ENERGY TREE CROPS

Renewable energy from biomass could be the commercial driver to large scale adoption of woody crops and to structural improvement to dryland agricultural systems in Australia.

FUTURE FARM INDUSTRIES CRC

Energy Tree Crops

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Cover: An energy tree crop comprising mallees planted in belts alongside a cereal crop.

Photos: FFI CRC.

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Energy Tree Crops

Energy tree crops, strategically integrated into dryland agricultural systems in narrow belts, and harvested every 3 to 8 years, have the potential to:

- Produce feedstocks for renewable base-load electricity and biofuels while reducing greenhouse gas emissions;
- Diversify farm incomes and regional economies by complementing rather than displacing existing agricultural industries and food production;
- Avoid trade-offs with water use in high-rainfall and irrigation areas;
- Provide salinity and biodiversity benefits; and
- Provide local base-load electricity generation in peripheral areas of the grid thereby reducing transmission losses.

Global estimates of future bioenergy use by the International Energy Agency indicate that by 2050 bioenergy could provide 25 to 33 per cent of total global energy requirements[1]. Biomass already provides 23% of primary energy and over 75% of thermal energy needs in Finland, and 32% of Sweden's final energy use. According to preliminary Swedish Energy Agency statistics presented by the Swedish Bioenergy Association, bioenergy passed oil as the biggest energy source in Sweden in 2009 in final energy use[2].

There are compelling economic, social and environmental reasons why Australia can also be prominent in developing bioenergy industries. Energy tree cropping can be designed and laid out in such a way that it cohesively integrates with agricultural enterprises on wheatbelt farms without compromising food and fibre production or security of water supply.

Mallee eucalypts are an ideal woody crop for biomass production in the extensive Australian cropping and grazing regions. After being harvested they regenerate readily by re-shooting (coppicing) from their rootstocks. Through repeated harvesting, mallee biomass can be a relatively secure long-term source of renewable energy.

Economic studies conducted by the Future Farm Industries Cooperative Research Centre (FFI CRC) demonstrate that energy tree crops have the potential to match financial returns from existing agricultural enterprises[3]. By growing mallees in skilfully designed layouts on less than ten percent of the property, enough cash flow is generated from the sale of biomass to cover establishment costs within the first cycle of 5 years. This financial payback is achieved with minimal trade-off in cereal crop production and water use. If there was a price on carbon, the relative competitiveness of energy tree crops would be improved, but even without a carbon market such plantings are potentially viable.

Other studies have shown that mallee bioenergy is cost competitive with other forms of renewable energy and that biomass electricity can be a strategically important base-load power complement to the currently more popular wind and solar energy sources. FFI CRC modelling of potential regional bio-electricity generation in WA and co-firing with coal in regional power stations in NSW and Victoria, estimates that the scale of mallee bioenergy could be 163,200 ha of belt plantings providing 2.6 million tonnes of biomass per year and offsetting the equivalent of 1.35 million tonnes of greenhouse gases (CO_2-e) per annum by displacing the use of coal. The cumulative greenhouse gas abatement potential of this enterprise is around 12 million tonnes over a 13 year period.

Under this coppice agroforestry system model, carbon dioxide (CO_2) from the atmosphere is recycled through the trees and the solar energy used to repeatedly grow the crop is made available by burning the biomass. Instead of having to off-set fossil CO_2 emitted elsewhere, users of energy tree crops will displace fossil fuels. By perpetually producing carbon-neutral energy, energy tree cropping will achieve more, in terms of limiting fossil carbon emissions, than carbon sequestration forests over the long term and so-called 'first generation' biofuels based on food crops. In the wheat-sheep regions, farmers, food production and agriculture are not displaced by energy tree cropping. The rural economy will be diversified rather than diminished.

Woody crops are best integrated into existing farm businesses, with about 10 percent of the land growing woody crops and 90 percent producing conventional crops and pastures. The deep-rooted tree belts do not compete fully with the annual crops, because the trees also exploit moisture and nutrients that have escaped below the root-zone of the shallow rooted annual crops. Well-planned tree belts also provide additional benefits such as wildlife habitat, shelter, salinity mitigation and erosion control.

Several belts of mallee energy tree crop on a cereal farm in regional Western Australia

The diversification of agriculture with woody crops will make both rural economies and environments more adaptable and resilient. The commercial activities of growing, harvesting, transporting and processing of biomass will require new regional industries, adding to the strength of rural communities. Energy tree crops have the potential to make a significant contribution to improving the agricultural environment, to renewable energy and to the mitigation of greenhouse gas emissions in Australia.

This paper presents the case for energy tree cropping, backed by regional scenario modelling and farm-level economic analysis that will guide development of tree planting, biomass production and bioenergy in the extensive cropping and grazing regions of Australia.

Energy Tree Crops allow more profitable farming, supply energy and reduce greenhouse gases

The overall potential benefit of developing large scale tree planting and woody crop industries remains attractive despite the Australian Government's deferral or replacement of the Carbon Pollution Reduction Scheme. There are several motivations to proceed with such developments:

- Climate change remains an issue of national and international concern.
- Australia has adopted a mandatory renewable energy target for electricity generation - 20 percent by 2020.
- Renewable energy technologies are rapidly developing and will become more attractive economically as well as improving national energy security.
- Biomass for bioenergy is a major renewable energy option. It is the only renewable source that can replace fossil fuels in all energy markets (heat, electricity and fuels for transport).
- Biomass for bioenergy at sufficient scale effectively offers renewable baseload power generation.
- Second-generation woody cellulosic biofuels are substantially more efficient in energy and greenhouse gas reduction terms than first-generation biofuels based on starch, sugar and plant-oils;
- In Australia, the production of biomass using various forms of woody crops can be commercially viable.
- Energy tree crops will be mainly native species, especially mallee eucalypts, and these could provide important biodiversity benefits, including habitat, avoiding the weed risk associated with exotic species and provide protection for areas of remnant native vegetation.
- Volunteer carbon sequestration by tree planting is a complementary measure being undertaken by many large companies.

Woody crops deployed in carefully designed layouts can contribute to more sustainable and profitable agriculture. Mallee eucalypts are an obvious selection for development as woody crops, but many other native species are potentially available to diversify the range of woody crops for the extensive rainfed cropping and grazing areas. Focusing on the 450mm to 600mm rainfall zone growing grains and producing livestock from grazing systems across southern Australia avoids the trade-off with water yields that could potentially occur with large-scale plantations in high-rainfall and irrigation districts.

We call this energy tree cropping.

Farming trees as energy crops - good for farmers, good for regions, good for the environment

Energy tree cropping produces a renewable biomass fuel by harvesting trees as a crop. The crop extracts CO_2 from the atmosphere and through the process of photosynthesis uses solar energy to store carbon in biomass. Using biomass as a fuel converts it to usable energy and returns the CO_2 to the atmosphere. Bioenergy from tree crops can therefore replace fossil fuels and avoid the release of fossil carbon into the atmosphere.

Good for farmers and the environment

Woody crops have many features that will make them a good biomass production option in dryland cropping and grazing regions of Australia. Native tree species are robust and well suited to Australian soils and climate. They can tolerate droughts and take advantage of irregular rainfall events. They coppice readily and trees live for several decades which reduces their planting and maintenance costs. When planted in a belt and alley system they can complement the existing farming systems as well as diversify farm income with products ranging from biomass to oil derived from their leaves.

In some farming systems woody crops have potential to manage water and nutrient balances. They are excellent as shelter belts for sheep off shears or during lambing. They offer aesthetics and environmental benefits, including food and shelter for fauna. Energy tree crops are also a positive factor in the carbon balance of the farm as they sequester carbon in their roots.

The two row belt configuration is recommended in order to achieve acceptable growth rates in the long term. Widely spaced tree belts (between 70 and 80 metres apart, 1,000 trees per belt kilometre) maximise tree production per paddock hectare, while allowing crops and pastures to grow in the alleys. Careful integration of the two forms of land use will increase the total productivity of the paddock mainly due to better use of water and nutrients via the deep tree root systems.

Energy tree crops are a diversification opportunity for rural landholders. By trading in feedstocks for bioenergy, farmers can take advantage of any increase in the value of renewable energy over the long term. Tree cropping also entails a level of risk, but farmers will have the flexibility to move in and out of energy tree cropping as they choose, subject to biomass supply contracts. Farmers are accustomed to making these business decisions.

Good for regions

Trees as biomass crops have large energy balance benefits and future energy markets will be large enough to absorb very large amounts of biomass. Farmers can grow the tree crop primarily as an energy feedstock and combine it with other currently under-utilised farm residues such as cereal straw to improve the economies of scale for bioenergy projects and increase farm returns.

The economic activity of repeatedly growing, harvesting, transporting and processing biomass creates long term employment and contributes to regional economic development. Existing modern farming enterprises will remain dominant in the farming business, but the woody crops provide an opportunity to diversify the rural economy and improve the environment.

Producing transport fuels from biomass grown in Australia will improve national energy security, and the balance of trade.

Start-up with Mallees

Mallees have been grown as a crop in the WA wheatbelt since the early 1990s, mainly as a potentially economic means of addressing landcare concerns. This existing resource, of about 13,000 hectares planted on 1000 wheatbelt farms, offers a valuable start-up supply.

Mallees are a forerunner to other energy crop species and they are an invaluable source of knowledge and experience which can be transferred, with important adaptations, to other parts of the Australia and potentially overseas.

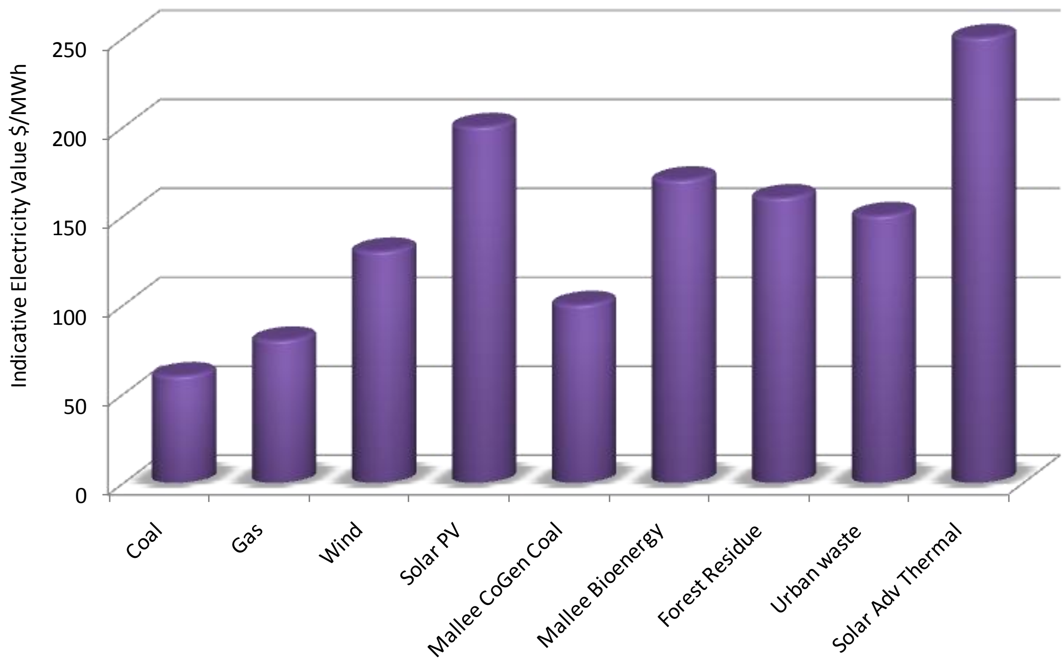
Comparing electricity costs using different fuels

For more than a decade Verve Energy, WA's leading energy producer, has been evaluating bio-energy options to expand its renewable energy portfolio. This included a demonstration 1 MW capacity integrated wood processing (IWP) plant at Narrogin that used mallee biomass sourced from wheatbelt farms as its feedstock. They found that a commercial-scale plant of at least 5MW could be economic but there was a high risk in the marketing of the products (electricity, activated carbon and eucalyptus oil), and it relied on a fully-developed harvesting/delivery system for the biomass, which was not then available.

As part of their continuing development Verve Energy commissioned a study to quantify total benefits and costs (financial and societal) associated with both a 5MW IWP project and an equivalent 7MW bio-energy plant, compared with other renewable energy options. In the case of biomass crops, total benefits include better management of salinity that provides a range of on and off-farm benefits. Of the eight options examined, including wind, solar PV and solar thermal, the mallee-based options provided the highest total economic (financial and societal) returns to the State.

From industry contacts, FFI CRC has been able to update and compare indicative electricity prices across energy options for meeting the 2020 Renewable Energy Target. Mallee co-generation with coal is the cheapest option and mallee bio-energy is on a par with other sources of biomass (forest residue, urban waste) and solar PV, cheaper than solar thermal but more expensive than wind. See Figure 1.

Figure 1: Indicative electricity value for conventional and renewable energy options.



The indicative electricity prices account for a realistic profit margin and return on investment to the generator. In this analysis it was assumed that:

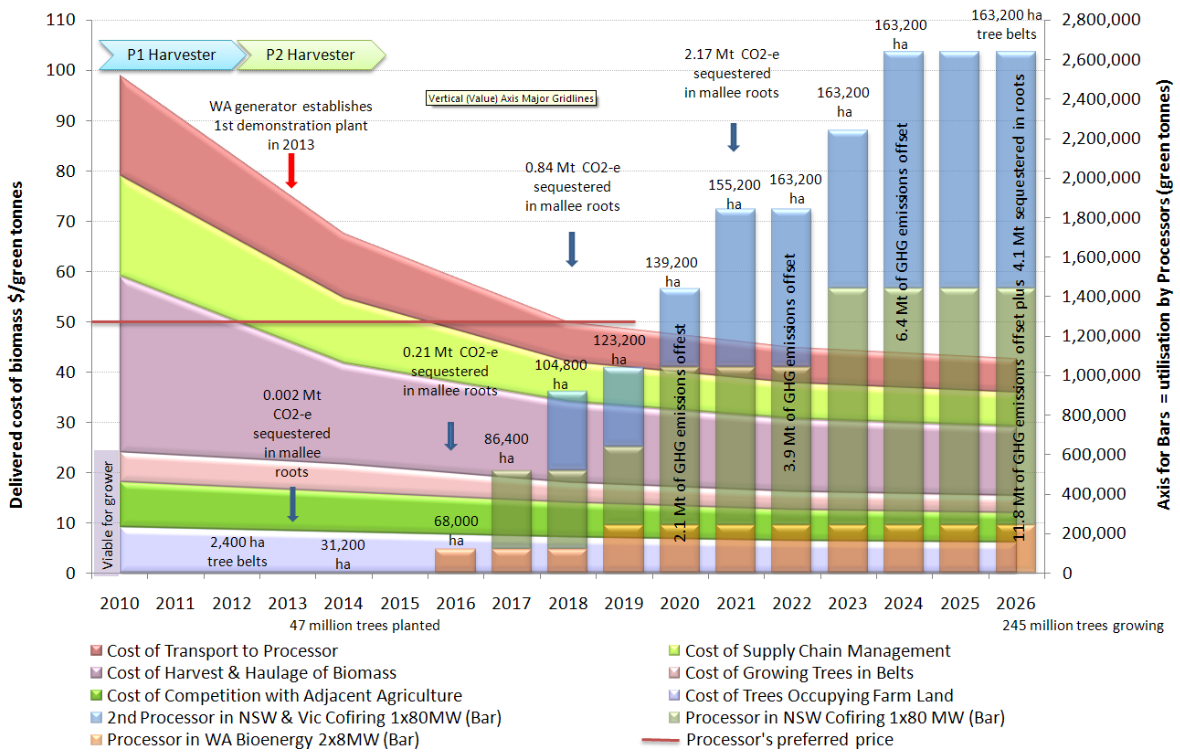
- To generate one MWh of electricity will require 0.55 tonnes of coal, one tonne of mallee biomass or 0.84 tonnes of forest residues. Mallee biomass typically has about 40 per cent moisture.
- The generation process will be considered by the regulator as carbon neutral. A $10 carbon price will raise cost of generation from coal by $10 /MWh and gas by $5 /MWh as the generator has to pay the cost of emitting GHGs.

Electricity generation from Energy Tree Crops

Scenario modelling by Future Farm Industries CRC estimates that 163,200 hectares of short cycle mallee tree crops could profitably supply 176 MW of electricity generation using 2.6 million tonnes of green biomass per year by 2026. At full development 1.3 million tonnes of greenhouse gas emissions could be offset per year, or close to 12 million tonnes over a 13 year period.

This scale of energy tree cropping would contribute significantly to the regional economy, generation of renewable energy certificates and diversification on the farm. Figure 2 shows how this occurs.

Figure 2: Delivered cost of farm grown biomass from mallee tree crops of WA, NSW and Vic, and utilisation by electricity generating plants.



This analysis is based on the electricity generator in WA developing two eight MW plants each requiring 120,000 tonnes of green biomass per annum. It is likely to use a modular dedicated bioenergy system that allows an increase in generation by 2 MW every couple of years. The two generators in NSW and Victoria would each require 1.2 million tonnes of biomass per annum for co-firing with coal in conventional generators. It is assumed that the processors in WA, NSW and Victoria will ultimately pay $50 per green tonne and sign forward contracts with growers to ensure plantings and delivery.

This scenario modelling draws heavily on FFI CRC's supply chain R&D and associated analysis of the total cost of delivered biomass (shown as a slowly declining set of all cost components over time with costs shown on left hand axis). Today's growing, harvesting and transport systems and infrastructure delivers biomass at just under $100 per green tonne. However, it's likely costs will progressively decline with technology advance and operational experience, to less than $50/gt by 2018.

The right side vertical axis shows the estimated amount of mallee biomass harvested, delivered and utilised by electricity generators in their bioenergy projects by 2026. Each bar shows the tonnage used by the processor. On top of each bar is the area of tree belts from which the volume of biomass will be harvested. Within each bar is the estimated cumulative abatement of greenhouse gases.

Other specific assumptions in this modelling include:

- The trees are planted in belts across the 450-600 mm rainfall zones of WA, NSW and Victoria within economic transport range of the electricity plants, staggered and scheduled to match future demand and reach the 163,200 ha by 2026. Each hectare has 1285 trees to give a total of 245 million trees.
- The schedule of tree plantings in three states to meet the projected future demand from electricity generators will be 19,200 ha in WA planted at 2,400 ha/yr from 2012 to 2019, and 144,000 ha in NSW and Victoria (half in each state) planted at 16,000 ha/yr between 2014 and 2022.
- The landholder grows the trees in two-row belts across 8 per cent of the farm and gets paid enough per tonne of green biomass to recover the costs of planting as well as the forgone net income from agricultural land use in the area occupied by mallee trees and the competition with adjacent crops. Tree belts offer shelter benefits to livestock and reduce the incidence of wind erosion. They compete with adjacent crops and pastures within a few metres of the tree belts.
- For each hectare of tree belt there will be about 12 hectares of conventional agriculture in the adjacent alleys. The mallee belts may have positive as well as negative effects on production within the adjacent alley.
- It is assumed the first harvest is in year 5 of each planting and then every three years afterwards. It is estimated that the trees will yield 50 green tonnes per hectare of belt at each harvest.
- The current Prototype 1 (P1) harvester has a capacity of 20 green tonne per hour but the more advanced P2 mallee harvester will be designed to operate at 60-80 green tonne per hour, and at lower cost.
- The GHG emissions abatement calculations are based on the assumption that 0.51 tonnes of GHG (in CO_2-e) are abated for each tonne of mallee biomass that replaces coal in the generation process.

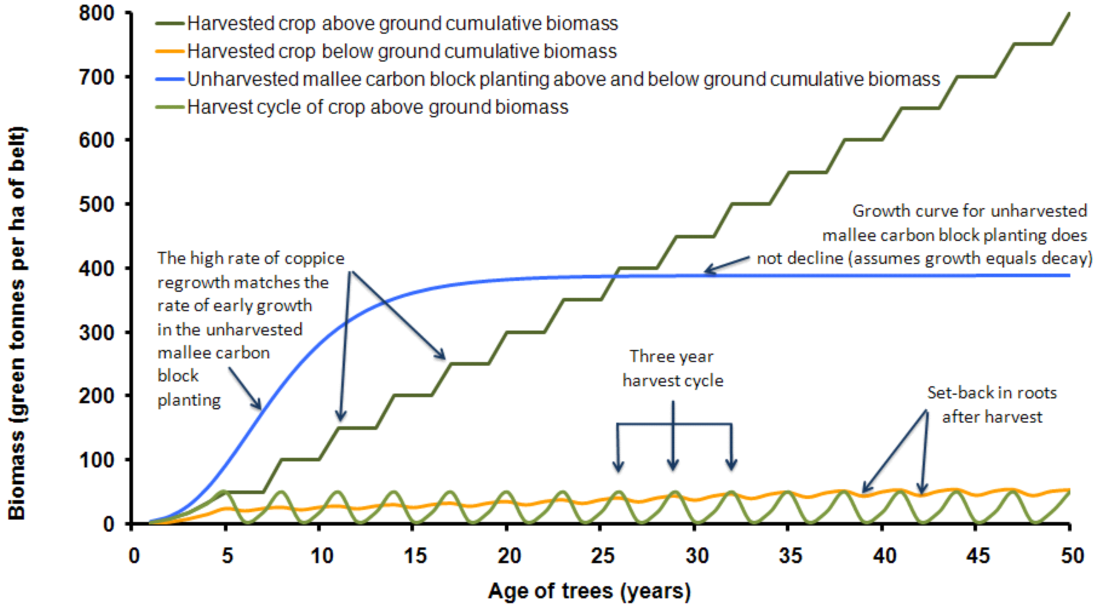
Demonstration of integrated wood processing, including 1MW electricity, at Narrogin, WA

Cash flows from crops and Energy Tree Crops

Economic modelling by the FFI CRC has compared mallees integrated into agriculture in the WA wheatbelt with business-as-usual cropping over a 50 year period into the future. The principles of this experience can be adapted to other areas of the extensive low to medium rainfall agricultural zone, as has already occurred in New South Wales.

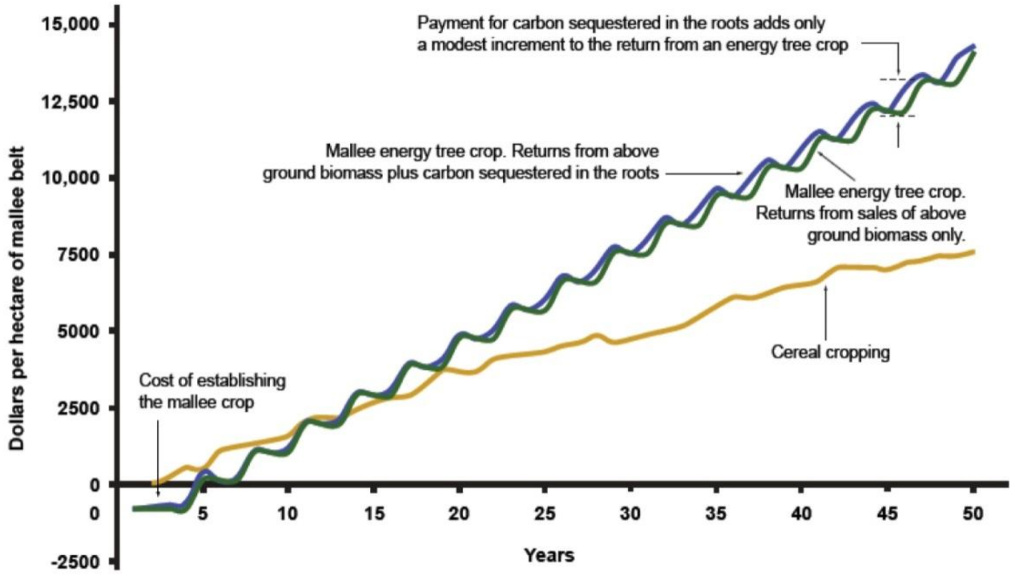
The study was based on mallees grown in two row belts and harvested and regenerated as depicted in Figure 3.

Figure 3. Modes of mallee tree biomass production for bioenergy and carbon sequestration at Narrogin, WA.



The production of mallee biomass from this strip of land (including an allowance for the competition between the mallees and the adjacent wheat crop) was compared with annual cropping on the same strip of land. The results are presented in Figure 4 over the page, and the assumptions are outlined below. A more detailed discussion is presented in Bartle and Abadi (2010)[3].

Figure 4. Cashflow for a mallee crop harvested for bioenergy versus business-as-usual agricultural land use which involves rotation of annual crops such as grain cereals with pastures for sheep grazing.



In an analysis of this type it is necessary to make some assumptions about the yields and prices of commodities of the alternative production systems proposed for an agricultural land. For instance the price of wheat was projected to follow past trends with variation in yields based on past variability in rainfall.

Historical records indicate that during the past 200 years, food prices have fallen in real terms and the terms of trade for food production have declined. In the past 50 years, this has mostly been due to improvements in agricultural efficiency. Future population growth is projected to decline to near zero by the end of this century. It was assumed for this study that agricultural practices will continue to advance as they have in the recent past. This is discussed in greater detail in Bartle and Abadi (2010)[3].

On the other hand, many industrial commodities have increased in value in real terms over this same period as wealth and consumption have increased. It is reasonable to assume that energy prices will increase substantially over the next few decades, making it likely that the price for delivered biomass will also increase.

Other, rather conservative assumptions of this analysis include:

- An annualised net present value from agriculture of $164 per hectare, derived from a cash flow configured to reflect seasonal variability.
- A realistic value of $50 per green tonne for biomass feedstock destined for renewable electricity production.
- Establishment costs for trees of $800 per hectare of belt area (a one-off cost).
- An annual maintenance cost of tree belts of $5 dollars per hectare.
- Above ground biomass is 50 per cent of total biomass to first harvest.
- A 30 per cent loss of root biomass on harvest, with a net 7.5 per cent gain by the following harvest.
- A projected rise in the carbon price from $25/tonne CO2-e in year one to $115/tonne at year 50.
- No emissions limits are currently applied to agriculture in Australia.

As the technologies develop in the future the best market for biomass is likely to be in biofuels, where energy values are significantly higher than for electricity.

Summary: Bioenergy from Energy Tree Crops is a strong contender for future renewable energy

Many new renewable energy technologies will be developed in the future, each with their relative strengths and weaknesses. The advantages of using lignocellulosic materials for bioenergy are:

- Biomass is a potential base-load fuel for electricity generation due to the ease with which the biomass can be stored.
- It is suited to electricity generation in rural regions, which will enable power stations to be sited at appropriate grid locations where transmission costs can be minimised.
- Biomass is a renewable source of organic material. Emerging technologies will be able to convert biomass into transport fuels which can be blended with petroleum based fuels and distributed through existing infrastructure.
- Significant transport activities occur outside the niche of battery-powered city commuting. Due to their energy density, liquid fuels are likely to remain the most appropriate form of energy for heavy road transport, air transport and personal rural transport.
- Woody crops have the potential to make an important contribution to the economic and environmental well-being of rural Australia.

Energy tree crops represent an alternative cropping enterprise for farmers which will do more to reduce carbon emissions as cumulative crop production exceeds the capacity of the same land resource to store carbon in aging carbon forests. By 2026 it is conservatively estimated that 163,200 ha of farm planting could be supporting two 8 MW bio-electricity plants in regional WA and co-firing in existing large coal-fired power stations, one each in NSW and Victoria. At this scale the advantages listed above will start to be realised.

Energy tree crops established strategically in the dryland wheat-sheep belt of southern Australia have the potential to deliver substantial benefits in renewable energy production, greenhouse gas mitigation, more diverse and resilient farming systems and regional economies, a distributed energy grid and environmental co-benefits such as erosion and salinity control and wildlife habitat, without compromising water yields or food and fibre production.

Energy tree crops offer a classic ‘win win’ option amid the often-conflicting insecurities at the intersections of carbon, water, energy and food.

Addendum: Future of bio-energy

Global bio-energy

There have been a number of important studies relating to bioenergy that have been published in the past two years[1,4,5] that have forecast the productive capacity of global agricultural land and commercial forests, and then related that capacity to projected global energy demand.

Bioenergy accounts for about 10 per cent of current global energy consumption. About half of this is fuel-wood for heating and cooking in traditional systems. However, the modern bioenergy proportion is now expanding rapidly. Sweden sources more than 30 per cent of its total energy requirements from forestry and timber processing residue, and in Brazil the proportion of ethanol from sugar cane in the national petrol supply is over 40 per cent. These two nations have seen steep reduction in bioenergy cost as the scale of their operations has increased. Many other nations are investing heavily in bioenergy R&D.

The technical potential volume of biomass supply at 2050 is projected to be sufficient to meet total global energy demand, without compromise to the required level of food production[4,5]. There are substantial current and projected biomass residues and these will make a major contribution to future bioenergy production. However, there is potential for large scale woody crops, especially where they are used in production systems that are complementary to agriculture, or where they utilise degraded land, to be competitive with residues and form a major component of future biomass supply. Projections by the International Energy Agency rank biomass as the largest renewable energy source with a market share up to 15 per cent by 2030 and 33 per cent by 2050[5].

Global corporate merger and acquisition (M&A) activity provides another insight into bio-energy's future. The recent 2010 survey of more than 250 senior executives in the renewable energy industry[6] indicated that large corporate utilities, in particular, were emphasising biomass targets in their M&A plans. The appeal of biomass projects to all companies and investors (37 percent of corporates looking for transactions) had risen to slightly exceed solar (36%) and onshore wind (35%). Biofuels came next, appealing to 29 per cent of renewable energy companies and investors. They were attracted to biomass by greater potential returns and its potential to operate as a base-load power source. The lack of visibility of long term resource supply and pricing was seen as a constraint.

Bio-energy in Australia

Bio-electricity and biofuels in Australia, in contrast to Europe and the United States, are operating at very small scales. In 2009 it was estimated that biomass contributed 0.7 per cent of total electricity and biofuels supplied 0.45 per cent of total transport fuels.

It is most notable that bio-energy receives very little attention in media coverage and policy discussion of Australia's renewable energy future. Yet if this nation is to achieve a low carbon future there are compelling reasons why bioenergy industries will be strategically important. For example, ClimateWorks Australia's 'low carbon growth plan'[7] released in March 2010 estimated biomass/biogas and biomass co-firing to be comparable to onshore wind and geothermal on the investor cost curve for greenhouse gas abatement (in the range of \$60-80 per tonne CO_2-e). For the period to 2020 biomass is predicted to be significantly cheaper per unit than solar thermal, solar PV and wind. The more recently published Beyond Zero Emissions 'zero carbon Australia stationary energy plan'[8] mapped a path to Australia's energy needs being met with 100% renewable by 2020. The technologies chosen were wind, solar thermal solar PV and hydroelectricity. Significantly, biomass energy supply was included as back-up electricity supply to offer energy security when a combination of low wind and low daily solar radiation occurs. This would be in the form of biomass co-firing of solar thermal plants, with 15 GW electrical equivalent of biomass-fired backup heaters representing about 2 per cent of total capacity. To achieve this more aggressive vision there would need to be \$6 billion invested in bioenergy supply as part of the total of \$370 billion, including a national transmission grid.

Energy Tree Crops, bioenergy and biofuels

Energy tree crops are only one potential source of biomass for bio-energy. The full range of sources can be classified as follows:

- Primary: various forms of energy crops, field residues from agriculture and forestry;
- Secondary: wastes generated in manufacturing products from agricultural and forestry feedstocks; and
- Tertiary: salvage material collected after secondary use.

In industrial systems there are two main forms of bioenergy:

- bio-electricity: commonly used where residues are readily available such as in forestry, timber mills and sugar mills, and in the future, from primary energy crops.
- bio-fuels: where starch, sugar and plant-oil feedstocks are converted to transport fuels using conventional technologies. These technologies are often referred to as ‘first generation’, in anticipation of emerging ‘second generation’ technologies to follow. Second generation processes are now being actively developed to convert the potentially large supply of low-cost cellulosic biomass from primary energy crops, both herbaceous (especially grasses) and woody crops, into the transport fuels of the future.

Primary energy crops will include:

- A range of starch, sugar and plant-oil producing species that have biomass components suitable for conversion to bio-fuels using conventional technologies, e.g. maize and sugar cane to ethanol, oil seeds and oil palm for biodiesel.
- Perennial woody and herbaceous species that produce high yields of cellulosic biomass and are able to regenerate by coppice/sprouting under a short harvest cycle.

Lignocellulosic biomass is a renewable source of hydrocarbons. This plant material embodies solar energy that may be stored in the standing crop or in stockpiles. By using CO_2 from the atmosphere to grow biomass, the carbon emitted from the combustion of the biomass does not cause the release of fossil carbon that causes so much concern in relation to climate change.

The biomass may be burnt directly to produce heat (thermal) energy for industrial and domestic uses, or to produce super-heated steam to generate bio-electricity. However, the greatest economic potential for cellulosic biomass lies in it being converted into higher value liquid or gaseous fuels[4] — the second generation bio-fuels. The various processes by which this can be done could also produce many of the compounds that are the basis of the wider petrochemical industry (for example, plastic precursors and resins).

Energy Tree Crops complement farming for food.

The term ‘bioenergy’ often raises concern about food versus fuel. This is due to the use of grains, sugar, and oilseeds to produce first generation biofuels. For example, the recent rapid expansion of ethanol from maize in the United States caused considerable controversy. This issue has stimulated interest in second generation fuels derived from lignocellulosic biomass such as cane bagasse, wood, inedible foliage and crop stubbles[3]. If woody crops such as mallee or willow are grown for energy, they can be established on land not used for food production, or configured in ways that allow the tree component to complement on-farm food production enterprises.

Most first generation biofuels also require large inputs of energy per unit of energy in the fuel produced. They are doing little better than converting fossil coal, oil and gas into biofuels. The energy efficiency of second generation biofuels production is much higher than for the first generation fuels.

If the future of biomass energy is focused on second generation fuels, there remains the question of the extent to which woody crops will encroach on the finite agricultural land resource and put upward pressure on food prices. This is not expected to be a problem because not all the potential economic production of bioenergy will come from woody crops, and in occupying agricultural land their economic value is likely to be greatest where they have a comparative advantage and deliver collateral benefits as a component of the agricultural system. These benefits include diversification of the rural economies, interception of nutrient rich run-off, salinity control, protection of soil from episodic wind erosion events, conservation benefits and provision of shelter for livestock during lambing and off-shears. Furthermore, with declining global population growth rates it is expected that advances in agricultural technology will be more than able to maintain food supply. Bartle and Abadi (2010) cite many studies published between 2003 and 2009 on this topic.

Further research

It was noted previously that there is a technical capacity to produce most of the world's energy requirements from biomass by 2050, but studies indicate that the economically viable proportion will be less, ranging from 10 per cent (of a larger energy market) under a business-as-usual scenario, to 33 per cent if there is a global endeavour to restrict CO_2 concentration in the atmosphere to 450 parts per million in 2030[1,5].

A very important factor that will constrain the expansion of cellulosic biomass for bioenergy is expected to be the cost of producing and delivering biomass to market. In consequence, it is anticipated that bioenergy will be most successful as second generation biofuels sold into markets traditionally supplied by the oil and gas industry[5].

In Australia there has been a sustained endeavour to reduce the cost of producing biomass from mallees to enable it to compete in the energy markets. To support the development of the new industry a prototype harvester is under construction at Toowoomba, Queensland. This work is funded through the Future Farm Industries CRC by the WA Government's Low Emissions Energy Development (LEED) fund. Field trials started in early 2010. The objective of this project is to produce technology that can harvest and chip small trees at a per-tonne cost of about half that of best practice in plantation forestry; an ambitious objective given that small trees are normally the most expensive to harvest in plantation forestry. This will be achieved by combining felling and chipping into a single continuously travelling machine analogous to the machinery used in sugar cane or forage harvesting operations.

Definitions

Alleys: The open spaces, where normal cropping and grazing enterprises occur, that separate belts of woody crops. Alleys are usually 90 per cent or more of the total paddock area.

Belts or **tree belts**: Trees may be integrated into agricultural systems by planting in narrow belts of two rows or more with wide alleys (between 70 and 80 metres) between the belts. Belts can be linear or on the contour and there are important interactions between the belts and the crops or pastures in the alleys.

Bioenergy: Any energy product made from biomass.

Biofuels: Liquid fuels produced from biomass.

Biomass: In this context, any traded or measured plant material either in its primary form (grown and harvested crops), secondary (as the residue of agricultural or forestry crops) and tertiary (urban and industrial wastes).

Blocks or **tree blocks**: Trees planted in contiguous areas varying from less than a hectare to many hectares, as is usually employed in high rainfall tree plantations. Block plantings operate somewhat differently from belts in that there is more competition between trees and they are not integrated into an agricultural system, meaning there is less interaction between the trees and the agricultural system.

Carbon sequestration: The process of placing CO_2 into storage to prevent the CO_2 from entering the atmosphere. It includes geosequestration and biosequestration. An example of geosequestration is the underground storage of fossil CO_2 from a coal-fired power station. By contrast, biosequestration is the removal of CO_2 from the atmosphere using photosynthesis by plants. Biosequestration is typically used to offset fossil CO_2 emitted elsewhere (for example planting trees to offset air travel).

Carbon sink: A store of carbon, in this context, a long term planting of shrubs or trees on former farmland, which would then be defined as a carbon forest.

Energy crops: Biomass crops grown primarily for bioenergy and usually defined by the plant form (tree, shrub, woody or herbaceous). For example, energy tree crop, woody energy crop.

First generation feedstocks: Materials such as cereal grain, oil seeds, palm oil and cane sugar which are readily converted into biofuels using existing technologies. The sugars and starches are fermented to produce ethanol and the oil feedstocks are processed to produce a diesel substitute.

Second generation feedstocks: In the context of this paper, biomass from woody plants containing the characteristic woody material of lignin combined with cellulose. Second generation feedstocks are also called lignocellulosic feedstocks. Agricultural wastes such as cane bagasse and cereal straw are also second generation feedstocks. There are numerous processes being developed to convert these materials into a range of biofuels.

Woody crops or tree crops: Any tree or shrub grown as a crop for harvest to produce biomass for processing into energy or other industrial products. Woody crops can be grown in large contiguous areas (plantations or forests), or be dispersed as small blocks or long belts. The term ‘woody crop’ can embrace plantation forestry, farm forestry and agroforestry. In the context of agricultural regions, woody crops usually refers to small trees and shrub-form species harvested on a short cycle of less than 10 years.

End notes

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