**Summary of full report**

# Wood for Alcohol Fuels Status of technology and cost/benefit analysis of farm forestry for bioenergy

RIRDC/Land & Water Australia/FWPRDC/MDBC Joint Venture Agroforestry Program
by Enecon Pty Ltd in association with Centre for International Economics Stephen Schuck & Associates Pty Ltd - November 2002
RIRDC Publication No 02/141 RIRDC Project No EPL-2A

# EXECUTIVE SUMMARY

**Background**

1. The Joint Venture Agroforestry Program has identified a need to develop farm forestry in many agricultural regions, in particular low to medium rainfall areas. Trees can help balance water flows in many landscapes and thus reduce the adverse impacts of salt that is otherwise brought to the surface by rising water tables. As such, large scale tree planting is seen as an important mechanism for reducing and managing dry-land salinity.

2. If new commercial uses were to be found for wood products, the incidence of tree planting by farmers would be expected to be far greater and more sustainable than if the trees were planted purely for environmental or aesthetic reasons. In addition, commercial uses for trees grown via farm forestry would provide new sources of income for farmers, and potentially add to the economic stability of rural Australia.

3. Plantation forestry, based around pine and eucalypts such as blue gum, is already well established in coastal regions with good rainfall. However, the dryer inland regions of Australia with rainfall of 600 mm or below are not so well suited to commercial forestry with such species. If commercial forestry is to be developed in these regions it will benefit from new industries that are based on the use of tree species particularly suited to the regions; for example the mallee eucalypts that grow in much of dry-land Australia.

4. Of many potential new industries, one that receives particular interest is the production of renewable biofuels from wood. These include the alcohols ethanol and methanol for use as liquid transport fuels. The potential market for these fuels in Australia is considerable, and a liquid fuels industry using biomass for feed may be a driver for tree planting on a massive scale.

**Why alcohol fuels?**

5. Ethanol is already in use in a number of countries, both as a liquid transport fuel in its own right and via blends of ethanol and petrol. It is generally perceived to offer a range of benefits over fossil fuels, including:

a) Lower greenhouse gas emissions
b) Lower levels of certain exhaust emissions
c) Provides octane enhancement to petrol/alcohol blends
d) Domestic production of ethanol allows reduced imports of fossil fuels
e) Can utilise sugar or starch by-products and be part of integrated processing industries.
f) Favours rural industry and employment.

6. Another potential benefit for alcohol fuels, and certainly a reason to better understand them now, is the knowledge that, at some time in the future, crude oil will rise in cost. Ethanol (and methanol) from renewable sources is currently more expensive than fuels derived from crude oil.

7. Against the significant benefits above, these alcohols must not be thought of as the only way to address fuel security and balance of trade issues (with non-renewable options in Australia including liquid fuels from shale oil, natural gas and coal). Also, as the oil industry notes, there are alternative mechanisms for reducing vehicle exhaust emissions that do not require the use of alcohol fuels. If alcohol fuels are to find a significant and secure place in Australia they must offer demonstrable benefits to the triple bottom line of environment, economics and community that make them a preferred choice for our future energy needs.

**Alcohol fuels from wood**

8. Ethanol may be used as a fuel in several ways:

> a) Low level blends with petrol - at levels of up to 10% ethanol may be blended with petrol (commonly called E10) and used in most modern car engines with no modifications.
> b) High level blends with petrol - in Brazil a blend of approximately 22% ethanol (E22) in petrol is used in many vehicles, with only minor modifications to fuel handling systems reported. In the USA there is increasing use of E85, with many major vehicle manufacturers producing flexible fuel vehicles (FFV) that have engines and fuel systems designed to properly utilise this level of ethanol.
> c) Pure ethanol - in both USA and Brazil some vehicles use pure, hydrous ethanol (an azeotrope of 96% ethanol and 4% water). In each case vehicles require engines and fuel systems that are designed with the high levels of ethanol in mind.
> d) Blends with diesel - low level blends of ethanol and diesel fuel are technically feasible. Several different mechanisms are being investigated to avoid phase separation between the ethanol and the diesel, including specialised emulsifiers such as those developed by APACE Research in NSW and other groups in Europe, and mechanical emulsification.

9. Ethanol in Australia is currently produced via the fermentation of materials available as by-products of the sugar and starch processing industries. Such production will be limited by the availability of such low value feed materials. Any new plants that use dedicated sugar and starch feeds successfully will presumably need to allow for the opportunity cost of such feeds for human or animal consumption. In the absence of such projects, any use of renewable alcohol fuels in Australia beyond a few percent of the total liquid fuels market will need to involve wood as feed material.

10. Technologies for the manufacture of ethanol from wood focus on two areas:

> a) Hydrolysis of the wood to recover the sugars that make up the cellulose and hemicellulose in the wood feed. Most current technologies use acid hydrolysis to soften the wood and then break the sugar polymers down into individual sugar molecules. There is also considerable work underway to develop enzymatic hydrolysis to the stage where it can be used instead of acid hydrolysis.
> b) Fermentation of the sugar solution produced. The sugars released from biomass by hydrolysis are a mixture of six carbon and five carbon sugars. This makes the fermentation step more complex than for cane sugar or sugars from starch, which are solely six carbon sugars. A range of organisms are being used and improved around the world for this fermentation step, including modified yeasts, bacteria such as E. coli and Zymomonas mobilis, and thermophilic organisms.

11. There are no full-scale biomass to ethanol plants currently operating anywhere in the world. However there is considerable expertise already in the relevant technologies. More than half a dozen groups in the USA, Canada and Europe have developed, built and operated multi-million dollar pilot plants to investigate different feed materials (wood, MSW, agricultural residues), hydrolysis routes (acid and enzyme) and fermentation pathways. Ongoing R&D work, particularly by NREL and its associates in the USA, is estimated to cost in the order of tens of millions of dollars over the next few years alone.

NREL has identified a range of opportunities for improvements that, if achieved, would serve to reduce the cost of ethanol from wood by up to 50% over the next 15 years. NREL has set a production target of US 28 cents/litre as a research goal for ethanol from wood. Therefore, while there is scope for improvement in many different areas, any work proposed for Australia should be viewed in the light of existing expertise and ongoing programs by experienced overseas organisations.

12. Wood can also be converted to methanol, via a quite different processing route to that used for ethanol. The wood is initially gasified to make a synthesis gas, followed by catalytic conversion of the gas and recovery of methanol. Biomass gasification is well understood already via its role in heat and power generation, although there is still much to learn about managing the gasification to produce synthesis gas optimised for subsequent catalysis. Similarly the catalysis of natural gas to methanol is practised world-wide and provides useful experience for potential wood-based systems. However the various elements of a wood-to methanol plant using this technology have not been put together into an integrated system, even at the pilot scale, and there appear to be no plans for any group in the world to develop such an integrated pilot plant. There is no full-scale wood to methanol plants operating at present.

13. The National Renewable Energy Laboratory (NREL) in the USA has estimated the cost of a 200 ML/y wood to ethanol plant, and the BAL Fuels Project consortium in Sweden has estimated the cost of a 390 ML/y wood to methanol plant. Data from the reports by both groups have been used to estimate the Australian costs for plants to produce ethanol or methanol from wood. Data from these and other reports have also been used to consider the possibilities of feed and process improvements over the next ten to fifteen years, and their impact on production costs.

14. Ethanol is estimated to cost 82 cents per litre in a 200 ML plant built today in Australia using world's best technology. If multiple improvements are achieved over the next 15 years this price may fall by 50% to as low as 41 cents per litre. This cost is based on biomass feed available at $30 per tonne delivered to the plant.

15. Methanol is estimated to cost 62 cents per litre in a 390 ML plant built today in Australia using world's best technology. Some improvements to technology may be possible over the next fifteen years and a price of 50 cents per litre has been used in this report for a lowest price projection in fifteen years time. As with ethanol, green feed delivered at $30 per tonne is assumed.

**Ethanol – wood versus molasses**

16. These cost conversions and price estimates are considered to be very preliminary, but they do allow initial comparisons between the cost of renewable liquid fuels and their fossil fuel counterparts now and in the future. They also allow comparison of the relative costs of ethanol from wood and ethanol from molasses. At present, ethanol from wood is generally more expensive than ethanol from molasses, particularly if the molasses is available at low cost. However forecast improvements could reduce the cost of ethanol from wood to the point that it is similar to or even lower than the cost of ethanol from molasses.

Environmental benefits from tree planting to make ethanol are not obtainable when ethanol is made from molasses.

17. It is also important to recognise that ethanol from wood provides significantly better greenhouse gas reductions than ethanol derived from molasses.

Whereas ethanol from molasses reduces CO2 emissions by 20 –50% over low sulphur diesel, ethanol from wood wastes provides a reduction of some 90%.

**Pricing relative to petrol**

18. A number of major energy groups world-wide regularly predict trends in the future price of crude oil. These have been summarised by the US Department of Energy 1. The consensus of these organisations is that while consumption of crude oil will increase significantly over the period 2000 – 2020, there will be no significant increase to the cost of crude oil over this period. This does not necessarily suggest that the price of crude oil will not increase beyond the twenty-year horizon. Other forecasters predict that oil supplies will start to decline after 2010, with possible effects on prices. For this study an ex-refinery petrol price of 35 cents per litre in 2015 is assumed, which is similar to current prices. Note that alcohol fuels need to be compared with petrol at an ex-refinery price and not a pump price. The price of methanol from natural gas is expected to fluctuate within the range US$100 to 200 per tonne over the next fifteen years, with no major impact from any decline of natural gas reserves. If a figure of US$150 per tonne is used, methanol from natural gas should be available in 2015 at 24 c/l.

19. Relative to petrol, ethanol has an energy density of 0.7. This suggests that, while in 2015 petrol may have an ex-refinery price of approximately 35 c/l, the amount of petrol with energy equivalent to a litre of ethanol will cost 25 c/l. With ethanol predicted to cost, at best, approximately 42c/l in 2015, there is still a considerable gap in relative costs.

20. Methanol has an energy density (MJ/L) that is lower than both petrol and ethanol. In 2015 there is also a cost gap anticipated, with methanol from biomass estimated to cost 50 c/l against methanol from natural gas at 24 c/l.

21. Alcohol fuels also provide octane improvements when blended with petrol for use in internal combustion engines, however a monetary value attributable to this benefit was not determined during this study. Petrol and alcohol fuels are both possible feeds to reformers for fuel cells, with similar energy efficiencies.

22. In view of this large price gap between the cost of alcohol fuels from biomass and the ex-refinery cost of petrol, alcohol fuels cannot be expected to compete on a simple economic basis (ie. No accounting for environmental or other benefits) against petrol unless there is a large, and sustained, increase in the price of crude oil. Such a cost increase is not anticipated over the next twenty years unless, perhaps, there is significant social, economic or political upheaval across the Middle East and the other oil producing nations. In its absence, and thus without consideration of security of supply, the case for alcohol fuels in Australia should be made on other benefits from such products and their manufacture.

**Benefits of a wood-based alcohol fuel industry**

23. It is recognised that alcohol fuels from wood feeds can provide significant benefits in terms of greenhouse gas reduction, both over petrol and over many other renewable fuels. The planting of trees in selected areas is also anticipated to bring about salinity benefits and potentially other benefits to the environment and rural Australia. In this study greenhouse gas benefits and on farm salinity benefits have been assessed in terms of their ability to "close the gap" that is identified for biomass based fuels.

A value of $56 per tonne for CO2 abatement has been used, based on work by ABARE. Values of 1.4 c/l for methanol and 3 c/l for ethanol were estimated for on farm salinity benefits, based on a case study for planting mallee eucalypts in alleys in the Western Australian wheat belt and the different ratios of biomass required per litre of ethanol or methanol produced.

24. While both these benefits reduced the cost gaps between biomass-based fuels and their fossil fuel equivalents, they did not close the gaps completely. The remaining gap, based on relatively constant petrol pricing over the next 15 years, was estimated to be 13 c/l for ethanol and 15 c/l for methanol. Australia is expected to import more than 50% of its crude oil from overseas by 2015, and if the price of crude oil increases, these gaps will decrease. Conversely, if the value of the Australian dollar increases against the US dollar (A$1.00 = US$0.50 was used in this study) the cost of importing crude oil will decrease, which will work against the use of alcohol fuels.

25. There are other environmental benefits and social benefits both on-farm and off-farm for widespread tree planting which could support the use of alcohol fuels. These benefits will help to further close the price gap, but they were not assessed quantitatively in this report.

They include:

a) Protection of roads, towns and other infrastructure from damage by waterlogging and salinity
b) Biodiversity benefits, particularly by reducing or preventing the flow of saline water into rivers, wetland and other biodiverse areas
c) Protection of the rivers in the Murray Darling Basin from salinity and its impact on irrigation-based industry
d) Contribution to sustainable farming, and thus to healthy, sustainable rural communities
e) Broader socio-economic benefits such as regional development and jobs (which have been identified in US studies of bio-ethanol production).

26. It is possible that other products could be produced in conjunction with the manufacture of alcohol fuels. The work proceeding in Western Australia with integrated processing of mallee eucalypts for renewable electricity, activated carbon and eucalyptus oil is one example of multiple products supporting improved project economics. Co-products relevant to liquid fuel production include oils extracted from leaf material and new products from the lignin. If produced in sufficient quantities or at sufficient value, such co-products would improve the commercial viability of alcohol fuel production.

**Alcohol fuels or renewable electricity?**

27. Electricity from biomass was also examined, as a comparison with biomass based liquid fuels. Technology for electricity from biomass is well established and widely used around the world. Based on a 30 MWe power plant using similar wood feed to the liquid fuel plants, electricity from biomass is more expensive than electricity generated from fossil fuels. However, when CO2 benefits and on farm salinity benefits are costed in the same way that they were in the liquid fuels analysis, biomass electricity becomes marginally cheaper than fossil fuel electricity. As such, on the estimates prepared in this study, electricity seems to be a more economically attractive product from biomass than ethanol or methanol over the next fifteen years, even when potential advancement in liquid fuel technologies are considered. Distributed electricity generation can have other benefits over centralised generation (such as optimisation of transmission infrastructure) however such issues typically occur on a case by case basis and were not considered in this study.

Any other benefits attributable to large scale tree planting and co-products should apply to electricity generation just as they would to alcohol fuel production.

**Recommendations**

Technology In any new Australian work looking at ethanol from wood, the large amount of technology available from overseas, and the large amount of research expected overseas this decade, should both be given careful consideration. In this way, local research can be focussed to give the best result for Australia without simply reproducing the work that will be available from other groups.

Particular areas of interest could include the examination of Australian biomass feeds (eg. eucalypts) as opposed to the straws and corn stover that are the focus of much of the overseas work. Examination of the processes and costs of taking these local feeds through to fermentable sugars will also be relevant to other new industries (for example renewable plastics such as PLA) and to production of co-products. The assessment of methanol from wood in this study has been hampered by a relative lack of data on its manufacture and its use in petrol blends. In the absence of integrated work overseas, even at the pilot scale, the development process for this technology in Australia could be more costly than that for ethanol.
Prior to any major research undertakings for methanol production, it is important that issues of blending and use are considered in more detail. It would also be possible to conduct a more accurate feasibility and costing study based on information from providers of each of the relevant processing units to make up a wood to methanol plant.

**Benefits to the triple bottom line**

If a more comprehensive cost benefit analysis is desired, work will need to be undertaken to examine the range of off-farm salinity benefits as well as other benefits, across a variety of regions. Ideally, particular regions would be identified that offer maximum benefits from large scale tree planting. This would be a far more significant undertaking that the work done for this report.

**Co-products:**

Other products produced synergistically with alcohol fuels offer another method of reducing the price gap between these fuels and petrol. Specific research pertaining to alcohol fuels and co-products from Australia plantation trees is in its infancy, and yet it offers great potential for sustainable new rural industry.

Current work with multiple products from Australian tree species must continue if this avenue for helping to close the alcohol fuel price gap is to be better understood. Work with value-added products from lignin may assist a new alcohol fuels industry and may also provide technologies of benefit to the existing lignin producers in the pulp and paper industry. In the absence of lignin co-products, the economics of parallel production of renewable electricity from lignin should also be better understood.

**Government policy:**

A large price gap exists between the cost of alcohol fuels from biomass and the ex-refinery cost of petrol. Unless there is a large, and sustained, increase in the price of crude oil, alcohol fuels cannot be expected to compete "head to head" against petrol on a simple economic basis (ie. No accounting for environmental or other benefits).

However, it is possible that alcohol fuel plants may be justified in certain regions from a "triple bottom line" perspective that offers multiple benefits to the community. In this case, it is essential that there are Government policies in place to provide financial incentives for alcohol fuel manufacturers that reflect these community benefits.

As with similar situations in other alcohol-producing countries such as the USA and Brazil, the policies will need to be sufficiently stable as to underpin major capital investments. Given the decline of domestic crude reserves and increased imports of overseas crude over coming years, it is expected that the Government will regularly consider the implications to Australia of increased crude oil prices and of increased risk to crude oil supply.

The strategic implications of an alcohol fuels industry should be included in any such considerations. It must be remembered that a large biomass alcohol fuels industry will involve billions of dollars of investment in plantations and processing plants and significant lead times for establishment of even short rotation plantations. Such an industry will ideally be established from a comprehensive base of technical, financial and environmental data.