current diesel price, likely future prices and price volatility make the status quo of onsite diesel electricity generation unviable and similar issues would be faced by the majority of KI entities with onsite diesel generation capacity.*

RuralAus has an opportunity to develop biomass based electricity generation capacity to reduce reliance on diesel based generation:

- ***Default option:*** Install at the sawmill an approximate 2.5 MWe_{GROSS} capacity biomass power-station fuelled by approximately 30,700 t/y log processing residues (mill residues);
- ***Broader KI option:*** Develop up to 10 MWe_{GROSS} of capacity connected to the KI grid (a higher risk and higher cost opportunity), maintaining the onsite diesel capacity for load-following, back-up and for power-station shuts. The electricity would increase on island supply allowing economic growth beyond the constraints of the current submarine cable. This would require sourcing biomass resource beyond sawmill residues.

The stated South Australian target of renewable electricity provided a platform to take the initial step in conducting a precursor study towards a potentially significant investment in a renewable energy (biomass based electricity generation) on KI. To support this project, RuralAus was successful in gaining financial support in the form of a grant from the *Renewable Energy Fund* as administered by RenewablesSA's. The following is a summary of the four sub-projects completed.

Study objectives and methods

This precursor study of biomass renewable energy generation on KI aimed to provide information to enable an informed market for electricity and biomass and to address the market failure caused by lack and imbalance of information between project stakeholders: to identify and collate information required by potential electricity consumers and biomass resource owners to supply feedstock to up to 10 MWe_{GROSS} of generating capacity. Given the potential for *clean and green* branding, there was a need to understand the potential airborne emissions and water management issues. As a by-product, the study demonstrated a framework for assessing renewable energy opportunities for other communities located at the end of existing distribution networks.

Analysis of the situation on KI and discussions with RenewablesSA identified a four part precursor study to address the lack of public information segmented into 4 sub-projects is presented in Figure 1. RuralAus developed detailed sub-project scopes and engaged 5 suitably qualified and industry recognised consultants to undertake the works[1]. Figure 2 presents more specific details of the linkages between sub-projects via the utilisation of the information collated and developed.

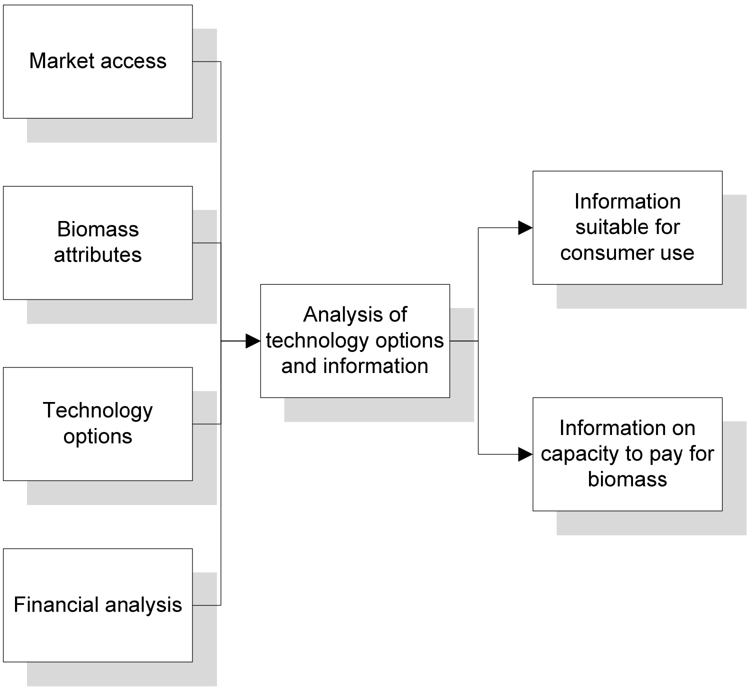

Figure 1 A summary of the precursor sub-project structures and links to outcomes.

---

[1] See Appendix A for details of the consultant groups.

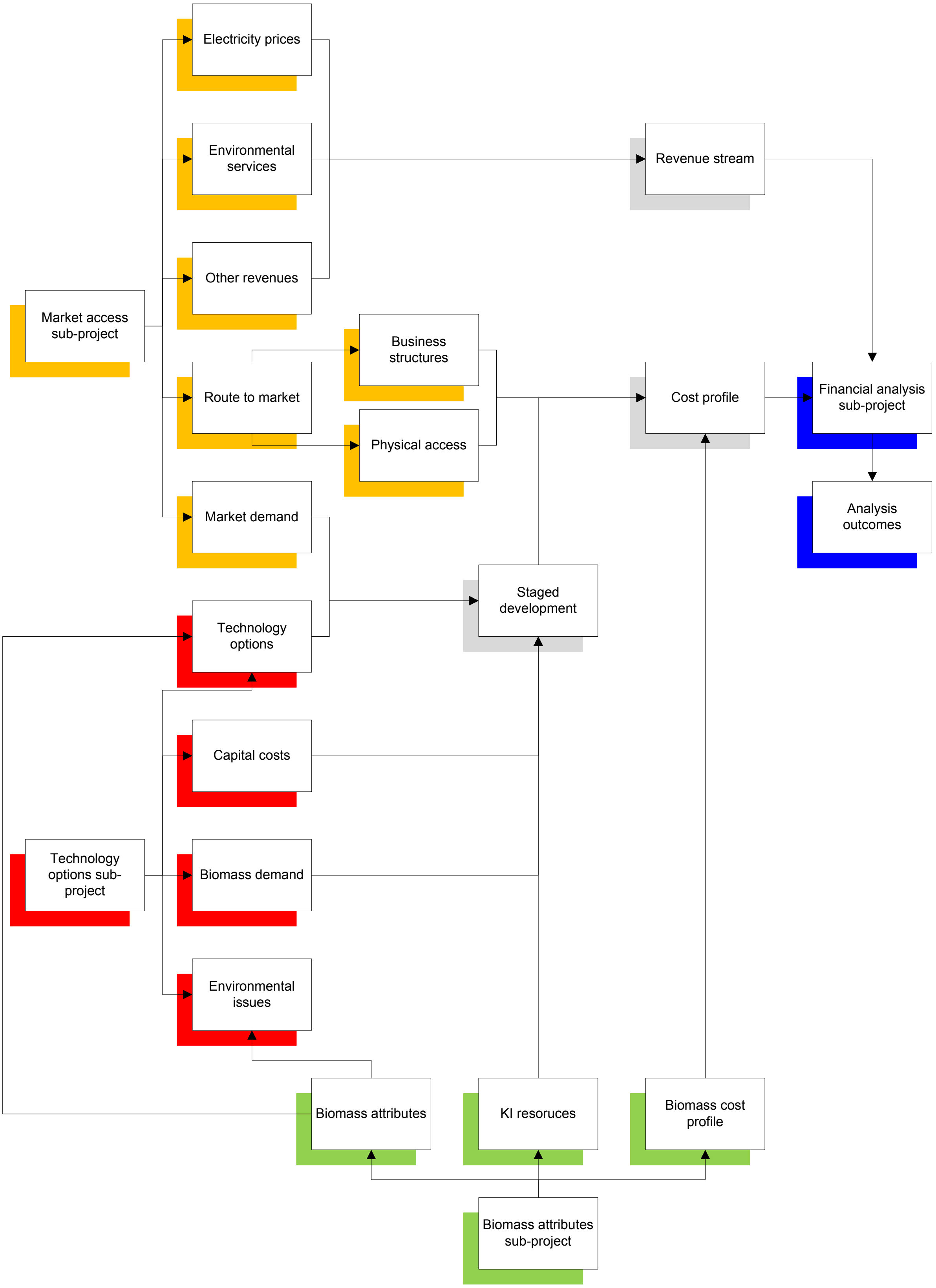

Figure 2 A summary of the sub-project linkages and information outcomes feeding into the financial analysis of a biomass power-station scenario.

Energy and community benefits on KI

Level of Government support

A stated objective of the South Australian Government is *"to ensure that government works alongside business and the community to help achieve results that benefit our State, as well as our planet[2]"* and support for this project has been gained at all levels of Government:

- ***Federal government:*** At the Federal level, the Hon. Mr Jamie Briggs MP (Federal Member for Mayo) recognises the broader benefit of the project to the people of KI and support was provided by Regional Development Australia (RDA): Adelaide Hills, Fleurieu and KI;
- ***State Government:*** At the State level, the project has the support of The Hon. Michael O'Brien (Minister for Forests) and a Case Manager was provided by the Department of Trade and Economic Development (DTED);
- ***Local Government:*** The project had strong local Government support on KI.

The level of Government support culminated in the receipt of a $254,520 (ex GST) grant from the South Australian Government, Renewable Energy Fund as administered by RenewablesSA.

Local economic development and a whole of island approach

The South Australian Government is committed to 33% of electricity from renewable energy by 2020[3] and renewable energy use has been suggested as complementary to KI marketing / branding as *clean and green* to tourists[4] and could provide additional jobs[5]. Development of biomass generation capacity and associated reduced greenhouse gas emissions would enhance such branding (e.g. potential to market low carbon holidays and products). Further, the Government is keen to promote economic development in the region and recent announcements support KI's growth as an internationally recognised tourism asset and premium agricultural producer[6]: the Government confirmed that it is seeking to:

- ***Tourism aspirations:*** Double the number of tourists to KI;
- ***Agricultural viability:*** Double KI farm-gate incomes.

To achieve this aspiration, existing constraints in the electricity network must be addressed as a major barrier to significant economic development is the lack of spare capacity on the submarine cable between the mainland and KI.

---

[2] Rann, Hon. M. (2010: p.1) ***CEDA Address: Leadership in a Carbon Constrained Economy.*** Tuesday 31st August, 2010.

[3] (RenewablesSA, 2010: p.1) ***Renewable Energy Fund: Grant policies and procedures.***

[4] Kirke, B. (2004:p.1) ***KI energy supply options.*** Report on visit to Kangaroo Island 8-9 September, 2004.

[5] Furniss, D. (2004: p.4) ***Joint submission to ESCOSA on Kangaroo Island Electricity reliability standards.*** On behalf of Kangaroo Island Council and Kangaroo Island Development Board.

[6] 1 Premier Mike Rann News Release ―Government Backs Growth for Kangaroo Island‖: Sunday, 24 July 2011 ―Paradise Girt by Sea‖ released by the Economic Development Board

Comment *The current network constraint provides a "Catch-22" in that as demand does not increase, it is difficult to justify an increase in electricity supply to KI.*

Other significant benefits would result from the development of biomass based electricity generation capacity on KI:

- ***Improvement in supply reliability and security:*** On-island generation would provide network support in the event of un-planned outages and catastrophic submarine cable loss;
- ***Deferred network augmentation:*** Augmentation of assets on the Fleurieu and the submarine cable could be deferred;
- ***Limiting standby diesel:*** Reduced need for high cost diesel generator standby units;
- ***Reduction of network losses:*** Reducing electricity transmission losses from the mainland supply.

The current sawmill electricity demand and the ability to develop matched biomass generation capacity can be independent of the local network, however this would forego a significant opportunity to address electricity supply issues on KI. It must be noted that the development of a single biomass power-station on KI will not resolve all of KI's electricity issues and development of this project in conjunction with other initiatives is likely to provide significant synergies.

Comment *The development of a biomass generation facility on KI would deliver significant benefits to the KI community with the potential for greater benefits if the project is considered as part of an overall electricity and development strategy for KI.*

Market access sub-project

Summary

The current electricity supply grid KI is via an aging and constrained submarine cable, placing the supply at risk due to potential catastrophic failure, and retarding local economic development. Based on current and projected KI gross demand and considering demand duration attributes, a 5 MWe_{GROSS} base-load biomass power-station (80%-90% run time) would be possible by 2013/14 freeing up current supply allowing economic development e.g. increased tourists and aquaculture. Once the created surplus capacity was allocated, a second tranche of 5 MWe_{GROSS} would be possible from 2015/16. A proportion of the proposed biomass capacity would be required to supply electricity to the sawmill, and it is suggested that load following diesel gensets (already at the sawmill) could be used to meet spikes in load due to mill operations. During non-operating hours, the power-station would supply all net electricity to the grid, and if required, minor quantities could be exported from KI to the Fleurieu Peninsula. Additional to the capital required to construct the power-station will be the need to connect the site to a suitable point in the KI grid and the capital required is unknown. Once connected, the resulting electricity must be sold and due to economies of scale and potential counter party risk, a power purchase agreement (PPA) with an appropriate retailer is suggested to be a suitable business model. The likely price paid to the power-station will be a residual of the fixed retail price paid by all South Australians regardless of location. The price paid is likely to match other renewable supplies and could be between $100 and $135/MWh (black electricity and any Renewable Energy Certificates - RECs claimed).

Introduction

Investment requires a detailed understanding of the market into which the goods and services are to be sold and the market access sub-project consider market related issues. The study collated existing information and captured additional data, explored appropriate electricity generation and sales business models to help determine the most appropriate structures with associated costs and risks. The analysis determined price points for the most appropriate electricity sales business models, customer willingness to pay (linked back to the price generated electricity could be sold for) and the impact of branding electricity as *clean and green*. The following is a collation of the information presented in the market access sub-project.

KI electricity demand: historic, projected and duration

Current status

Regardless of change in South Australian capacity or that of the overall National Electricity Market (NEM) supply from the mainland to KI will remain at risk due to infrastructure limitations (a regulatory failure) in the absence of action. The KI electricity supply is via the Fleurieu Peninsula, and the greater Fleurieu Peninsula is projected to face increased pressure on supply, increasing load and hours at risk, placing KI's supply at greater risk. The first submarine cable linking KI with mainland electricity grid was installed in 1965[7] and the current submarine cable was laid in the late 1980's directly onto the seabed, and was scheduled for replacement around 2010, electricity supply adequacy and reliability and the potential for catastrophic failure in the submarine cable (due to age), combined with the Australian Electricity Regulator (AER) preventing ETSA Utilities investing $95 million in the critical upgrades[8], places the KI network electricity supply at risk. ETSA Utilities has 6 MWe of diesel generation capacity as back-up of submarine cable failure as an immediate solution[9]. The current total KI peak demand for electricity is expected to match the 10 MVA (8.0 MWe at 0.8 power factor) submarine cable capacity by 2012/13 and with increased demand, exceed the capacity by 2013/14[10] (Figure 3). Figure 4 presents load durations for KI indicating the proportion of the time that electricity demand is at the levels indicated. Due to transmission infrastructure limitations, not all current private end user generation plant (estimated total private capacity of 5.4 MWe is close to the current network supply[11]) in service would be able or willing to connect to the network.

Proposed base-load capacity

Development of a biomass power-station would provide base-load electricity independent of whether the wind blows or the sun shines, but with limited flexibility to rapidly change (increase or decrease) output. Therefore determination of the timing of capacity installation must consider both the gross KI demand and the demand duration (e.g. the proportion of the time at which demand is above set levels of capacity). Based on Figure 4, a base-load power-station operating 80% to 90% of the time would be constrained to a maximum capacity of 40% to 48% of capacity, hence a target 10 $\text{MWe}_{\text{GROSS}}$ power-station would require a KI load of 21 to 25 MWe. Figure 3 presents historic and projected current demands and ETSA Utilities planned forecast (restricted by existing network constraints) and potential load growth due to increased economic development targeted by the South Australian Government: doubling of tourist visitor numbers over a five year period and increases in the existing abalone farming industry. A 10 $\text{MWe}_{\text{GROSS}}$ power-station could not be accommodated on KI until 2025 unless a significant amount of electricity could be exported from the Island, whereas 5 $\text{MWe}_{\text{GROSS}}$ (KI load of 10.5 to 12.5 MWe) could be accommodated from 2013/14.

---

[7] RuralAus (2009: p.2) ***Biomass power preliminary feasibility.*** Internal RuralAus document.

[8] AER (2010: p.228) ***Final decision: South Australia distribution determination 2010–11 to 2014–15.*** May 2010

[9] ElectraNet – ETSA Utilities (2010: p.7) ***Projected distribution network constrains: Bulk energy supply to the Fleurieu Peninsula.*** March 2010.

[10] ACIL Tasman (2010: p.270) ***Electricity system development plan***. Issue 1.4 prepared for ETSA Utilities. Downloaded from http://www.etsautilities.com.au/centric/our_network/annual_network_plans.jsp nn 09/02/11.

[11] Davidson, M. (2009: p.9) ***An investigation into the utilisation of end user generation on Kangaroo Island.*** A report prepared for the Kangaroo Island Development Board. January, 2009. The stated capacity of 6.8 MVA was converted to MWe assuming a 0.8 power factor.

Fit with KI profile

A base-load biomass power-station would generate electricity for approximately 80%-90% of the time and the sawmill would operate for a nominal 8 hour shift 5 days per week[12]. Figure 5 was prepared to demonstrate the fit of the sawmill needs and supply to the KI grid. During non-sawmill operations, 100% of the generated electricity would be available, and if supply exceeded KI demand, small quantities could be exported to the mainland via the submarine cable. During mill operations, load would spike (e.g. when logs hit the saw) increasing electricity consumed and to smooth out the available electricity, load following diesel generators would be used to maximise the base-load available for supply to the grid.

Comment *A rational approach to the development of a power-station at the sawmill would be staged commissioning. Analysis of the duration curve for KI indicates that a 4.5 - 5.0* MWe_{GROSS} *facility could reasonably be commissioned in 2013/14, followed by a second tranche up to 10* MWe_{GROSS} *in 2015/16 to 2020/21 depending on demand growth.*

Specific issues to address

Connection to the grid

Connection of a 5-10 MWe_{GROSS} power-station at the sawmill would require the construction of a 33kV feeder to MacGillivray (a distance of approximately 20km). The power-station would also have to meet technical criteria, set by ETSA Utilities prior to connection, that address system safety, protection, voltage control and synchronisation with ETSA Utilities generation assets in Kingscote. To establish the cost of providing 33kV connection, ETSA Utilities has indicated that they would require a formal connection application to be submitted. ETSA Utilities would then undertake detailed network studies and costings on a fee for service basis.

Business model

It was identified that the most commercially attractive route to market was to enter into a Power Purchase Agreement (PPA) or off-take agreement with an electricity retailer (or other creditworthy wholesale electricity purchaser). This would:

- ***Supply risk:*** Reduce the risk of being stranded with unsold electricity contracts;
- ***Customer costs:*** Mitigate the cost of customer acquisition;
- ***Market risk:*** Mitigate price risk through a back to back pricing arrangement with the generators and the retail customers.

---

[12] A decision is required as to whether 100% of the electricity is exported to the grid or whether the net of the sawmill needs is sold.

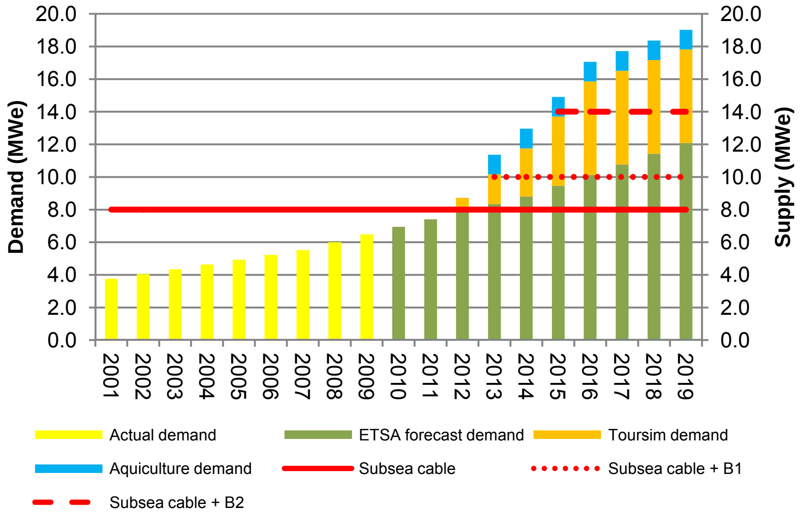

Figure 3: Modelled change in demand for electricity on KI based on assumed forecast demand by existing consumers, due to tourism industry expansion and aquaculture development. B1 = first tranche of capacity and B2 = second tranche of capacity.

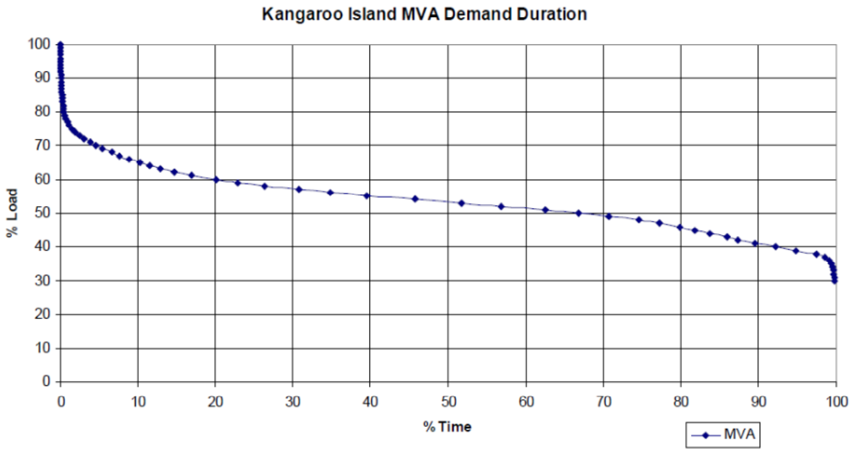

Figure 4: A current demand profile for electricity on KI.

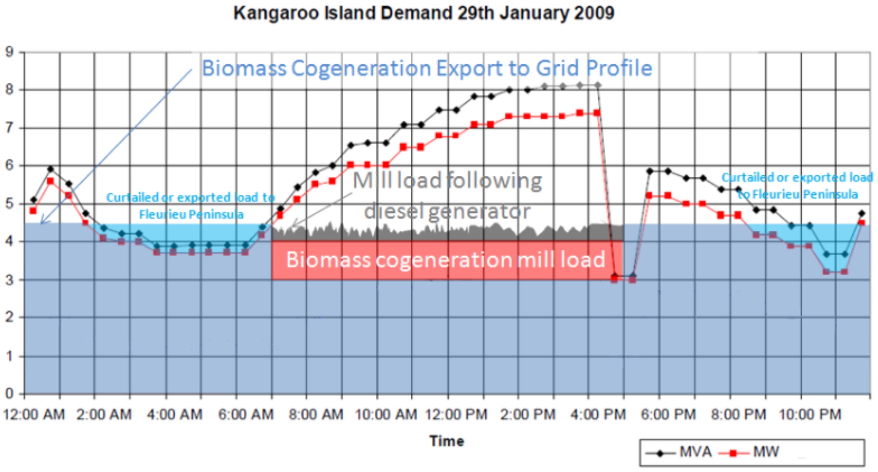

Figure 5: A demonstration of the fit of electricity generated and the ability to provide base-load to the grid after supply to the sawmill.

Generated electricity sales price expectations

It is expected that any future PPA price for a new renewable generation project, would reflect the cost of the least expensive renewable electricity alternative (currently wind generation). There is little public visibility on recent PPA prices achieved as such contracts contain commercially sensitive material. However, available industry publications generally suggest a generator would receive sales prices ranging from approximately $100-135/MWh (electricity and RECs[13]) which have been achieved for wind generation projects (see Figure 6 for an analysis commencing with a retail tariff of $282/MWh). This price range is consistent with recent modelling results completed for Federal Treasury who assessed the cost impacts of carbon policies on the electricity market.

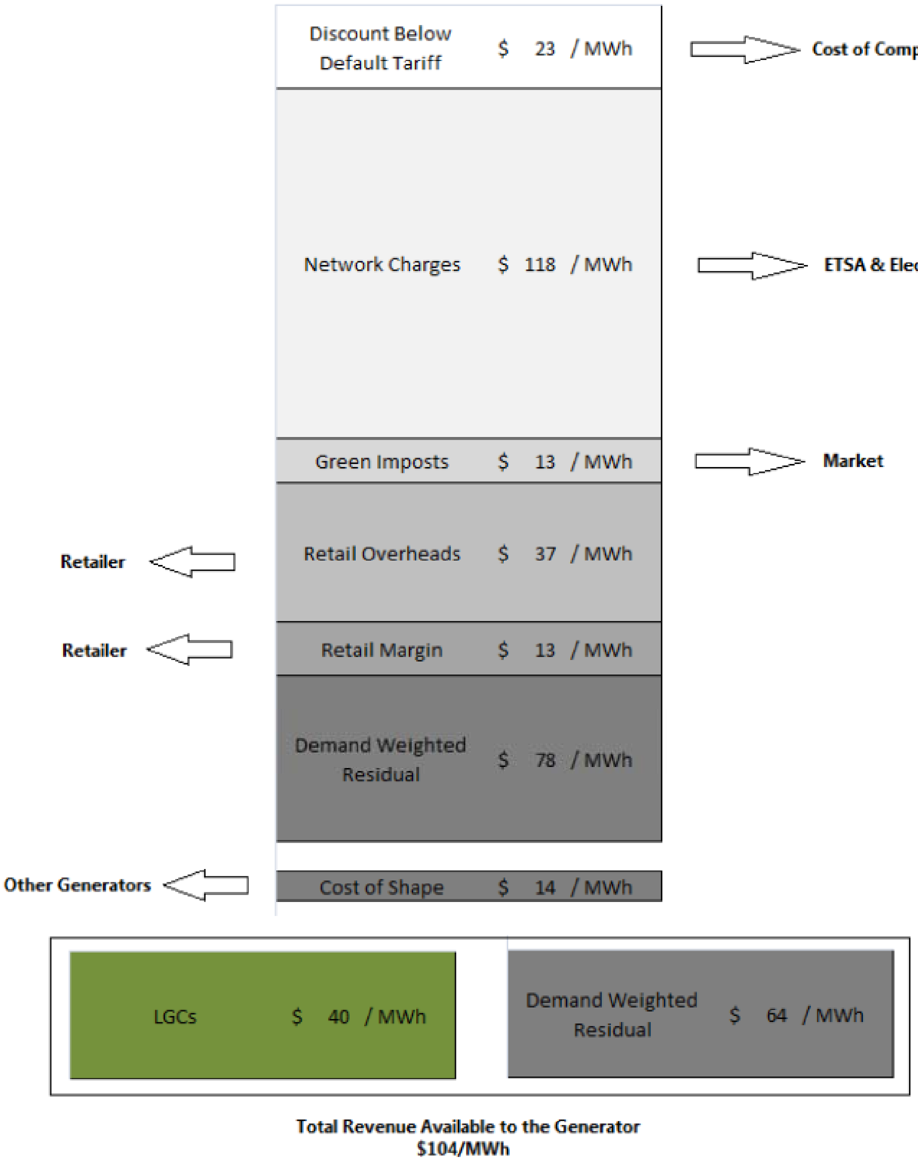

Figure 6 A summary of the breakdown of the retail tariff ($282/MWh) for electricity into the different components, indicating $64 + $40 = $104 /MWh (36.7% of the retail tariff) available to the generator.

---

[13] REC = renewable energy certificates.

Biomass suppliers study

Summary

Plants capture solar energy and CO_2 during photosynthesis and on combustion this energy is released to provide heat e.g. for electricity generation, and then if re-grown, the released CO_2 is biosequested. To ensure certainty, the Federal Government has placed a limit on eligible biomass which includes radiata pine plantation materials and sawmill processing residues, indicating that the proposed KI power-station should be able to claim RECs. The net energy available to generate electricity is the gross energy contained in the bone dry biomass, less the energy required to evaporate water from within the biomass. Depending on the biomass, ash will be produced and analysis has shown that on a per tonne of green biomass basis, leaves and needles result in greater ash on combustion than the other biomass components. To provide certainty to an investment in a biomass power-station, a secure feedstock supply must be available and the current level of sawmill residues plus the resulting harvest residues from clearfalling plantations to produce sawlogs equates to approximately 70,000 t_{GREEN}/y (adequate for approximately 5 MWe_{GROSS} of capacity) depending on the harvest residues recovered. Removal of all harvest residues has implications for site productivity and sustainability, and the replacement value of nutrient removal (based on the cost of nutrient replacement) was estimated to range from: radiata pine needles = \$28.00 /t_{GREEN} to eucalypt wood = \$1.50 /t_{GREEN}. The estimated cost of biomass recovery and delivery to the power-station ranged from \$24 to \$55 /t_{GREEN} depending on harvesting strategies and the materials recovered.

Introduction

The step from 2.5 MWe_{GROSS}[14] to 10.0 MWe_{GROSS} requires a significant shift in biomass input from onsite sawmill processing residues to include other biomass streams. A fundamental question is what is the relative value and therefore capacity to pay for the other sources of biomass to secure access to the materials? Each biomass owner will be required to make a decision on whether to supply and presently there is a lack of price information and therefore the price that biomass owners could reasonably expect to receive. Determination of the capacity to pay for biomass should inform the expectations of price offers and this will be driven by relative energy values, collection costs, transport costs and any required processing costs. This sub-project determined the range and scale of biomass types available on KI and the attributes of each, addressed the impact of biomass moisture content on total feedstock required and / or the technology to manage such materials. Following the determination of biomass attributes, the power-station mill gate handling costs was estimated and the associated information required by biomass owners to inform a balanced negotiation on plant gate price was prepared. The following is a summary of the sub-project analysis.

---

[14] The default option to provide the sawmill alone.

Biomass and renewable electricity

Plants capture solar radiation and use the energy to convert carbon dioxide (CO_2) and water (H_2O) into carbohydrates as building blocks of their structures (Figure 7). While fossil fuels are derived from plants, the definition of biomass includes the qualifier of recent, limiting biomass to non-fossil fuel materials. Biomass is an important renewable electricity source in that it is renewed once used e.g. plants can re-grow and to provide certainty, the Government has legislated to limit acceptable renewable electricity sources which includes biomass. To provide greater certainty to the community and to ensure compliance with international requirements, eligible biomass is further defined to include woody waste from processing, plantation management residues and woody / plant material from municipal waste streams. Compliance with the Government requirements will be critical for the project and administrative systems will be required to ensure that all such requirements are met as part of any biomass purchase agreement.

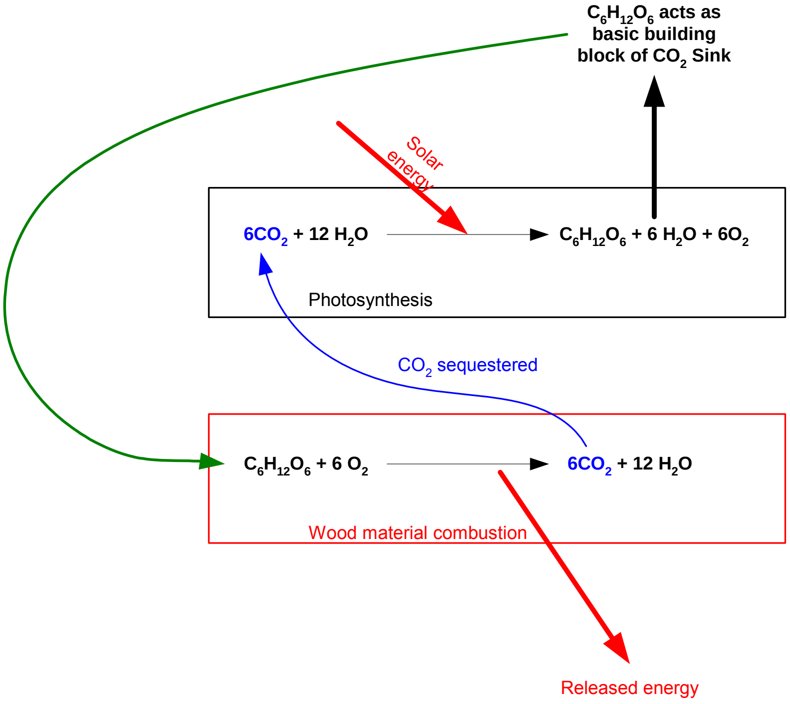

Figure 7 A basic representation of the process of (solar) energy storage and release by plants during photosynthesis (storage) and plant material combustion (release).

Biomass as an energy source

Figure 8 presents a summary of biomass as an energy source. The utility and value of biomass feedstock is determined by the net energy content with the gross energy content of dry wood as the starting point in any assessment. Biomass samples were collected on KI and were assessed for gross energy content, and indicated a degree of variation between species and between the biomass components within a species. Of greater impact is the biomass moisture content (as delivered to the laboratory) reducing the available (net) energy to less than half the gross energy. During combustion ash is produced as a by-product with the leaf and needle biomass components contributing the greatest proportion of the resulting ash per unit of input. The dominant ash was calcium oxide (CaO) with a range of other ash types tested for and for which furnace design specifications will be required to consider. In any design and operation, a trade-off is required between the energy content and ash produced for each biomass component and it would appear that the leaf and needle materials are the least attractive. Apart from impacting on net energy, biomass moisture will affect the presence of biological agents creating a risk of spontaneous combustion. Biomass as a biological product may pose health risks (as identified by a number of industries) and this will require appropriate due diligence in plant management and design.

The inherent gross energy stored in biomass is derived from the solid plant matter, and water and mineral impurities will reduce the gross energy content. The solid plant matter will vary with species and the components of the total biomass recovered e.g. bark, branches, leaves etc. Water in the biomass will vary with management and time from at harvest levels of generally greater than 50% $_{\text{GREEN BASIS}}$, and will require evaporation from the biomass on combustion consuming some of the available gross energy. On combustion, water is a by-product and will add to the energy consumed further reducing the net available energy (see Figure 7). Mineral contaminants do not add to the biomass energy content and dilute the available energy per unit weight of biomass feedstock. Handling during harvesting and at the power-station will influence the mineral contamination of the biomass.

The technology deployed must match the likely future feedstocks as a trade-off between the materials to be combusted compared to the generation technology. The primary feedstock will be timber processing residues meeting the requirements for eligibility under the Renewable Energy Targets (RET) scheme[15], supplemented with plantation harvest residues, potential for purpose grown biomass or other cellulose, hemicellulose or lignin sources such as cropping residues and some components of municipal waste streams are possible.

Comment *Increasing the scale of generation capacity to meet the broader KI needs will require feedstock supply beyond timber processing residues, significantly changing the project.*

---

[15] See the *Renewable Energy (Electricity) Act 2000*: **Part 2** Renewable energy certificates, **Division 3** Accreditation of eligible power-stations.

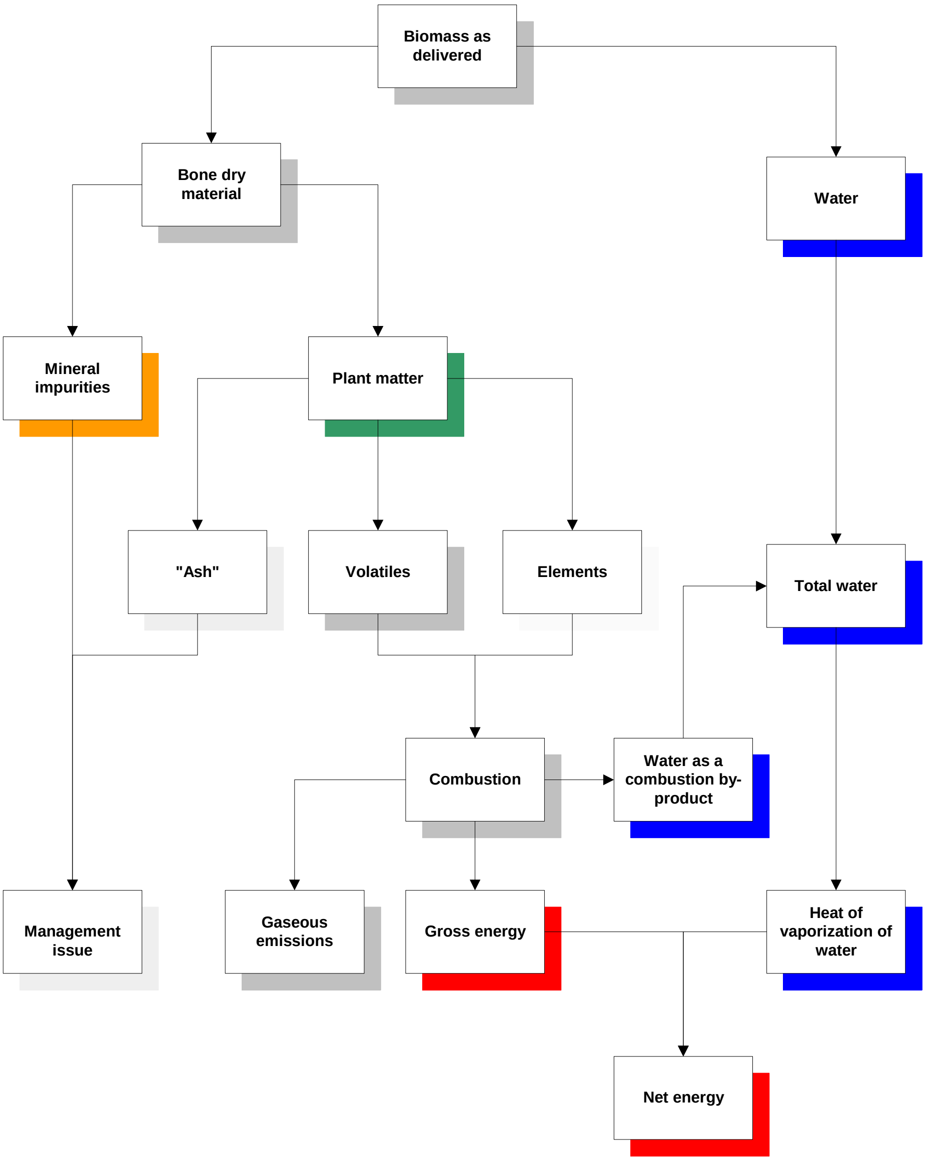

Figure 8 A breakdown of biomass composition and the energy source and losses due to the energy consumed to vaporise water.

The biomass resource: inventory and units

The current plantation estate has been developed to service the sawn timber and export woodchip markets and any biomass feedstock will be supplied as a by-product of such operations, hence, the supply will be contingent on the success of such operations and the willingness to sell biomass. Figure 9 presents a summary of the potentially available resources by control: any PPA will require a secure biomass feedstock for the full amount of capacity contracted.

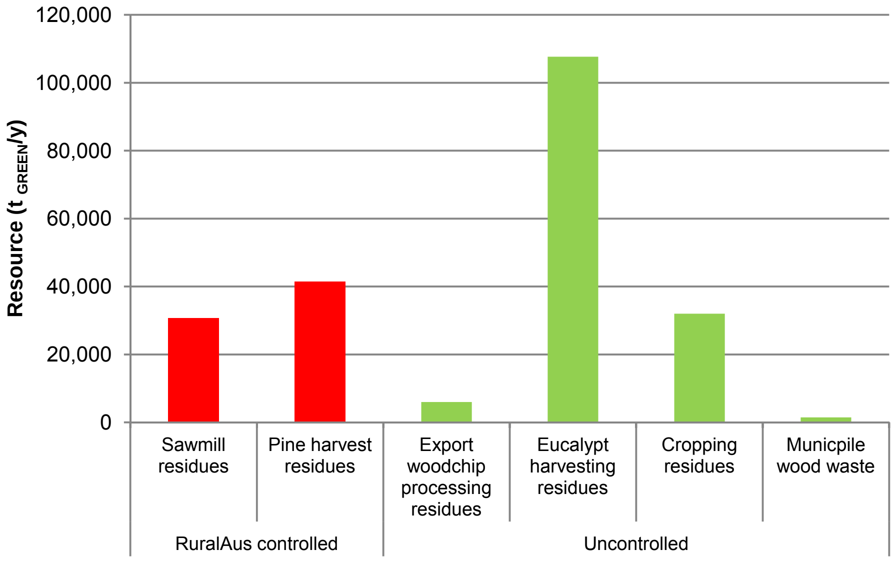

Figure 9: A summary of the modelled KI biomass resource data segmented into resources controlled by RualAus and uncontrolled by the company.

Comment *Based on indicative biomass consumption rates of 15,000 t_{GREEN}/MWe/y, the current controlled biomass would support approximately 5 MWe_{GROSS} of capacity. Progress towards development of 10 MWe_{GROSS} would require access to additional and non-controlled resource. Such a scale of resource is significant and investment in the power-station will require mechanisms to secure access to such materials over an extended period of time.*

Sustainability issues

The impact of complete removal of biomass from plantations is well recognised with the primary Australian example of the second rotation decline indentified in the 1960s for *P. radiata* growing in South Australia which led to changed management practices including the retention of harvest residues. Similar practices have been adopted across most plantation estates in Australia. Data obtained from the biomass analysis was used to estimate the nutrient removal by recovery of the biomass and the key macro and micro nutrients included were: nitrogen (N), copper (Cu), manganese (Mn), zinc (Zn), potassium (K), magnesium (Mg) and calcium (Ca). The main sources of the key nutrients were the leaves and needles. In routine harvesting, stem-wood and perhaps bark are recovered and removed, and it is reasonable to assume that the stumpage paid includes compensation to allow replacement of the nutrients. Figures 10 and 11 presents a summary of the cost of replacement of the nutrients in the biomass recovered: leaf and needle matter are the most expensive and the least expensive is the wood component.

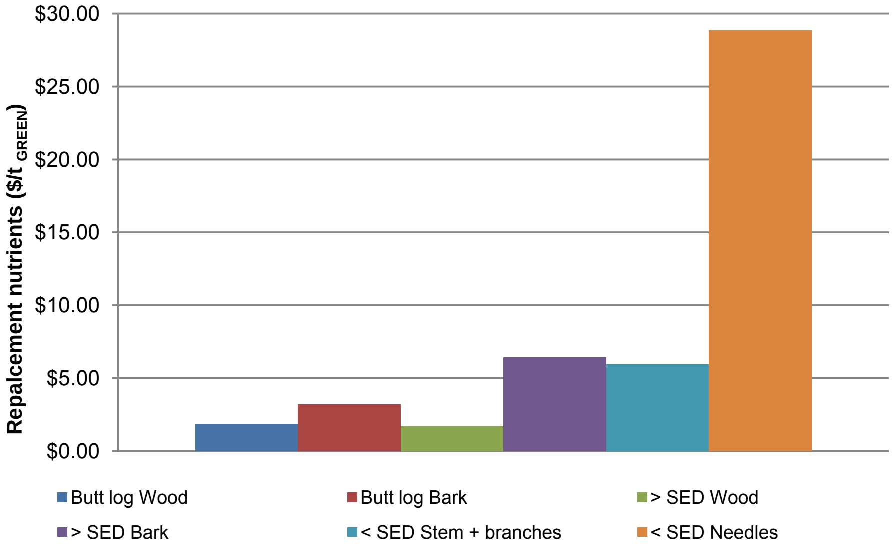

Figure 10: Total nutrient replacement costs for biomass recovered by biomass component for *P. radiata* presented on a per t GREEN BASIS recovered basis. (Note: SED = small end diameter)

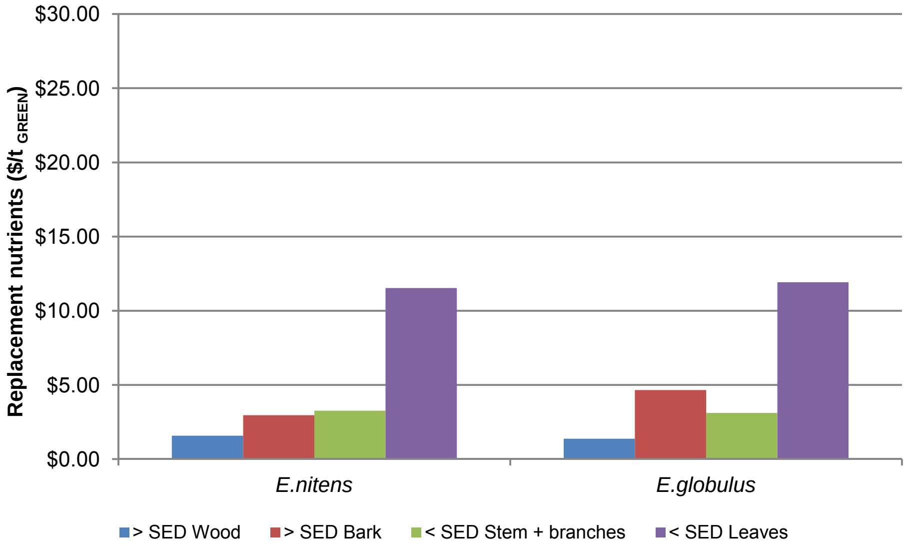

Figure 11: Total nutrient replacement costs for biomass recovered by biomass component for *Eucalypts* presented on a per t GREEN BASIS recovered basis.

Logistics, handling and mill gate price

The cost of biomass feedstock delivered to the sawmill and prepared into a format ready for use will be driven by the degree of integration of biomass recovery into routine harvesting of the primary log products. Where biomass is NOT a consideration, harvest residues may be spread across a site or aggregated in rows at the roadside, both of which can be unsatisfactory due to cost and the potential for mineral contamination (Figures 12 and 13). A further consideration is the materials recovered: is it 100% of the above ground biomass or a select component, and if less than 100% recovery, there are set combinations possible due to operational limitations: if needles or leaves are not required, then the branch material is unlikely to be able to be separated and would also remain onsite. Due to legal limitations on KI, it is likely that B-Double truck configurations will not be a general option. The analysis indicated a mill door cost profile for the biomass delivered as feedstock (processed and received by the power-station): \$25.08 /t $_{\text{GREEN BASIS}}$ to \$55.43 /t $_{\text{GREEN BASIS}}$ for *P. radiata* and the eucalypt \$23.39 /t $_{\text{GREEN BASIS}}$ to \$51.78 /t $_{\text{GREEN BASIS}}$. Bailed cropping residues would cost at least be \$41.20 /t $_{\text{GREEN BASIS}}$ assuming nil return to the cropping farmer.

Figure 12: The end result of the full tree system applied to an *E. globulus* plantation and a windrow of (residues) biomass remaining at the roadside.

Figure 13: The residues remaining after a sawlog only harvest of a *P. radiata* plantation with the biomass spread across the site.

Technology attributes study

Summary

A range of technologies are available to convert biomass into energy, however given the isolation of KI, degree maturation and robustness was a critical determinate of a focus on combustion as an appropriate technology. Combustion technology includes fixed, travelling and fluidised bed grates on which the biomass is combusted with differences in capital cost and operating attributes which will require careful assessment in the final project design. The heat released on combustion converts water into steam in a boiler to drive turbines to create electricity. One variation is an Organic Rankine Cycle system where the boiler water is replaced by an organic liquid with enhanced operating attributes. Based on the analysis conducted capital costs ranged from \$4.6 to \$7.5 million / MWe_{NET} capacity, which would indicate a need for appropriate due diligence capital v operating costs, particularly with parasitic loads (internal power-station needs) reported as 12 to 21% of the gross generating capacity. Operating costs include biomass (modelled range 16,800 to 23,300 /MWe_{NET}/y) and water consumed by the boiler and in converting steam back to liquid in condensers (20.4 to 76.8 m^3/MWe_{NET}/day). A trade-off exists between the use of water cooled condensers (water and water pumping parasitic loads) and fan based systems, and in terms of KI, this is a mute point given the quality and quantity of water required for cooling towers: regardless, this issue will require careful attention in subsequent analysis. Potential atmospheric and particulate emissions will be driven by attenuation technology applied to the smoke stacks and the biomass combusted – reliance on plantation residues and sawmill processing residues is likely to be significantly less problematic compared to the introduction of municipal waste streams. Similarly, with plantation based biomass, there is unlikely to be ash disposal issues as the by-product may in fact be a resource.

Introduction

A range of technology options are available to be deployed in the biomass power-station project and the technology sub-project reviewed those available to provide recommendations of which options best has the best fit with the situation on KI. Indicative capital and operating costs were also produced from a number of technology options. It is also important that the power-station does not have a negative impact on the *clean and green* status of KI, hence technology specific analysis considered water management and potential airborne emissions. The information generated was applied in the financial model and the following provide a summary of the technology sub-project outputs.

Generation technology and combustion systems

Technology options

RuralAus is not linked to any specific technology or supplier of technology for electricity generation, hence the precursor study explored the most appropriate technology combinations match to KI and the results are presented in Table 1.

Comment *Of the technologies investigated, direct combustion in a boiler with a steam turbine generator appeared to be the most suitable for KI due to technology maturity and operation under an island conditions.*

Combustion and boiler systems

Within a boiler water is converted into steam to transfer biomass embodied energy via a steam turbine generator (STG), into electricity and Figure 14 presents a simplified schematic of a biomass combustion system and the various by-products (Figure 15 presents the existing sawmill boilers and kilns). There are three general types of boilers available:

- ***Fixed grate:*** Fuel is feed onto the boiler grate and burnt in a pile. Units are less capital intensive and simple to operate, but can be less efficient and ash removal is more difficult;
- ***Travelling grates:*** The grate is mobile introducing the fuel to the boiler and removing ash. They are more capital intensive and have superior efficiencies;
- ***Fluidised bed:*** Bubbling fluidised bed (BFB) and circulating fluidised beds (CFB) technologies have inert material through which air and fuel are injected and where combustion takes place. They are often more tolerant of different feed-stocks, can better accommodate incombustible materials and are generally more capital / operator skill level intensive.

Organic Rankine Cycle

The *Organic Rankine Cycle* (ORC) is an alternative system utilising a thermodynamic process similar to a conventional STG but using a different media to drive the turbine such as high molecular organic fluids e.g. Isopentane. The organic media is compressed and circulated in a closed loop by a pump, evaporated in a shell and tube heat exchanger by absorbing the thermal heat of the thermal oil primary circuit. The organic vapour expands in a specially designed turbine which drives the electrical generator and is condensed in another heat exchanger using a cooling media e.g. air or water. The condensate is then compressed again by the circulation pump, closing the thermodynamic cycle. Neither the thermal oil of the primary circuit, nor the cooling water, if used, is in direct contact with the organic media. ORC systems allow a much better utilization of the exhaust heat in biomass fired combustion systems.

Table 1 A summary of the assessment of the technology options under KI conditions.

	Combustion:	***Gasification:***	***Pyrolysis:***	***Modified combustion***	***Anaerobic digestion***
Air supply	Sufficient to allow complete combustion.	20 - 50% of the air needed for complete combustion.	0 - 20% of the air theoretically needed for complete combustion.	Direct combustion of the feedstock in a pressurised fluidised bed boiler.	Absence of oxygen to
Output	Energy is released as heat.	A low energy fuel gas is produced.	Pyrolysis oil (a liquid bio-fuel), gas, and char.	Pressurised flue gasses.	Methane and carbon dioxide.
Application	Heating applications, or for conversion into steam and/or electrical power.	Heating, steam or power generation.	Heating, steam or power generation. Not commonly employed in an electricity generation context.	Drive a turbine.	Methane used to drive reciprocating engines.
Technology sensitivity	Minimal: designed to a feedstock.	Heat required is provided by partial combustion of the biomass undergoing gasification.	Highly sensitive to process parameters, requires specialised and technical plant.		Woody feedstocks are either slow or impossible for the micro-organisms to break down.
Stage of commercial development	Completed.	To some extent proven and commercially available in the United States and Europe and have been used in wood-processing facilities in Australia.	Pre-commercial.	Pre-commercial.	Pre-commercial.
Suitability for KI	Technology available off-the-shelf from a range of manufacturers and agents.	This technology does not appear to have the level of maturity or vendor support to make it feasible for KI.	Not considered a suitable technology for KI.	This technology is relatively immature and therefore not suitable for KI.	Given the low moisture content of wood based feedstock (as compared to animal manures, effluent etc), combustion is more favourable.

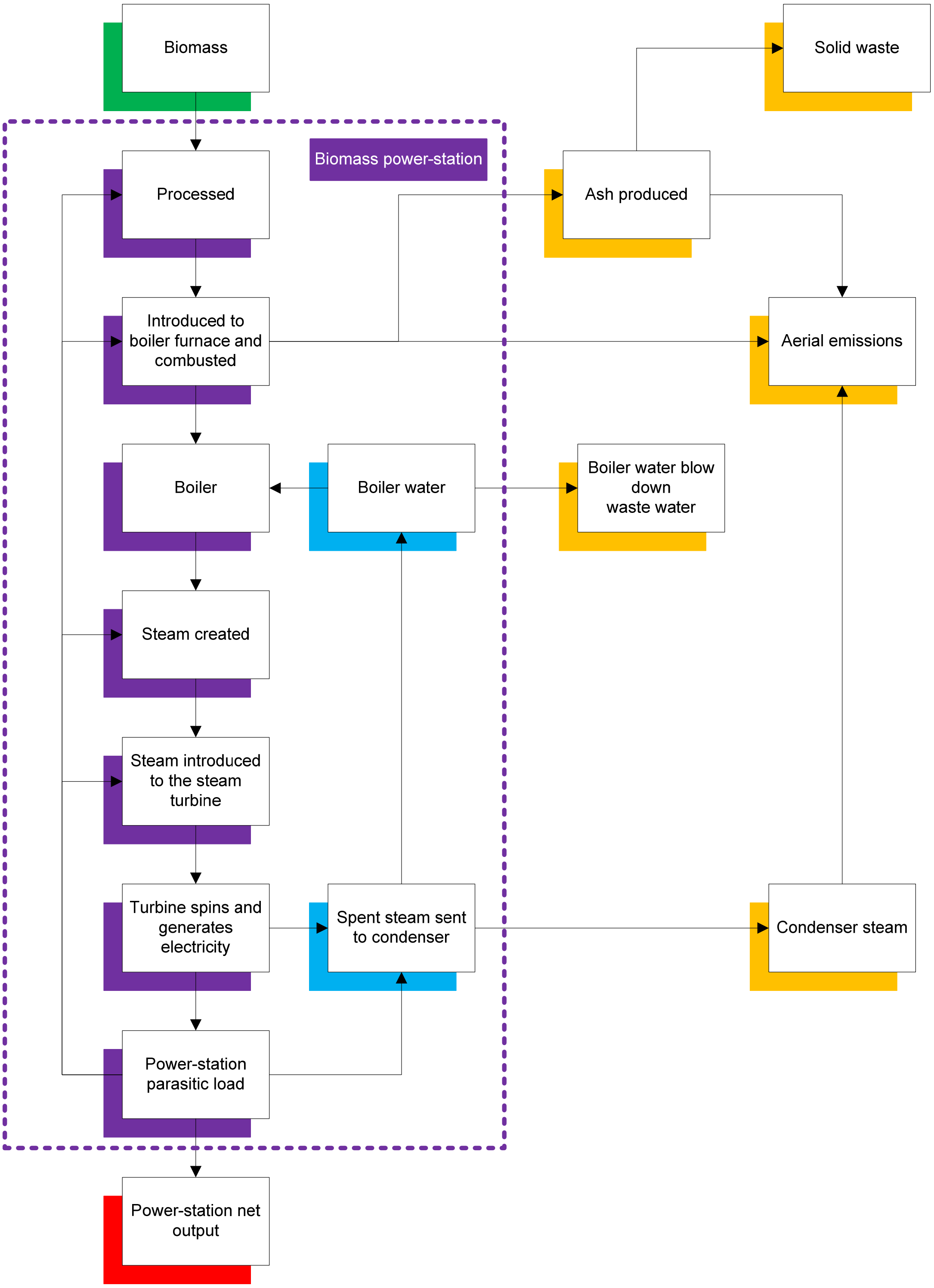

Figure 14 A high level systems diagram of a biomass power-station based on combustion technology.

Figure 15: The current sawmill residue management and boiler system providing heat to kiln dry green sawn timber prior to subsequent value adding.

Capital costs, availability and net output

Figure 16 presents a summary of a range of capital costs for a biomass power-station of differing outputs, indicating a high degree of variation that will require refinement by subsequent analysis. Ideally a power-station would operate for 24 hours per day every day of the year. However machinery requires maintenance and breakdowns occur, particularly with woody biomass provided in a variable state (e.g. moisture content, particle size, and density differences). A reasonable expectation is that the power-station would have between 90 and 95% availability. The level of availability will also be dependent on any contractual arrangements (e.g. the PPA) and demand curve requirements (see Figure 4). The analysis focussed on a target of up to 10 MWe_{GROSS} of generation capacity and consideration was taken of the internal needs of the proposed power-station (referred to as parasitic load). Figure 17 presents a summary of the scenarios investigated and indicates the difference between gross and net electricity outputs e.g. parasitic loads. In considering options, care is required to ensure whether a power-station out-put is quoted as MWe_{GROSS} (before parasitic loads) and MWe_{NET} after the electricity consumed onsite.

Resource consumption

Biomass demand

A range of biomass consumption rates (expressed as t $_{GREEN}$/MWe/y) resulted from the analysis: 16,800 to 23,300 /MWe_{NET}/y (14,600 to 18,500 /MWe_{GROSS}/y), which a significant variation (see Figure 18). It should be noted that the different studies took different views of the biomass attributes (MJ/kg and moisture content).

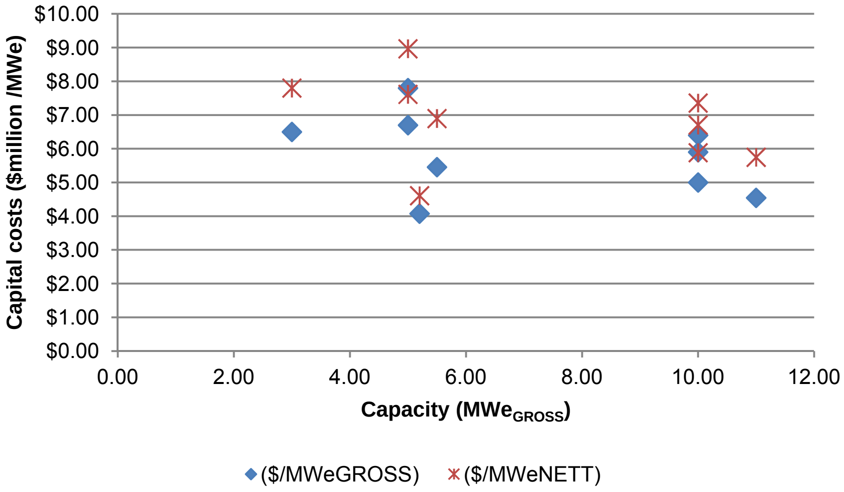

Figure 16: A summary of the technology scenarios tested: the capital cost for each option on a $/MWe basis segmented into gross and net of parasitic loads.

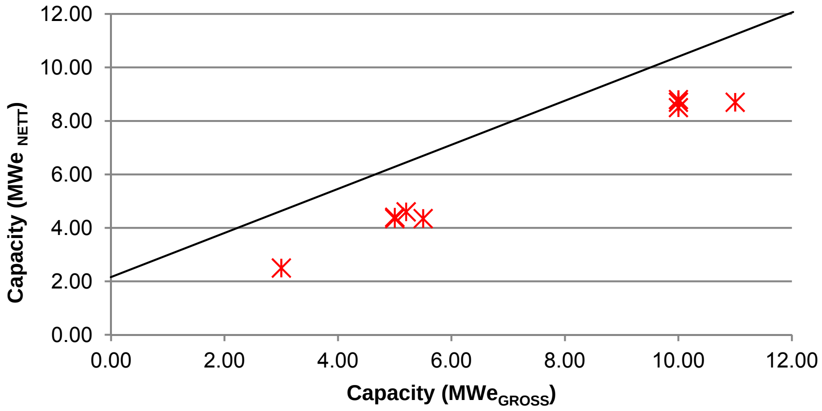

Figure 17: A summary of the technology scenarios tested: segmented into gross and net of parasitic loads.

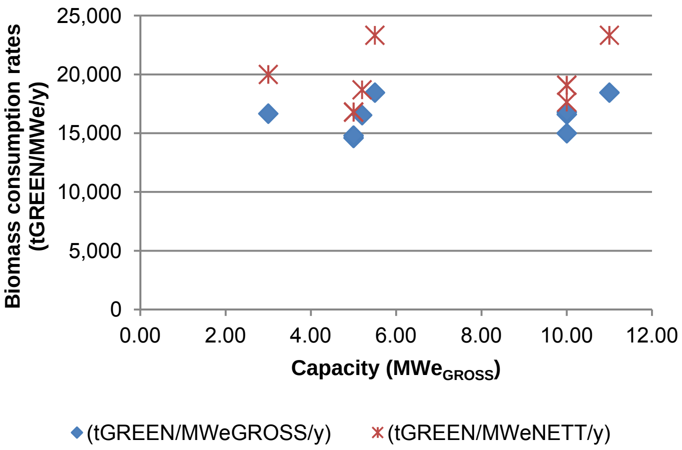

Figure 18: A summary of the technology scenarios tested: the biomass consumption rates for each option on a tonnes green per MWe basis segmented into gross and net of parasitic loads.

Water quality

Natural water contains impurities and Table 2 presents a summary of typical minimum water quality requirements that must be addressed to protect boiler components, depending on operating pressure and steam utilisation. The type of water treatment plant installed combined with water quality will determine the amount of boiler blow down[16] required to reduce dissolved solids to acceptable levels.

Table 2 A summary of the typical requirements for boiler feed water quality.

Parameter	Unit	Value
Operation pressure	(bar)	< 44
Water-chemical operation mode		salt-free
General requirements		Colourless, clear, free of non-dissolved particles
pH-value at 25 °C		> 9.2
Conductivity at 25 °C	(µS/cm)	< 0.2
Total alkaline earths (hardness)	(mmol/l) (°dH)	< 0.005 < 0.03
Oxygen (O_2)	(ppm)	< 0.02
Carbonic acid, bound (CO_2)	(ppm)	< 0.1
Iron (total Fe)	(ppm)	< 0.03
Copper (total Cu)	(ppm)	< 0.005
Oxidability (Mn VII – II)	(ppm)	< 0.75
Oils & fats	(ppm)	< 0.5
Silicic acid (SiO_2)	(ppm)	< 0.02

Water consumption and condenser technology

After steam is exhausted from the STG, it is directed to a condenser which converts it back to liquid form so that it may begin the cycle again. Water based condensers are normally preferred and the evaporative coolers associated with such condensers require large quantities of water. Water makeup varies and typical values range from less than 10% of steam production (well managed plants) to 30% (lesser plants or plants with high solids loading in the raw water): a 10 MWe plant would likely produce 85 t/h or steam, therefore the volume of water makeup ranges from 0.8 to 3.2 m^3/MWe/h (20.4 to 76.8 m^3/MWe/day). Air cooling condensers (ACC) can be used (a higher capital cost) with

---

[16] Water blow down is the removal of water with high levels of contaminates from the boiler and the water becomes a waste product.

higher parasitic loads, although there is a degree of disagreement on this issue given that the pumps required to move 32 m^3/h of water would also consume significant amounts of electricity.

Emissions, noise and waste products

The required level of emissions, noise and waste products will depend on the vendor's standard configurations and operations. Hence, the design criteria for pollution control equipment are directly related to the process characteristics, including emissions, gas volume and temperature, dust concentration and particle size, dew point, dust resistance and chemical composition of the gas, among other factors. Once these parameters are known, the design of equipment can move forward.

Comment *RuralAus will be required to comply with any air quality standards and apply for any required licensing and permits.*

Atmospheric and particulate emissions

A modern power plant is designed to limit atmospheric emission to very low levels and the products of combustion are principally CO_2 and water (see Figures 7&8). However, combustion can result in a certain amount of pollutants in the flue gas and the following should be considered:

- ***Atmospheric emissions:*** In general, the emissions from combustion technology will result in low NO_x and low SO_2 emissions and their presence or not is dependent on fuel quality and source. Remedial equipment may be required to reduce emissions to acceptable levels;
- ***Particulate emissions:*** Particulate emissions are controlled with combinations of technologies: a minimum solution would be a bank of cyclones, (multicyclones) which can remove particulates down to 1 micron size and economically 150/Nm^3 (parts per normal cubic meter of flue gas). For more stringent requirements either filter chambers or electrostatic precipitators are commonly specified to reduce fly ash and dust particles as small as 0.1 microns in the waste gas.

Ash

Ash is produced as a result of combustion and based on the feedstock assumed (Figure 19), it is expected to be a benign waste product that may be disposed of in normal landfill, distributed as a fertiliser or utilised as an ingredient in cement. If municipal waste is introduced, this may complicate ash management requirements.

Noise

The proposed power-station site is located with an existing sawmill facility and with vendor's standard noise attenuation provisions, the estimated breakout noise from the boiler house or the STG enclosure is estimated to be 80 dB at approximately 3 m from the respective buildings.

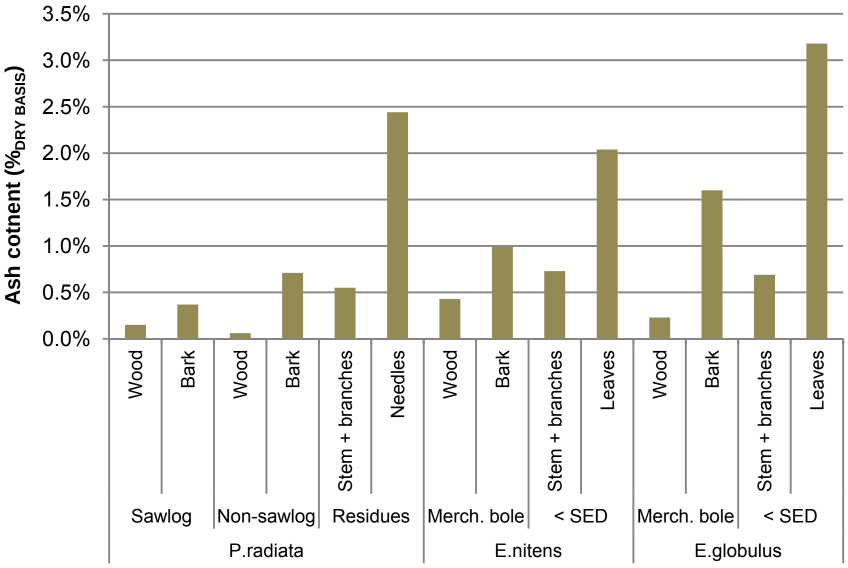

Figure 19: Variation in biomass component ash content as delivered to the laboratory.

Financial determination

Summary

A financial analysis was conducted combining the results of the various sub-project into a single financial model. The model was populated with additional information provided by the consulting group undertaking the financial analysis where there were gaps in the information. A base-case scenario was prepared indicating that the cost of generating the electricity was greater than the likely revenues at the current point in time. When an analysis was conducted of the project cashflows out over time and the internal rate of return (IRR) was estimated to be a nominal 2.68% (with assumed inflation of 2.75%) due to assumed real increase in revenues (black electricity) above the impact of inflation. Sensitivity analysis was conducted of expenses and revenues to determine the main drivers of IRR based on percentage change in the assumption and the outcome IRR. CAPEX and biomass costs were found to be the most significant expense drivers, where as black electricity price and change in black electricity price were the most significant drivers of IRR. This is a significant outcome given that the CAPEX excluded any connection to the grid and that the biomass excluded any stumpage to the growers. In order the refine the analysis, more detailed design and costings are required.

Introduction

Investment in a biomass based power-station requires a significant deployment of capital as determined by the *Technology sub-project*, however, the selling price of the resulting electricity is fixed by a combination of regulation (setting the retail tariff) and the market (the process of a residual price paid to the generator) as determined by the *Market access sub-project*. The *Biomass analysis sub-project* indicated a potential cost and price for biomass as feedstock, as well as the likely biomass feed-stocks on KI. When combined, the three sub-projects provided consistent conclusions that a maximum of 5 MWe $_{\text{GROSS}}$ could be supported as a first tranche of installed capacity:

- ***The market access sub-project:*** This study indicated that a maximum of 5 MWe$_{\text{GROSS}}$ could be supported as a first tranche of capacity based on load demand and total demand currently experienced on KI. With time and increase in demand stimulated by local economic growth (freed up due to reduced reliance on the submarine cable), an additional tranche of 5 MWe$_{\text{GROSS}}$ could be installed at some time in the future in response to demand;
- ***Biomass sub-project:*** The current biomass resource controlled by RuralAus is close to adequate to feed 5 MWe$_{\text{GROSS}}$ of capacity and subsequent tranches of capacity will require securing non-controlled biomass;
- ***Technology sub-project:*** It is possible to install up to 10 MWe$_{\text{GROSS}}$ in two tranches of 5 MWe$_{\text{GROSS}}$, and this was further explored by the *Financial analysis sub-project*.

The culmination of all other sub-projects is to complete a financial analysis and prepare a base-case scenario and outcome, and then to vary the key assumptions to test the impact on returns. This analysis and model framework was used to explore initial high level project viability and the capacity to pay for biomass.

Financial analysis

Analysis basis

Given a lack of specific details in terms of business models and capital sources (e.g. debt or equity) internal rate of return (IRR) for capital and operational expenses were combined with an assumed revenue stream from the sale of black electricity and RECs claimed. IRR is the interest rate at which the net cashflows discounted at that rate of interest equal zero, and is effectively the rate of return that would have resulted if the cash inflows had been deposited into a bank, accrued compounded interest and returned the deposited capital plus interest at the end of the investment period. The model output was a nominal IRR[17] and a cost and return profile for the generation and sale of 1 MWh of electricity was prepared.

Base case assumption and analysis

Table 3 presents a summary of the base case assumptions to developed biomass electricity generating capacity of 5.2 MWe_{GROSS} (4.6 MWe_{NET}). To achieve a smooth base-load, load-following diesel generators were assumed and assumptions were made of the percentage of electricity required and the associated cost. Some of the generation out-put is sold to the sawmill at a market rate and the balance is sold via the grid to a third party under an assumed PPA. Additional income is provided by sale of RECs and a minor income stream comes from carbon sequestration benefits associated with returning ash (which will contain some carbon) from the burners to the plantation. Figure 20 presents a summary of the analysis of the base case, indicating that the proposal is marginal under the current assumptions and unlikely to the financially attractive to an investor. The outcome of the base-case was an IRR of 2.68% on a nominal basis with an assumed rate of inflation of 2.75% (excluding the impact of a carbon price).

Sensitivity analysis

Figures 21 and 22 present the result of varying the assumptions indicated and recording the outcome IRR on a nominal basis. As indicated, in terms of cash outlays, CAPEX and biomass cost (excluding grower stumpage) are the main driver of returns, where as black electricity price and the change in black electricity price are the key drivers of returns. While change in plant run time was as sensitive, this assumption has limited capacity to increase, and hence is a significant issue, unless it falls.

---

[17] A nominal rate of return is the effective change in purchasing capacity plus the impact of inflation.

Table 3 A summary of the assumed base case parameters for financial analysis of a proposed biomass power-station scenario.

Unit	Technology			An ORC system with ACC
	Gross capacity		(MWe)	**5.20**
	Parasitic loads		(%MWe)	11.5%
	Net capacity		(MWe)	**4.60**
	Output	Black electricity	(MWh/y_{NET})	**36,600**
		Diesel electricity	(MWh/y_{NET})	**120**
		Total		36,720
			(MWh/MWe_{GROSS})	7,062
	Capital cost		($ millions)	**$21.20**
			($/$MWe_{GROSS}$)	$4.08
			($/$MWe_{NET}$)	$4.61
	Capital structure			Equity
Operating	Overall net efficiency			**20%**
	Assumed run time		(hr/y)	**8,000**
			(% y)	91%
	Feedstock		($ million/y)	$2.30
			(t_{GREEN}/y)	**86,000**
			($/$t_{GREEN}$)	$26.74
			($\%_{GREEN}$)	**55%**
			(MJ/kg)	**9.00**
			(t_{GREEN}/MWe_{GROSS}/y)	16,538
			(t_{GREEN}/MWe_{NET}/y)	18,696
	Opex and maint cost		($ million/y)	**$0.85**
			($/$MWe_{GROSS}$)	$0.16
			($/$MWe_{NET}$)	$0.18
			(% initial capital)	4.0%
	Diesel		($ /y)	$45,000
			($/L)	$1.32
			(L/y)	34,091
			(L/MWh)	284
Revenues	Electricity		($ million/y)	$2.40
			($/MWh)	$65.36
	RECs		($ million/y)	$1.40
			($/MWh)	$38.25
	Totals		($ million/y)	$3.80
			($/MWh)	$103.61
Financial treatments	Depreciation (capital)	Method		Straight-line
	Costs	Inflation	(%)	**2.75%**
		Real change	(%)	**0.00%**
		Total	(%)	2.75%
	Black electricity	Inflation	(%)	**2.75%**
		Real change	(%)	**2.25%**
		Total	(%)	5.00%
	RECs	Inflation	(%)	**2.75%**
		Real change	(%)	**0.00%**
		Total	(%)	2.75%

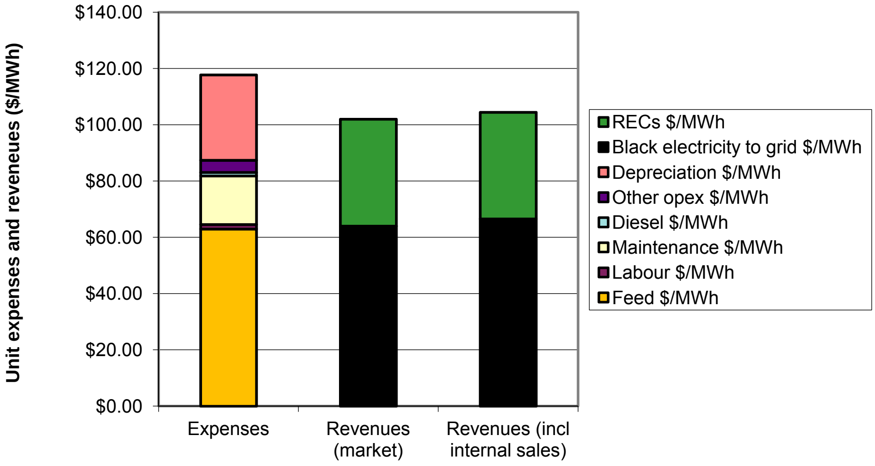

Figure 20: A summary of the cost of electricity generation and the potential revenue streams associated with the base-case scenario.

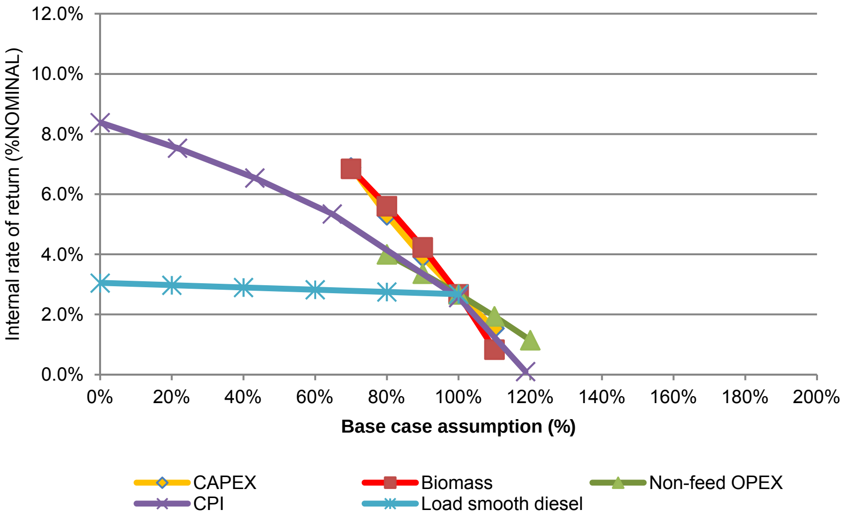

Figure 21: An outcome of the sensitivity analysis of the main expense assumptions assumed in the financial analysis.

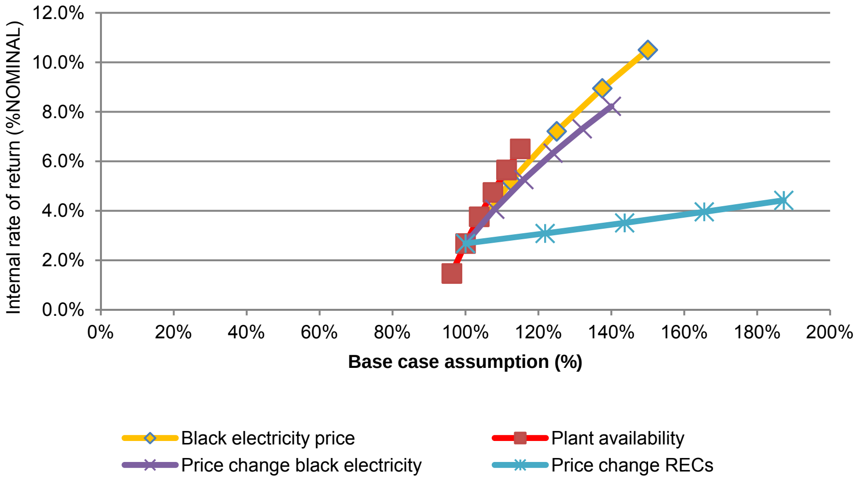

Figure 22: An outcome of the sensitivity analysis of the main revenue assumptions assumed in the financial analysis.

Comment *It would appear that addressing CAPEX is the most likely avenue to address the financial viability of the proposed biomass power-station project, and this could be via a level of external party support to the project.*

Proposed further analysis

The following analysis and additional works are required to be undertaken in support of the project (as a starting point for the subsequent stages of the project):

- ***Capital costs:*** Improve the capital cost estimate;
- ***Sawmill demand:*** Assess the nature of the demand for electricity from the sawmill, and then assess the benefits of selling it electricity;
- ***Grid connection:*** Determine what upgrading is required to supply the grid with the exported electricity, and who will pay for it;
- ***Condenser:*** Determine whether an air-cooled condenser (rather than water-cooled) is the best way to proceed;
- ***Government grants:*** Determine the size of any government grant that could be factored in and whether grants would be directed to both the power-station project and any necessary network upgrades;
- ***Biomass resources:*** A detailed inventory and yield modelling is required of the biomass resource on KI;
- ***Green benefits:***
  - Assess the future variability of electricity and REC prices and their effect on project returns;
  - Confirm eligibility of fuel for generation of RECs with Office of Renewable Energy Regulator (ORER).
- ***Carbon tax:*** Assess the impact of a carbon price / tax on the project;
- ***Revenues:*** The following must be considered:
  - Explore additional potential revenue streams that may be available to the project;
  - Explore and commence negotiation of PPAs for the electricity produced;
- ***Operating costs:*** Confirm
  - Attendance requirements for an thermal oil / ORC system of this size.
  - Likely maintenance costs
- ***Financial viability:*** Reassess the financial viability of the project when assumed inputs are more tightly known.

Acknowledgements

The RuralAus project team would wish to acknowledge the support of the following people:

- Annie Ngo: Principal Adviser, Renewable Energy Sustainability & Climate Change Division Department of the Premier and Cabinet;
- Col Stuckley: Director, Enecon Pty Ltd;
- Daniel Rowley: General Manager - Asset Services, KI Council;
- David Viola: Industry Development Manager (CleanTech Sectors), Dept of Trade & Economic Development;
- Michael J Davidson: Managing Director, Wessex Consult Pty Ltd;
- Nicholas Jacobson: Senior Engineer Renewable Energy, RenewablesSA;
- Terry Lee: Director Strategy and Major Projects, Regional Development Australia Adelaide Hills, Fleurieu and KI;
- Jayne Bates: Mayor, Kangaroo Island Council and staff.

Appendix A Sub-project authors

The following service providers completed the four sub-projects and their assistance is very much acknowledged:

- ***Market access sub-project:*** Wessex Consult and Solstice Development Services Pty Ltd;
- ***Biomass sub-project:*** Sylva Systems Pty Ltd;
- ***Technology sub-project:*** Commercial in confidence;
- ***Financial analysis:*** ENECON Pty Ltd.