CONCEPTUAL DESIGN OF ACACIA NILOTICA PROJECT

D. Cork [1*] and P. Laska [2]

[1] Corky's Sustainable Energy, Newcastle NSW, Australia
[2] Pioneer Corporation, Brisbane Qld, Australia
** Corresponding author. Tel: +61 2 608847, E-mail: david.cork@thecorkysgroup.com.au*

ABSTRACT. Pioneer Corporation, with help from Corky's Sustainable Energy, have been searching for the best land management practices for sustainable biomass production. The biomass feedstock will initially be prickly acacia a (Declared Weed of National Significance) and hence the project is known as the Acacia Nilotica project. The example project is integrated with respect to farm management, tree planting, nutrient recycling, harvesting, timber and pellet production, pellet and chip torrefaction, and power generation. This dry land weed has a very high density, durable wood with an impressively high energy yield. As a dry land species the biomass load (tonnes per hectare) is low. The Acacia Nilotica project is saleable by having many repeatable centres of operation, without the usual problem of large scale biomass, that is, without long trucking distances. This paper will discuss some of the reasons why biomass projects fail and how, with good land management and win-win relationships, this project is financially attractive in addition to demonstrating its environmental credentials.

Keywords: *forestry, poly product, node, bio-char; pyrolysis; gasification; embedded power*

Introduction

Prickly acacia is 'Declared Weed of National Significance'[1]. It is also a resource of national significance which can stimulate major regional development in northern Queensland. Importantly, this project is good for the farmers, regional towns, and the local and international environment.

In 1926 it was recommended by the Department of Agriculture & Stock as a suitable shade for sheep in western Qld and was extensively planted around homesteads, bore drain & dams. [1] Seeds were often carried around in saddle bags and distributed from horseback. This recommendation to plant prickly acacia occurred not only for the shade but because prickly acacia is deep rooted, and withstands dry periods providing fodder for both cattle and sheep. The seed pods are rich protein and thus seed can be spread in cattle manure.

Predominately the worst infestation is in valuable grazing land around the Mitchell Grass Downs with smaller infestations in the NT & WA. Potentially it is one of the most serious weeds in Australia, rapidly establishing impenetrable thickets on low stocking rate pastoral land, and creates problems such as erosion and in harbouring feral animals[1]. The worst prickly acacia infestations are shown in Figure 1 and are north-west of Julia Creek, around Richmond, west of Hughenden, north of Winton, north of Muttaburra and north of Barcaldine.

The exact area covered by the infestations is not known but Carter et al. [2] indicate that in nine shires surveyed, 6.65 M ha or 28% of the grazing area, was infested. This figure has been quoted in many subsequent publications but is sourced from 1991 data. The Department of Lands Protection Qld. estimated the mass of the resource, as 92M tonnes in 1996. Modelling the infestation growth rate at 6% increase per year, assuming little growth during the 9 year drought in the 1990's matches the quoted land area biomass resource. Therefore, the current estimated volume now is likely to exceed 120M tonne of available biomass.

Working With Framers and Security of Supply

Pioneer Corporation, understanding the farmer's need for shade and fodder foliage, will start the process by planting suitable replacement trees. This is perhaps a surprising starting point when the starting amount of biomass is so large. Nevertheless, through an extensive consultation process it has been found necessary.

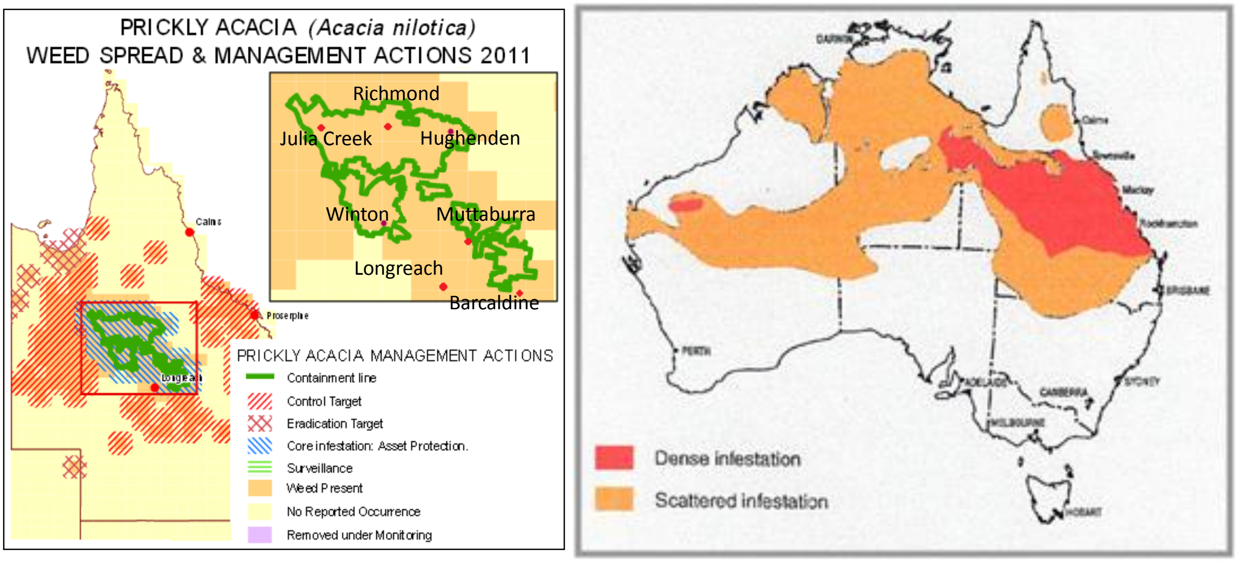

Fig.1. Current Prickly Acacia location and Predicted infestation by 2020 (assuming no extra control).

Many graziers perceive that “trees have something to do with how much rain falls. Their observations show that in areas where there is forest, there is rain - not heavy but constant, light rain that keeps the soil wet and productive. Where the rain comes in heavy torrents and there's nothing for weeks, there's lack of forest in the area. So they understand the importance of leaving some forest on their property and use the remaining land for crops. This way they get so many benefits - there's more water in the soil and the soil is fertile.” (http://forum.sustainabletasmania.com/Thread-Forests-attract-rain (posted 2010)

“The underlying mechanism emphasizes the role of evaporation and condensation in generating atmospheric pressure differences, and accounts for several phenomena neglected by existing models. It suggests that even localized forest loss can sometimes flip a wet continent to arid conditions.” [3]

Farmers want shade in their paddocks and in particular around watering points. They wish to keep their top soil. They want the thorny thickets to be removed so that there is more land area for growing grass and improved livestock access to the watering points. Many graziers are nervous about over clearing and are seeking a balance; a balance where the future farm income can be generated by diversity of sources. (eg from sawn logs and CO_2 credits in addition to grazing). This extra cash flow will be unaffected by short term fluctuations in both weather and the meat or wool markets.

Pioneer will build processing plants in the heart of the forest, increasing bio-diversity and supporting farmers with their aims. In simple terms, there is a three tree plan. There will be a replacement tree or environmental tree. This tree will be a suitable [4] Australian native. Trees two and three will be planted with the intent to grow and harvest for a sustainable timber industry. Trees two and three will be multipurpose trees providing cabinet, construction, timbers and fuel wood. They will be a mixture of natives and exotic trees. Selective harvesting will result in between 20 to 25% retention of trees in the landscape. There is already risk to farmers from general climate change. Whilst not everyone agrees that trees attract rain, the precautionary principle applies and tree planting allows progress without increasing the risks to farmers about micro climate change on top of the broader climate change issues.

Security of biomass supply is achieved by way of Government approval / Permit to harvest along with a legal binding agreement with landholders. Importantly, grazers still have what they need without the invasive thickets. The regional communities will be revitalised by investment and new industries and jobs. The wood recovered from harvesting the prickly acacia will be turned into timber, power and fertiliser.

Due to the relatively light biomass load per hectare it is proposed to have many centres or nodes of operations, with each node being based around a prickly acacia outbreak, a regional town and a mini power station / torrefaction / fertiliser plant to process the woody by-product of farm reclamation.

This poly-product concept is shown in Figure 2 with potential products shown. The aim is to use the waste from one process as the feed stock of another value adding process in a similar way to an integrated steelworks consuming its own waste. Whilst these are rural, agricultural processes the proposed approach of integrated processes is directly from heavy engineering and allows significant economy of scale without the need to harvest many more trees. Even though prickly acacia is a declared weed it will be managed as a resource with appropriate consideration to the value it currently holds for graziers as a shade and fodder tree.

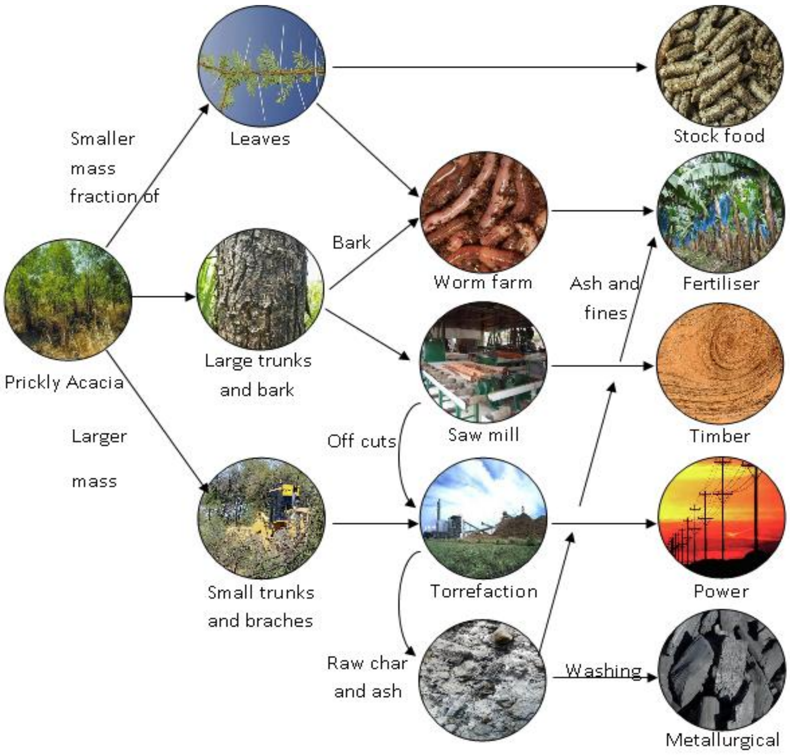

Fig.2. Potential Agricultural Poly Products Centre

Poly Products Node and Embedded Power Stations

At each wood processing node there will ultimately be; tree nursery, saw mill, worm farm, pellet plant, torrefying plant and waste heat power station. Six regional nodes are immediately obvious.

The mass yield of the various products will vary by node and will be subject to future feasibility studies. An indicative mass balance based on the dissection and weighting of 20 trees from two locations near Julia Creek in 2008 is shown in Figure 3. Whilst none of the trunk sections measured were large, the yield of sawn logs was 20% leading to a predicted yield of dressed timber being 15%. In the interests of conservatism, and cognisant of the small sample size, the average yield of dressed timber has been assumed to be just 10%. That is, it is assumed that of the 120 million tonne of prickly acacia biomass there is 12 million tonne of dressed timber or 9.6 million cubic metres of saleable timber even though the preliminary data suggests a greater volume. The mass balance has been extrapolated to potential future markets. The partition of the medium value small trunks and branches into raw pellets and torrefied wood is somewhat arbitrary at this stage and would be subject to future market forces.

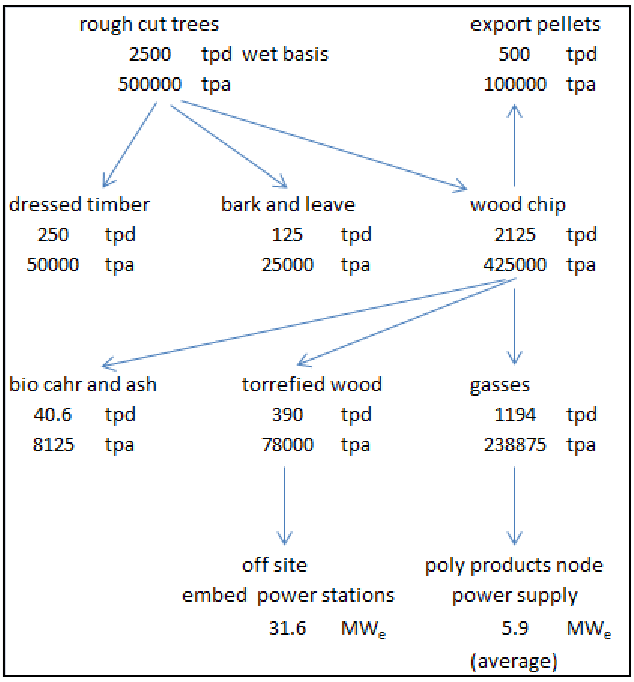

Fig.2. Arbitrary but indicative distribution of products from a single poly products node (200 working days per year)

These market forces are now in play. Demand for wood pellets already outstrips the supply of sawmill residues. Global pellet production increased on average 24% pa between 2000 and 2010 [5]. This projects ambition of 600,000 tpa of pellets by 2020 represents 2.0% [6] of the low demand forecast and 1.5% of his high demand forecast. This would indicate low impact of pellet price.

Large scale power utilities operators are looking for medium/long term supply agreements with well defined volumes and prices [7]. Outside the nodes, typical at remote high energy demand locations, there will be embedded power stations.

At each node a gasifier is used to generate process heat, bio char and a heat transfer gas which is very low in oxygen and rich in hydrogen. This heat transfer gas is used to torrefy the balance of the wood chip not used for pellets. Torrefying the wood removes the most of the oxygen from the wood and some of the hydrogen in the form of either CO_2, CO or H_2O. The energy density of the wood can double in the process. As the torrefied wood is now more energy dense than a good quality coal it is feasible to transport it to client embedded power stations a few hundred to a thousand kilometres away from the poly-products node. These embedded power stations are typically off grid attached to the power user.

The pellets will be supplied to the export market and are expected to have the gross as received basis properties shown in Table 1.

Table 1 Pellet Properties (gar basis)

Specific energy	16.2 to 16.9 MJ/kg
Ash	1.2 to 1.5 %
Moisture	12 to 15%
Sulfur	< 0.04%

The emphasis of supplying torrefied chips to off grid customer's results from the low price offered by power distribution companies and the perceived lack of interest in distributed power generation within Australia. By supplying off grid customers Pioneer is competing against expensive diesel generation rather than competing against cheaper black coal generation.

The off gases from the gasifier and torrifiers are used to generate heat and then electricity to supply the power needs of the poly-products node. The balances of products shown in Figure 5 imply that the waste heat power station at the node principally supplies the node's industries and there is little spare capacity for export power.

Torrefaction of biomass makes a product that is; more energy dense (hence cheaper to transport), more brittle (easier to process in hammer mill), less reactive, more chemical stable and less hydroscopic. Each customer will have their own preference. The low yield, highly torrefied product shown in Figure 2 is arbitrary as it is possible that a less torrefied product is also acceptable.

The bio-char and worm farm digested bark is used in the Biological Farming System. The moisture, CO_2 rich off gas can be used in green houses if desired to aid vegetable production. Excess fertiliser will be sold.

The intent is not to build all nodes simultaneously but rather to build node 2 capacity after optimising and refining operation and maintenance at node 1 as shown in Figure 3. Node 2 products will be committed in forward contracts based on the specification of products delivered from node 1. This concept is called "learn by doing". Whilst all the biomass processes discussed in this paper are establish in northern Europe based on pine or straw, Pioneer are cognisant of Prickly acacia being harder, more energy dense and having higher resin and wax content than the European feed stock. By necessity a small research and development program will be required to optimise unit operations.

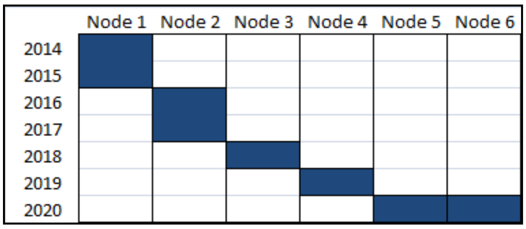

Fig.3. Node Capacity Construction Program

Poly Products Node and Embedded Power Stations

Perhaps the biggest differences between traditional biomass projects and the Acacia Nilotica project are approach, scale and feedstock energy density. These differences are shown in Table 3. The Acacia Nilotica project can be massive but will still feel local to those on the ground.

At one level one could say that the internal rate of return of the project would be improved for investors if there was no tree replanting. However, why would farmers yield their shade and fodder trees for no return? By seeking a win:win relationship between stakeholders security of supply has been achieved and true economies of scale are feasible. The project's internal rate of return may be more modest than some venture capitalist may require but the risks of the project are significantly reduced by development of symbiotic relationships between the regional towns, landholders, customers and investors.

After achieving security of supply the vast nature of the project can be appreciated. It took a little over 100 years to grow a 120 million tonne resource. Harvesting at a rate of 10 million tonne per year is unlikely to stop infestation growth in a good growth year and may only just contain the problem in a poor growth year. This project will not eliminate the non-native weed Prickly Acacia. However, by selectively harvesting Prickly Acacia and back planting competing trees the landscape will be transformed into a more productive one.

Prickly Acacia represents a massive deposit of stored solar energy that can be sustainably harvested indefinitely. The cost of developing unique processing equipment may be prohibitive at the 100,000 tonne a year harvest rate, but is not prohibitive to the Acacia Nilotica project scale. Development cost and the required research are not barriers at this scale. In fact this project will spawn technologies and concept that will have application outside of central Qld. For example the concept is equally applicability to other dry land wood invasive native species in NSW, NT, WA etc. The torrefies and power stations could be adapted to use lower grade biomass like city council green waste.

Scale does have its own traps. There could be the temptation to build a big centralised power station. For example a 20 MWe power station could reasonably be expected to cost in the order of $70 Million whilst a 40 MWe power station on the same feed stock may only cost $112M. The bigger power station has a lower capital cost per MWe of installed capacity but it must draw on a much bigger supply area resulting in higher transport costs.

Table 2 Project Differences

Criteria	Typical biomass projects	Acacia Nilotica project
Benefit	Benefit of project concentrated to a few	Distributed benefit The biomass owners are equal stakeholders with project developers and investors
Security of supply	Low security of high volume or only high security of low volume	High security of high volume
Economy of scale	Suffer from poor economy of scale or Large scale but suffering large distance trucking costs	Economy of scale achieved through multiple nodes rather than bigger plant
Power generation	Main product or seasonal by-product	Secondary product without seasonality Main products are high energy density torrefied wood pellets by volume and dressed timber by value
Power customers	Sell to grid	Internal consumption and embedded power users
Seasonality	variable	stable
Energy density	8 to 12 MJ/kh wet basis	Wood 15 to 19 MJ/kh wet basis Torrefied 32 to 36 MJ/kg wb
Value add	Mono product plant	Poly-products plant Ability to move feedstock between used to optimise economics

Biomass in general is a low energy density material. Prickly acacia does not have a high biomass load on the ground compared to the wetter coastal forests, although prickly acacia does have a very high energy density on a gross as received basis compared to other biomasses. Moving biomass long distances can result net reduction in profitability. An alternative to a big centralised plant is many smaller, distributed plants. The cost per MWe of installed capacity may go up but the operating cost falls and there is increased probability of waste heat and nutrient recycling. The node concept allows transport distance to be no greater than 40 km and also give each town new industries.

Too many biomass project developers have optimised their unit operations around capital cost without consideration of optimising the entire value chain. Biomass can learn from those that franchise their ideas. They do the hard work once to develop a marketable product and then reproduce that product many times. The Acacia Nilotica project seeks to reproduce the developed processes to the many other available nodes (regional towns).

The lack of interest by power distribution companies in distributed power has hurt the growth of solar, wind and biomass energy. This project aims to bypass low wholesale power prices and sell bio-energy directly to those off grid. To make transport viable the wood is torrefied to increase its energy density, thus halving transport costs.

Harvesting at a rate of 16 square kilometres per year, per node would sustainably consume approximately about 3.0 Mtpa of prickly acacia biomass. It would take approximately 19.6 years to harvest within 40 km from a single node before one would need to revisit the same paddock. In that time a new plantings will have grown. The new crop will have less prickly acacia but be supplemented by the planted trees.

The combined gross power generation within the nodes would approach 35MWe. There would be enough torrefied wood, 470 ktpa, to generate a further 190 MWe (η=20%) to 280 MWe (η=30%) depending of the power conversion efficiency. In addition there would be exported 9.9 TJ of energy per year in the form of pellets. If there was demand for more pellets then the resource is capable of further intensification. There is also the possibility of building extra processing nodes between those already proposed.

These new emerging markets have led to the world's first biomass exchange launched in at Rotterdam at the end of 2011. The new exchange will allow market participants to trade standard contracts in a transparent environment. Certification for sustainability is mandatory for traded lots. [7].

The certification will require the biomass to be harvested sustainably, not destroying native habitat, not reduce biodiversity, is not competing with food production and have correct carbon accounting. The reason this certification is needed is that many other proposed projects have not met these criteria in the past.

Significantly, and unlike many other biomass projects, this project does not rely on green credits of any kind. In an unstable green credit market the project must be underwritten by proven commodity prices and must assume that the credits will remain low in value. Nevertheless the criteria for Certification of sustainability can be, and will be, sought.

Carbon Credits

This section on carbon credits contains many assumptions that will need to be amended after measured tree growth. Nevertheless, it is easy to see the magnitude of potential CO_2 capture and abatement which is summarise in Table 3.

The typical Prickly Acacia above ground mass was 0.75 tonne based on the field tests in 2008. A harvesting rate of 3 million tonne per year implies harvesting 4 million Prickly acacia trees and planting a further 12 million trees per year.

The assumptions are:

- A tree uses about 1.6 tonne of CO_2 to make each tonne of dry wood. This number is based on the chemistry of cellulose.
- The carbon content of the bio-char and ash is 60%
- The growth of new trees above harvest rate is 1.5 million tonne per year or 1.0 million tonne of dry wood
- The torrefied wood offset diesel power
- The torrefied wood power conversion efficiency is 30%
- The CO_2 equ emission from diesel power is 0.5 t CO_2 equ per MWe.h

Table 3 Potential Sources of CO_2 reduction

	ktpa (db)	kt pa reduction CO_2 equ
wood	300	480
char	48.75	
carbon in char	29.25	107.25
forestry	1000000	1600
	MW_e	Kt pa reduction CO_2 equ
power	284	1137.5
net benefit		3324.75

Conclusions

Sustainability concerns of the farmers must be well addressed before there can be any change. Both the timber and large scale power utilities operators are looking for medium to long term supply agreements with well defined volumes and prices. Only by thinking big can the economies of scale be grasped and long term supply can be contemplated. Only by acting locally do the individual land holders allow access to their farms.

Solid biomass trade has grown exponentially over the last decade. Significant further increases will be required to meet short term (2020) renewable energy targets in e.g. the EU, Japan China or Korea, but also long term (2030/2050) global climate targets.

The concepts of processing nodes and poly products centres achieve the objectives of reducing transport distance and cost, creating local jobs, stimulating regional investment, encouraging nutrient and waste heat recycling and improved economy of scale. Nodes and poly products centres improve delivery reliability and allow for tailoring of individual nodes to supply a particular customer’s needs.

The implemented conceptual design will capture and abate between 3 to 4 Million tonne of CO_2. At $6 per tonne this could account for at least a further $18M pa in project income.

Whilst further feasibility and optimisation studies are anticipated it is already known that:

1. The resource is large enough to support the development described
2. Wood and pellet prices are high enough to support the project as described
3. There is good will from the farmers and local towns to support the project as described
4. The market for the project's products is growing
5. This project avoids the mistake of other biomass projects in having
    a. Surety of biomass supply
    b. Economy of scale
    c. Local support based on long and extensive consultation
    d. Increased biodiversity
    e. Not clearing virgin native forests
    f. Diversity of products and locations
    g. No completion with food crops
    h. Improved farm productivity
    i. Further product development possible
    j. Further scale up possible
    k. A need to act quickly
    l. Not relying on green credits

There is a flow on effect from this project form the first nodes to later nodes, from Queensland to the invasive native species of other dry land farming areas of NSW, NT WA and SA, and ultimately to our cities. This is a "learning by doing" project so that 2nd & 3rd generation plants may be viable for greater feedstock and product diversity. There has already been 8 years of development. There is an expectation of exports exceeding $100M per year after node 1 construction. Ultimately uptake of similar technology in every Local Government Area across Australia (utilising all manner of biomass feedstock) is possible after demonstration as well as the potential for technology export.

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