Eucalyptus biomass fuels: Price competitive or way off the money?

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Abstract

This paper examines the costs and benefits of producing biomass fuels from mallee eucalypts grown in low rainfall areas of Western Australia. The fuels examined are ethanol and renewable electricity. As a means of examining the competitiveness of these energy sources with conventional fossil fuels, we estimate the price gap between ethanol and petrol and the cost of producing a unit of electricity by conventional means versus biomass electricity. Both comparisons are made on an energy equivalent basis. The potential for future advances in processing technology is built into the analysis. We find that ethanol is not price competitive with petrol, even after considering environmental benefits associated with biomass fuels. This finding raises questions about the wisdom of pursuing a biofuels target, a recent policy of the Commonwealth government. The picture for biomass electricity is brighter. When carbon sequestration benefits are taken into account, the cost of biomass electricity is on a par with conventional power.

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This paper is based on a consultancy undertaken by the Centre for International Economics (CIE) and Enecon Pty Ltd for the Rural Industries Research Development Corporation (RIRDC). The full report is available from the RIRDC website (see RIRDC 2002 for details). The authors are economists with the CIE, a private consulting firm in Canberra. All correspondence should be directed to Dr Martin van Bueren (mvbueren@thecie.com.au).

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Introduction

There is considerable interest in the commercial opportunities and potential environmental benefits of producing ethanol and renewable electricity from eucalyptus biomass. Short rotation tree cropping involves the establishment of mallee eucalypts on farmland in low to medium rainfall areas. The trees are grown in belts and harvested every three to four years. Replanting is not required after harvest because the trees are allowed to regrow (or coppice) from the stump. Agricultural production can continue to be practiced on the land in between the belts of trees. The potential benefits of eucalyptus biomass production include:

- increased employment and income diversification in rural and regional areas;
- a reduction in air pollutants from the transport sector by the combustion of ethanol-petrol fuel blends;
- a net reduction in carbon dioxide emissions through the carbon uptake (or sequestration) by the trees;
- a reduction in dryland salinity; and
- other environmental benefits, such as biodiversity, livestock shelter, and erosion control.

Commercial interest in the biofuels/renewables industry has been spurred on by a number of Commonwealth government initiatives, which are designed to promote greater use of renewable energy sources. In 2000 the Commonwealth government introduced a mandatory renewable electricity target (MRET) which requires wholesale purchasers of electricity to proportionately meet a target of sourcing 9500 giga watt hours of electricity from renewable sources. This legislation has provided a market for renewable electricity, including power generated by the combustion of biomass. Similarly, the Commonwealth's Greenhouse Gas Abatement Program (GGAP), which offers financial support for projects that significantly reduce carbon dioxide emissions, is encouraging private investment in renewable energy projects.

The Commonwealth government is also keen to promote the greater use of biofuels (ethanol, biodiesel, diselhol) and has announced a biofuels production target of 350 million litres by 2010, up from the current production level of 40 million litres. Until recently, ethanol was exempt from the Commonwealth fuel excise of 38 cents per litre, which applied to petrol and diesel. New legislation introduced last year has replaced the excise exemption with a producer subsidy for ethanol and other biofuels equal to 38 cents per litre, thus maintaining support for biofuels at the same level as existed under the excise exemption scheme.

Despite these various support schemes, eucalyptus biomass production is still at an embryonic phase. The most significant development to date has been in Western Australia, where a pilot integrated tree processing plant is being built by Western Power (the State's electricity company) in partnership with private investors. The plant will process eucalyptus biomass into eucalyptus oil, charcoal, activated carbon and renewable electricity. Over 7000 hectares of mallee trees have been established to date as feedstock, and this area is expected to grow if the pilot plant is successful (RIRDC, 2001). The pilot plant, which is based in Narrogin, will produce 1 mega watt of power. At this stage there are no plans to produce ethanol.

If the eucalyptus biomass industry is to mature and 'stand on its own two feet', it will be necessary for the industry to be cost competitive relative to fossil fuel products and other renewable energy sources. The purpose of this study is to estimate the costs and benefits of producing ethanol and renewable electricity from eucalyptus biomass. In order to assess the competitiveness of these energy sources relative to conventional fuels, we estimate the costs of producing ethanol and electricity from biomass — net of environmental benefits — and compare these costs to the prices of petrol and conventionally generated electricity, respectively. Both comparisons are made on an energy equivalent basis and do not include any subsidies offered for biofuels or renewable electricity.

Analytical approach

As this primary intent of this study is to examine the future prospects for a eucalyptus biofuels industry in Australia, we recognise that a snapshot of the current situation may not be the most appropriate basis for the analysis. Instead, we base our analysis on a period 15 years hence. A number of factors are likely to change over the next 15 years:

§ the costs of converting biomass to ethanol can be expected to fall significantly over the medium term — which will increase the economic attractiveness of biomass based fuels (RIRDC 2002);

§ a carbon tax or regulatory cap on greenhouse emissions may be introduced — which will favour the production of renewable, low emission energies relative to non-renewable energies; and

§ the costs of producing electricity and transport fuels from non-renewable sources are also expected to decline over time — which will reduce the economic attractiveness of renewable energy pathways such as eucalyptus biomass (ABARE 2002).

We start by assuming that eucalyptus biomass will be used either for producing ethanol or renewable electricity, but not a combination of both from the same plant. While it is technically feasible to combine the two operations and channel a proportion of the biomass into each production process, increased ethanol recovery will be at the expense of reduce biomass residue for electricity generation. Therefore, there are few synergies to be exploited beyond generating biomass electricity on-site to power the ethanol facility (RIRDC 2002).

The study focuses on the low to medium rainfall zone (250 to 400 mm) of the Western Australian wheatbelt, as this area has been indentified as having good potential for supporting a large-scale eucalypt mallee industry (RIRDC, 2001). The cost of producing ethanol or electricity from biomass will depend in part on the scale of operations. The larger the scale the lower the unit costs. The scale of operations that can be supported will depend on:

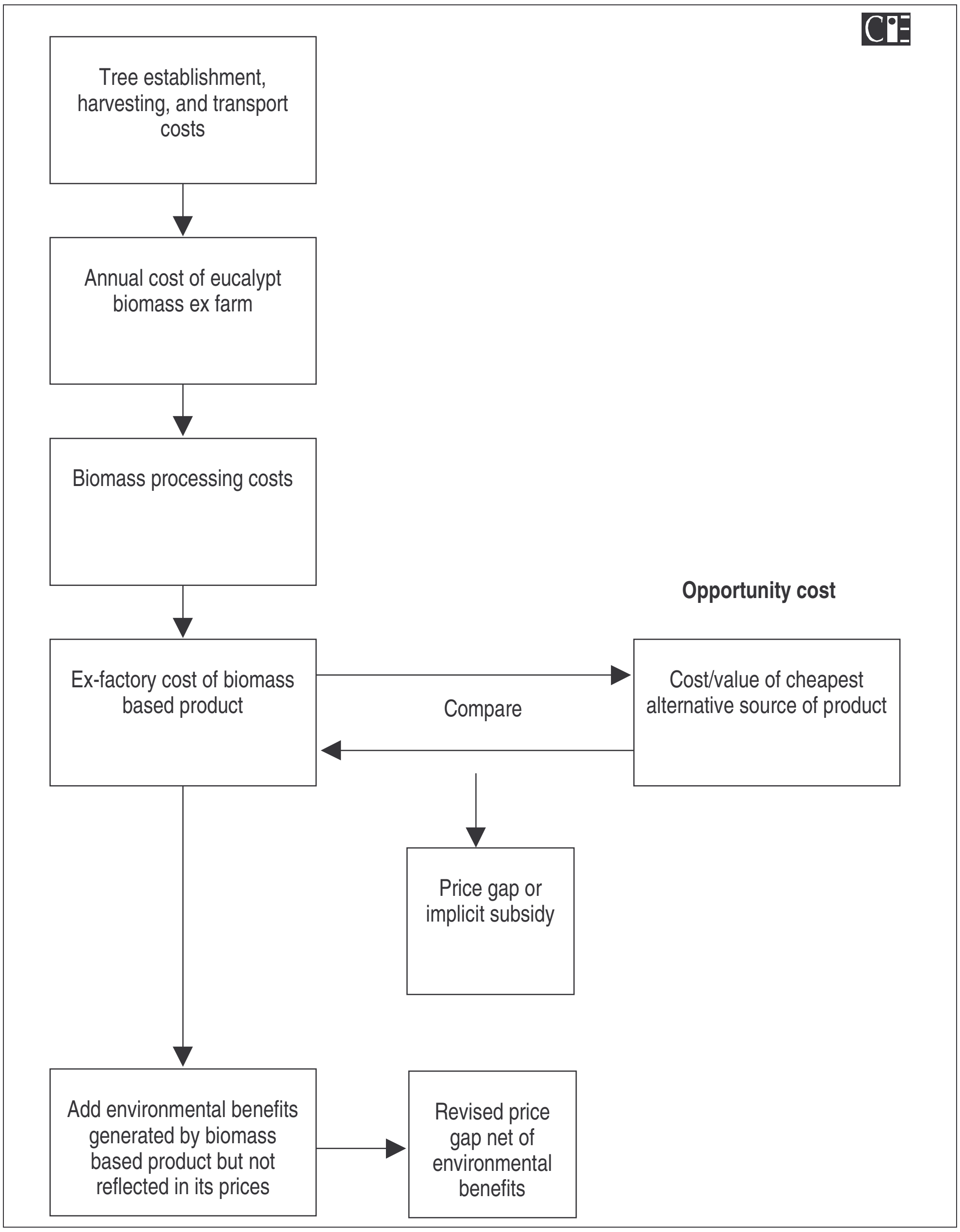
- the volume of biomass available for harvest within a economically viable haulage distance from the plant, which in turn will depend on;
  - the commercial attractiveness of tree cropping to farmers plus any positive environmental effects, and
- the economic size of the conversion plant, which will depend in part on the;
  - the size of the market for the product located within a 'commercial' distance of the plant (this is an important issue in the case of electricity because the existing grid cannot take more than 30 MW of electricity from outside generations); and
  - the economies of scale achieved by large processing plants.

In our analysis we assume that it would be feasible for 1.5 million green tonnes of biomass to be grown on an annual basis. This would be sufficient to supply an ethanol plant with a processing capacity of 200 million litres (ML) per year or a power plant generating 150 mega watts (MW).

Based on this scale of operation, the next step in the analysis is to establish the cost of producing each biomass product (ethanol and electricity) and comparing these costs to the price of equivalent energy products generated using 'conventional' non-renewable sources (chart 1). The difference is termed the 'price gap' or implicit subsidy required to support biomass fuels. Thus, ethanol is compared to petrol (ethanol is substitutable for petrol as a transport fuel) and the cost of producing biomass electricity is compared to conventional coal-fired power generation.

Having established the price gap between the biomass products and their conventionally produced counterparts, the third step is to estimate the environmental benefits associated with tree cropping and determine the extent to which these benefits close the price gap.

Chart 1 Comparing the costs and benefits of biomass products alongside conventional energy sources



Biomass production

The on-farm costs of growing eucalyptus biomass are detailed in a feasibility study by RIRDC (2001), which was undertaken in the lead up to the development of the Western Australian integrated tree processing plant. The feasibility study provides detailed estimates for biomass yields and the cost of growing, harvesting, and transporting biomass to a processing plant. The costs are net present values averaged over a 20 year time frame. It is estimated that $23 per green tonne will cover the on-farm costs of growing biomass, including the opportunity costs of foregone agricultural production. Because salinity could worsen in the 'no trees' scenario, opportunity costs are assumed to decline over time to reflect progressively lower agricultural productivity. The cost of biomass to a processor is assumed to be $36 per tonne after allowing for harvest and transport costs (see box 1 for details).

In order to supply 1.5 million tonnes of feedstock each year, it is estimated that approximately 714 000 hectares of agricultural land would need to be converted to mallee belts with 50 metres of alley land between the belts (see box 1). Alternatively, 120 000 hectares of block plantings would be required. In practice, most mallee tree cropping projects in Western Australia have adopted an alley planting design which allows agricultural cropping and grazing to be practiced in the alleys (RIRDC, 2001).

It is technically feasible that tree cropping on this scale could be implemented as the low to medium rainfall zone occupies 10 million hectares of cleared agricultural land, of which at least one million hectares (10 per cent) is regarded as suitable for growing mallee trees (Shea et al. 1998). It is possible that all biomass requirements could be sourced from within a 70 kilometre radius of a processing plant provided that 46 per cent of land was converted to tree cropping in alley formation (table 1). This area of agroforestry represents a very large increase on current plantings. The logistics of achieving tree cropping on such a large scale within 15 years have not been investigated.

Table 1 Required tree cropping adoption rates to supply 1.5 M tonnes biomass[a]

Radius from processing plant	*Area of zone*	*Required proportion of area to be tree cropped*
kilometres	hectares	per cent
50	785 400	90
60	1 131 000	63
70	1 540 000	46

[a] Annual biomass production from trees grown in alley formation, as specified in Box 1.

Source: CIE calculations

Box 1 Biomass production and costs — key assumptions

Planting design

- § Trees planted in 4-row belts spaced 50 metres apart.
- § Rows are spaced 2 metres apart and a 2 metre buffer is allowed for either side of the belt to take account of competition effects between the trees and pasture or cropland in the alley. Thus the total belt width is 10 metres.
- § Trees are spaced 1.5 metres apart within each row.
- § For every hectare of land converted to tree cropping, this design produces 0.167 hectares of tree belt and 0.835 hectares of alley land.

Minimum area to supply biomass requirements

- § Based on the planting design specified above, 1 kilometre of belt occupies 1 hectare. Assuming a yield of 15 kg of green biomass per tree and a 95 per cent tree survival rate, 1 hectare of belt will produce 37.8 tonnes of biomass.
- § Trees are harvested once every three years, so annual average yield per hectare of belt is 12.6 tonnes.
- § At this yield, 120000 hectares of block planting would be required to supply 1.5 million tonnes. Alternatively, 714300 hectares of alley tree cropping would be required (ie. 1500000 tonnes/(0.167 ha belt *12.6 tonnes)).

Establishment and on-going maintenance costs

- § Tree establishment costs $1270 per kilometre of 4-row belt.
- § Maintenance costs of $8 per kilometre of 4-row belt.
- § The opportunity cost of converting agricultural land to trees is assumed to be $40 per hectare, phased down to $20 per hectare over a 20 year period due to the effects of salinity.
- § Total biomass production over a 20 year period (6 harvests) from a hectare of land converted to tree cropping is 12.6 tonnes. Total on-farm production costs amount to $23.00 per tonne in net present value terms averaged over a 20 year timeframe.

Harvest and transport costs

- § Single row harvest operation at a harvesting speed of 5 kilometres per hour with 33 per cent downtime.
- § Harvesting cost of $23 per tonne at each operation, which includes a bin transfer cost of $2 per tonne.
- § Transport costs of $4 per tonne based on an average haul distance of 50 kilometres.
- § Total harvesting and transport costs, in net present value terms averaged across the 20 year timeframe, amount to $13 per tonne.

Discounting the flow of costs

- § The flow of costs over a 20 year period are consolidated and converted to a present value using a 6.5 per cent discount rate. This value is then expressed as an average cost per tonne of biomass produced over 20 years.

Source: Based on the oil mallee feasibility study in RIRDC (2001)

Ethanol from biomass

Estimates of the current cost of producing ethanol from eucalyptus biomass were sourced from Enecon Pty. Ltd., an Australian firm specialising in renewable energy technologies (see RIRDC, 2002). Table 2 sets out the *current* ethanol production costs for a plant processing 1.5 million tonnes of feedstock and producing 200 ML of ethanol each year.

An ex factory selling price for ethanol of $0.82 per litre would be required for a plant with this cost structure to generate the required rate of return for this investment (which is taken to be a 15 per cent internal rate of return over 15 years).

However, our focus is not on production costs now but in 15 years time. In the interim, the unit cost of ethanol production and hence the required selling price ex factory to ensure profitability of the plant, can be expected to fall significantly. In addition, the minimum quantity of biomass required to support a 200 ML plant will fall as conversion efficiencies improve. Research and development (R&D) is likely to deliver:

§ improvements in enzyme production and performance via protein engineering to accelerate the rate of cellulose hydrolysis;

§ improvements in the efficiency of ethanol producing micro-organisms; and

§ improved levels of carbohydrates and ethanol yields through genetic engineering of mallee plants.

These developments will increase conversion rates and reduce both operating costs and capital costs. Based on US data an optimistic scenario on R&D outcomes could lead to up to a 50 per cent reduction in total processing costs over the next 15 years. If this is achieved the required selling price for ethanol could fall to around 42 cents per litre ex factory.

The cost of fuel from alternative sources

Ethanol can be produced from many other forms of biomass such as raw sugar byproducts, sweet sorghum and wheat starch. It can also be

Table 2 Current ethanol production costs (200 ML per year output)

Plant details	***Unit***	***Estimate***
Conversion rate	litres ethanol per tonne green feed	140
Quantity of green feed	million tonnes per year	1.43
Unit cost of green feed	$ per tonne	36
Costs		
Total operating costs	$ million	70.3
Capital costs	$ million	470
Required product selling price ex factory[a]	$ per litre	0.82

[a] To generate an IRR on investment of 15 per cent over 15 years

Source: RIRDC (2002)

produced from natural gas. We have taken the relevant cost comparison to be with petrol as a transport fuel because it is envisaged that the primary use of ethanol from biomass will be a petrol additive, thus serving as a partial substitute for petrol. In Australia a mix of 10 to 20 per cent ethanol with petrol (E10 and E20) is being used in some States. The cost to motorists of changing to a ethanol blend are expected to be negligible because conventional motor vehicles can generally run on ethanol–petrol blends with minimal or no engine modifications (provided the blend does not exceed 20 per cent).

The price of petrol 15 years hence will depend on the world price of crude oil in US dollars and the A$/US$ exchange rate. The forecasting of oil prices is controversial. However, on balance, the prospect over the next 15 years is for declining rather than increasing crude oil prices because new technologies in power generation, transportation and energy utilisation are likely to dramatically improve energy use efficiency. Consensus forecasts collated by the Energy Information Administration in the US suggest prices between US$21 and US$22 per barrel between 2010 and 2015. We take US$22 as the most likely figure.

On the basis of previous forecasting experience, long term projections in the exchange rate of the Australian dollar with the US dollar have little credibility. An optimistic forecast from the vantage point of a domestic ethanol from biomass industry would be for no recovery in the value of the Australian dollar from 50 cents US. This analysis takes a conservative approach and assumes an exchange rate of US$0.50 to the Australian dollar will prevail in 2015.

There is no simple relationship between the crude oil price and the price of refined petrol. The gap depends on the size of the refinery, supply and demand conditions at the time for the various products of refined crude oil and the product mix targeted by the refinery. Refinery margins are not static. Current margins of Australian refineries are considered inadequate to attract new refinery capital into the industry. But new refinery equipment will be needed to meet the planned introduction in 2006 of the proposed new Euro standards for sulphur content. This could add up to 2 cents per litre to petrol costs (Coffey's Geosciences Pty Ltd 2000).

This analysis assumes an ex-refinery petrol price of 36 cents per litre (before tax), which is based on no recovery in the exchange rate and allows for the cost of transporting oil to the refinery and standard refining costs (including a small increase post-2006 to meet the higher fuel standards).

The gap between ethanol and petrol

For the purposes of comparing ethanol with petrol it is necessary to account for ethanol's lower energy density relative to petrol — a factor of 0.7. Therefore, the projected ethanol price of 42 cents per litre becomes 61 cents per litre for comparative purposes with petrol at 36 cents per litre. The price gap, between petrol and biomass ethanol is therefore around 25 cents per litre. Putting aside the potential enviromental benefits, ethanol is clearly uncompetitive compared with petrol.

Environmental benefits

A number of environmental benefits are associated with the production of ethanol, and these need to be taken into account if a valid comparison is to be made between the price of ethanol and the price of alternative fuels. The potential benefits include:

- greenhouse benefits from the sequestration of CO_2 by tree crops;
- lower air pollution from the use of ethanol as a road transport fuel; and
- reductions in dryland salinity.

Greenhouse benefits

The carbon sequestered by mallee trees could be eligible for accreditation under the Kyoto Protocol. While Australia and the United States are not yet party to ratification, it is probable that domestic trading schemes for carbon credits and emission entitlements will become established in these countries as international trading arrangements and accounting systems evolve. If an international trading scheme is implemented and the Kyoto targets are upheld, ABARE (2002) forecasts that the price of carbon permits (and credits) could be in the order of US$102 per tonne of carbon by 2010 (equal to A$56 per tonne of CO_2). By way of comparison, carbon is currently trading under the voluntary UK emissions trading scheme at approximately US$10 per tonne (or $5.50 per tonne of CO_2). The price of carbon is expected to increase sharply as Kyoto targets are tightened and low-cost abatement strategies for initial emission reductions are exhausted.

The carbon credits generated by tree cropping would be sufficient to offset CO_2 emissions from ethanol combustion, thus rendering ethanol a zero-emissions fuel. The roots of mallee trees are capable of sequestering 0.5 tonnes of carbon per hectare of plantation each year during the first four years of growth, and then one tonne per hectare in subsequent years (Shea et al. 1998). In addition, it is possible to maintain an average of 3 tonnes of carbon per hectare in the tree foliage in a plantation that is harvested in rotation. Together, the above and below ground biomass is sufficient to offset downstream CO_2 emissions.

The downstream carbon emissions from petrol and ethanol are approximately the same on an energy equivalent basis (table 3) but ethanol has the advantage of having virtually zero emissions over its 'lifecycle'. For every litre of ethanol substituted for petrol, approximately 1.6 kilograms of CO_2 is prevented from entering the atmosphere. This is calculated on the basis that petrol combustion emits 2.3 kilograms of CO_2 per litre and a litre of ethanol is equivalent to 0.7 litres of petrol on an energy equivalent basis.

Assuming a carbon price of A$56 per tonne of CO_2, the economic value of the greenhouse benefit is 9 cents per litre of ethanol.

Table 3 CO_2 emissions from the combustion of different fuels

	CO_2 emissions	*Energy content*	*CO_2 emissions on energy equivalent basis*
	kg/L	MJ/L	kg/MJ
Ethanol[a]	1.5	23.0	0.065
Diesel	2.7	38.6	0.070
Petrol	2.3	32.4	0.071

[a] Assumes anhydrous form.

Source: CSIRO (2000).

Other air pollutants

Using ethanol as a blend with petrol has been shown to reduce air pollutants from motor vehicles such as carbon monoxide, nitrous oxides, sulphur dioxide, and volatile organic compounds. However, cost effective technology now exists to control petrol emissions. For example, carbon monoxide and nitrous oxides can be efficiently reduced by fitting a catalytic converter to the vehicle, and sulphur dioxide can be managed by modifying the properties of petrol at the oil refinery. The literature suggests that blending ethanol with petrol may actually produce a small net increase in emissions of volatile organic compounds, although the use of ethanol in fuels at the concentrations mooted is unlikely to have any harmful effects on humans and the environment. Thus, on balance, it is concluded that blending ethanol with petrol does not offer a significant environmental benefit over-and-above existing technologies in terms of reducing toxic air pollutants.

Dryland salinity benefits

Tree cropping with mallee has the capacity to control salinity by reducing the amount of recharge entering the ground water aquifer. The potential benefits from controlling salinity stem from:

- yield benefits to agricultural production in the alleys;
- increased agricultural production on land 'downstream' to the tree cropping enterprise; and
- off-farm benefits including;
  - improved water quality for household consumption and industrial uses;
  - reduced damage to roads, railways, and buildings;
  - protection of natural areas (for example, wetlands and associated biodiversity); and
  - reduced flood risk.

Our analysis has already taken into account the on-site yield benefits of reducing salinity on alley land via the assumption of declining opportunity costs (see Box 1). However, the off-site benefits of salinity control have not been accounted for. It is difficult to estimate the value of these benefits. What is known is that the costs of doing nothing are significant. For example, infrastructure damage across six rural townships in Western Australia has been estimated to cost approximately $9 million (net present value) over a 30 to 60 year period (WA Salinity Taskforce, 2001).

The extent to which tree cropping can reduce these future costs is unknown. Pannell (2001) suggests that the off-site salinity benefits from tree planting may limited because in catchments having regional groundwater flow systems (which are predominant in Western Australia), the impact of trees on reducing saline discharges into waterways will probably be a century or more into the future. Furthermore, large scale tree planting within a catchment has been shown to reduce the amount of surface water run-off which could be detrimental to water yield and could possibly increase stream salinity through less dilution.

Given the uncertainty about the level of off-site salinity control offered by tree cropping, we use a threshold value approach — which involves determining how big the salinity benefits would need to be to offset the price gap between ethanol and petrol. After accounting for the greenhouse benefits associated with ethanol, a price gap of 16 cents per litre remains. Based on a plant producing 200 ML of ethanol per annum, this equates to a gap of $32 million per annum. In other words, the tree cropping project –

which involves 714,000 hectares of land – would need to produce a salinity benefit of $32 million each year in present value terms to break even with the option of using petrol.

In summary

The price gap between ethanol and petrol is estimated to be 25 cents per litre before any environmental benefits are considered. The greenhouse benefits of ethanol close this gap to 16 cents. Air pollution benefits are considered to be negligible. This leaves a price gap of 16 cents per litre (or $32 million across the biomass project) which needs to be made up by off-site salinity benefits.

Electricity from biomass

Estimates of the current cost of producing electricity from eucalyptus biomass are set out in table 4. Unlike ethanol production, efficiency gains are not anticipated over the next 15 years because the power generation technology is mature.

The unit cost of production is estimated to be $93.50 per mega watt hour (MWh). This figure is based on a combustion plant producing 30 MW of electricity (240 000 MWh per year) and requiring almost 405 kt of green feedstock per year. This is less than one third of the estimated annual harvest of 1.5 million tonnes, which has been used in the calculations for the ethanol plant. Despite the fact that a lower per unit cost of generation could be achieved from a larger plant, the existing electricity grid can not take more than 30 MW of electricity from outside generations. Major grid work (and capital expenditure) would be needed to accept input from a plant with a generating capacity in excess of 30 MW.

Table 4 Current electricity production costs from eucalyptus biomass (30 MW capacity producing 240 000 MWh per year)

Plant details	***Unit***	***Estimate***
Conversion rate	MWh per tonne of green feed	0.59259
Green feed required	million tonnes per year	0.405
Unit cost of green feedstock	$ per tonne	36
Costs		
Capital expenditure	$ million	42
Operating costs	$ million	14.1
Required product selling price ex factory[a]	$ per MWh	93.5

[a] To generate IRR on investment of 15 per cent over 15 years

Source: RIRDC (2002)

The cost of electricity from alternative sources

Table 5 shows that electricity generation costs from coal and natural gas are currently around $10 per giga joule ($35.70 per MWh). These costs are expected to fall in the next 15 years by up to half of 1 per cent each year due to efficiency gains in power generation. By 2015 it would seem reasonable to expect these costs to have fallen to around $33 per MWh.

Table 5 Unit costs of electricity generation from alternative non renewable sources 1998–99

Feedstock	*Costs*
	$ per giga joule
Black coal	
Existing technology	9.08
New technology with 15 years	8.74
Brown coal	
Existing technology	9.70
New technology within 15 years	8.37
Natural gas	
Existing technology	10.22
New technology within 15 years	9.09
Oil	
Existing technology	38.54
New technology within 15 years	34.52

Source: ABARE Australian Energy Projections to 2019–20, Research Report 01.11 (2001).

The gap

The price gap between biomass energy and conventionally-generated electricity is estimated to be **$60.50 per MWh**, which assumes that conventional power costs $33 per MWh and biomass energy costs $93.50 per MWh.

Environmental benefits

As for ethanol, there are a number of environmental impacts associated with producing electricity from biomass. These benefits/costs need to be considered if a valid comparison is to be made between 'green' electricity and power produced using a conventional coal-fired generator. The potential benefits include:

- greenhouse benefits from CO_2 sequestration; and
- reductions in dryland salinity.

Greenhouse benefits

Before considering sequestration, the generation of electricity from biomass produces higher CO_2 than conventional coal fired power stations. The latter emits approximately one tonne of CO_2 per MWh of electricity output, while biomass plants typically emit 1.7 tonnes of CO_2 per MWh (Polglase and Stein, 2001).

However, biomass produced from tree cropping is generally regarded to sequester sufficient quantities of carbon to completely offset these emissions. Under NSW legislation zero net CO_2 emissions are assigned to the generation of electricity from biomass crops grown for energy use on land which has not supported native forest since 1990 (MEU, 2000).

Therefore, assuming a CO_2 price of $56 per tonne, the greenhouse benefit from biomass electricity in terms of emissions prevented from entering the atmosphere is $56 per MWh.

Dryland salinity benefits

The off-site salinity benefits would need to be $1.08 million per annum to cover the $4.50 per MWh price gap that remains between biomass electricity and conventional power after allowing for greenhouse benefits. This is calculated by aggregating the $4.50 gap to the total annual output of the power plant (240,000 MWh). Given the scale of off-site damage caused by salinity in Western Australia, it is conceivable that this threshold could be met.

In summary

Before considering environmental benefits, the gap between biomass electricity and conventionally generated power is $60.50 per MWh. When greenhouse benefits are incorporated, the gap reduces to $4.50 per MWh. Thus, the threshold level of off-site salinity benefits required for biomass electricity to breakeven with conventional power is $1.08 million across the whole project.

Conclusion

This study demonstrates that, putting aside the potential environmental benefits, neither ethanol or biomass electricity are cost-competitive with conventional energy sources (petrol and fossil-fuel power respectively). The assumptions used in the analysis do not discriminate against the biomass products. If anything, we have been optimistic in our choice of parameter values. For instance,

§ a low A$/US$ exchange rate has been used, which makes petrol relatively expensive as oil must be imported, and

§ it is assumed that technological improvements will reduce the current costs of ethanol production by 50 per cent within 15 years.

Even after allowing for potential greenhouse benefits (valued at A$56 per tonne of CO2), ethanol is not competitive with petrol. CO2 would need to be valued at A$100 per tonne to make ethanol break even with petrol. Alternatively, the project would need to yield salinity benefits of approximately $32 million per year (table 6).

The picture for biomass electricity is a little brighter. With the addition of carbon credits (valued at A$56 per tonne of CO2), the net cost of producing biomass electricity is almost equivalent to that of conventional, fossil-fuel power (table 6). At $56 per tonne of CO2, the salinity benefits would only need to be $1.08 million per year to make the project break-even.

The findings suggest that government should be cautious about subsidising biomass fuel projects. The net value of such projects is critically dependent on the future price of carbon, which is by no means certain or guaranteed to rise above $50 per tonne of CO2. Furthermore, the salinity benefits from tree cropping would need to be significant for biofuels to break even with alternative fuel sources. This is particularly true for ethanol production.

The size of implicit subsidies required to support a eucalyptus biomass industry on the scale examined in this study would be considerable. For

Table 6 Summary of findings

	Price gap relative to alternative product	
	Ethanol (200 ML per year)	**Biomass electricity** (240 000 MWh)
Before environmental benefits	25 cents per litre	$60.50 per MWh
Plus carbon benefits		
§ A$56 per tonne CO2	§ Closes gap to 16 cents/L	§ Closes gap to $4.50 MWh
§ Breakeven carbon price	§ A$100 per tonne CO2	§ A$60.50 per tonne CO2
Threshold salinity benefits to breakeven	$32 million over the whole project	$1.08 million over the whole project

Source: CIE estimates

instance, the 25 cents per litre price gap between ethanol and petrol would require a subsidy of $50 million per annum to support the 200 ML ethanol plant. For the 30 MW biomass electricity plant, the required subsidy would be in the order of $14.5 million per annum.

Importantly, there may be cheaper, more cost-effective ways of achieving the same environmental outcomes. For example, there are many other ways of reducing greenhouse gases, which could be cheaper to society than subsidising biomass fuels. Similarly, it may be more efficient to subsidise farmers directly to plant trees for salinity control than to provide the subsidy via the development of a biomass industry.

References

ABARE (Australian Bureau of Agricultural and Resource Economics) 2002, *Kyoto Protocol—first commitment period and beyond*, Australian Commodities, March Quarter 2002 pp 176-197.

__________2001[b] Australian Energy Projections to 2019–20, Research Report 01.11.

Coffey's Geosciences Pty Ltd 2000, *Review of Fuel Quality Requirements for Australian Transport*, report for the Australian government, March.

CSIRO (Commonwealth Science & Industry Research Organisation) 2001, Comparison of transport fuels, CSIRO Atmospheric Research Division, www.dar.csiro.au/res/ggss/

__________2000, Life cycle emissions analysis of alternative fuels for heavy vehicles. Report to the Australian Greenhouse Office, March 2000

MEU (NSW Ministry of Energy and Utilitites) 2000, Greenhouse gas emissions from electricity supplied in NSW: Emissions Workbook, October 2000, http://www.energy.nsw.gov.au

Pannell D J, 2001, Dryland salinity: economic, scientific, social and policy dimensions. Australian Journal of Agricultural and Resource Economics, vol 45: 4, pp 517-546

Polglase, P and Stein, W. 2001, Relative CO_2 emissions from power stations fired by wood or coal – comments on the Peter Barnes Model. July 2001, published on the CSIRO website: www.ffp.csiro.au/fap/bioenergy.html

RIRDC (Rural Industries Research & Development Corporation) 2001, Integrated tree processing of mallee eucalypts. A report for Joint Venture Agroforestry Program by Enecon Pty Ltd. November 2001, RIRDC publication No. 01/160

__________2002, Wood for alcohol fuels: Status of the technology and cost-benefit analysis of farm forestry for bioenergy. Prepared by Enecon Pty Ltd in association with the Centre for International Economics and Stephen Schuck & Associates, November 2002, RIRDC Publication No. 02/141. (available for download at www.rirdc.gov.au)

Shea, S, Butcher, G, Ritson, P, Bartle, J, and Biggs, P. 1998 The potential for tree crops and vegetation rehabilitation to sequester carbon in Western Australia. Paper presented at the Carbon Sequestration Conference, 19-21 October, Melbourne, 1998.

WA Salinity Taskforce 2001, Salinity: a new balance. The report of the Salinity Taskforce established to review salinity management in Western Australia, September 2001