ENERGY RESEARCH AND DEVELOPMENT CORPORATION

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Biomass in the Energy Cycle Study
Part 1 - Main Report

Strategic Industry Research Foundation
written by principal researchers
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September 1994

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PREFACE

This report is the result of a twelve month study conducted by the Strategic Industry Research Foundation. The study was initiated and managed by the Energy Research and Development Corporation (ERDC).

The principal researchers were Dr Ron Mendelsohn and Kim Sweeny. The other member consultants were:

ACIL Economics & Policy
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Bio-Resources Australia
Biosis Research
Redding Energy Management
Read Sturgess and Associates
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Nine Federal and State bodies combined to fund the report—Australia's first ever market-driven study into the use of biomass as an alternative energy source. These bodies are:

Energy Research & Development Corporation
Department of Environment, Sport & Territories
Department of Industry, Science and Technology
Rural Industries Research and Development Corporation
Grains Research and Development Corporation
Land & Water Resources Research & Development Corporation
NSW Office of Energy
MFP Australia
SA Office of Energy.

Following the oil crises of the 1970s, there was considerable interest in Australia in the development of biomass as an alternative energy source. Work carried out at the time focused on the development of hydrocarbon fuels, particularly ethanol, for transport purposes. However, interest and funding waned again during the 1980s.

The development of biomass-derived energy services which can convert it to electricity, for example, has been increasing in recent years. The economic potential for Australia to develop the industry and its related export services and products is substantial.

This study was initiated to try and define the market potential of biomass as an alternative energy source and to develop a strategic plan for the industry's future.

It has identified markets, analysed current biomass resource supplies and conversion technologies and examined key issues relating to further development of the industry.

The strategic plan has set out a program of activities to develop and promote the biomass-based energy industry in Australia. These activities range from market development both in Australia and overseas, through to research, development and demonstration of promising technologies.

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EXECUTIVE SUMMARY

ENERGY MARKETS

While most biomass to energy technologies have still to prove their economic competitiveness, they continue to attract government support because of their assumed benefits in helping to solve economic and strategic problems associated with a perceived increasing dependence on fossil fuels, principally oil.

Over recent years the emphasis has focussed on the role biomass-derived energy may play in meeting increasingly stringent environmental targets for atmospheric pollution and greenhouse gas reduction and land rehabilitation .

Government subsidies have been introduced in Europe and the USA to encourage the development of the biomass energy market. In Europe this has been done to promote the role of energy crops as a substitute for crops for food. In the USA the emphasis has been to divert less productive agricultural land to energy biomass production.

The analysis of international and Australian energy markets indicates that the price of conventional energy sources will rise only mildly on world markets over the next fifteen to twenty years and there appears to be little in the way of supply constraints emerging over this period.

The price of petrol and diesel to the customer in Australia has a large component due to government taxes and excise, whereas this is not the case for biomass derived ethanol.

The market for electricity in Australia is currently subject to radical change which is likely to lead to pricing reflecting the true cost of supply. This will probably mean that prices to commercial and industrial users in urban areas will fall, while prices to consumers at significant distances from generating facilities are likely to rise. Prices to remote users will rise further if it is necessary to extend or upgrade the grid.

The arguments for supporting biomass to energy technologies in the medium term will therefore rest mainly on environmental concerns rather than economic feasibility in other than niche applications.

Technologies based on using various animal, human, food processing and abattoir wastes may prove the exception.

Countries with fast developing economies in the Asia-Pacific region have rapidly increasing demand for power and transport fuels. The inadequate infrastructure in these countries opens opportunities for the introduction of systems for producing electricity from biomass. In the longer term opportunities could exist for alternative transport fuels. The most prospective countries would appear to be Korea, Indonesia, Philippines, China and India. For certain niche areas the USA is a potential market.

RESOURCES

Biomass resources have been reviewed to assess their availability, both current and in the future, together with an assessment of likely costs and availability.

The resource scoping is presented in the following sections: field crops for starch and sugar; field crops for vegetable oil; lignocellulose production from forests, crop and forest wastes including municipal solid wastes, animal wastes and waste as by-product from food processing. Information for each of the resources studied provides data on production volumes, land areas being used, composition characteristics of the biomass that are of importance to energy production and price. Comment on expansion potential is also included.

The review has shown that crops used for food are very expensive, costing between $150 and $400 a tonne. Major opportunities exist in residue utilisation from growing field crops and growing trees for wood, pulp and land rehabilitation (agroforestry). Industry, animal and municipal wastes are of particular interest given there is an increasing cost of disposal associated with their production.

CONVERSION TECHNOLOGIES

The report provides an overview of the state-of-development of each biomass to energy conversion route, together with the key technical and economic parameters required to calculate the cost of energy products over a range of capacities.

The technologies reviewed fall into two broad categories for the biomass, thermal/chemical and biochemical conversion routes.

Included in the first category are direct combustion, gasification, pyrolysis, cogeneration, methanol production, vegetable oil extraction and esterification and oxygenates production.

The second category includes biochemical conversion to ethanol and anaerobic digestion to biogas.

Australian technologies assessed include small and large scale gasifiers, anaerobic digestors, and an emerging process for production of furan oxygenates. All these technologies offer opportunities for further development.

The study was unable to access sufficient information to fully evaluate an Australian technology being developed for converting lignocellulose to ethanol.

ENVIRONMENT

Biomass systems were considered in terms of both their global and local impacts.

Global environmental issues considered were:

Greenhouse gas emissions and global climate change;

Deforestation and land degradation, through erosion, salinisation and/or desertification which has resulted in significant loss in the extent of arable land;

Unsustainable land use practices, including forestry;

Loss of biodiversity.

Whilst the State and Commonwealth Governments have established a number of relevant policy activities to combat these problems, the most direct externality is the cost to rehabilitate and revegetate degraded and cleared land.. There is already a substantial amount spent on revegetation and land rehabilitation each year across Australia without a direct income incentive. Much of the re-afforestation is potentially a significant resource for energy production if the appropriate species are planted.

Energy production from biomass resources has the potential to significantly reduce the impact of these general or global environmental issues :

A significant replacement of fossil fuel use with biofuels would result in reduced greenhouse gas emissions together with progress towards carbon neutral fuel production, where the volumes of carbon emissions are equivalent to those sequestered in the biomass feedstocks;

Economic demand for biomass feedstocks would result in dedicated re-afforestation plantations on suitable degraded or marginal agricultural land. This has the potential to rehabilitate large areas of land affected by erosion or salinisation without creating an economic burden to the nation;

Integrated harvesting of a range of biomass feedstocks has the potential to reverse unsustainable land use practices in Australian agriculture. However, for forestry, potential environmental benefits may be offset by corresponding impacts of intensive harvesting and management techniques; and

Re-afforestation and rehabilitation of degraded or marginal agricultural land has the potential to reduce the need or the desire to clear native forests, woodlands and grasslands, and which could result in the effective maintenance of Australia's biodiversity.

There are local environmental issues which need to be considered on a case-by-case basis when biomass based systems are introduced.

In the case of ethanol as a neat fuel, special vehicles and a modified distribution network would be required. The fuel-flexible vehicle has been demonstrated in the US to facilitate market entry by enabling the use of petrol and ethanol in any combination.

Food Processing Wastes

Ethanol produced from food processing wastes is the process most competitive with petrol and diesel fuels with the cost of ethanol produced ranging from 20 to 50 cents a litre.

Based on available information, there is at least a potential to produce 200 million litres of ethanol a year. It is likely that there is room for at least a further 100 million litres a year, and possibly a total capacity of up to 500 million litres.

Assuming a single plant capacity of 15 million litres, the total number of plants could range from 13 up to 33. This implies a workforce associated with these plants of between 150 and 400 people. A further 75 to 200 jobs arise from the indirect effects of the introduction of these plants. This however, does not take into account any job losses arising from any transport fuel production facilities displaced.

The impact of introducing these plants at a national level would be small, but the impact on regional economies could be significant

Other issues raised in the case studies related to the capital and operating cost estimates of this type of ethanol facility. Estimates made by the food industry were significantly lower, by a factor of two or three, than those made from the formal engineering approach developed in this study. It is of importance to clarify whether this type of plant can be built cheaply as its potential impact on project returns is of some importance.

The conversion of food wastes to ethanol raises environmental issues. The use of ethanol in place of petrol or diesel fuels results in reduced greenhouse gas emissions from vehicles, and the utilisation of food processing wastes to produce the ethanol is positive with respect to disposal of the waste, which would otherwise be discharged to landfill or dumped into the environment. However, the ethanol plant produces two waste streams itself The solid wastes, containing yeasts, essential amino acids and other food values can be sold as animal feed. The liquid wastes will be relatively high in oxygen demand and probably require aerobic treatment before being recycled or disposed of as irrigation water. These requirements will vary from site to site, and evaluation is important before a project is initiated, given the additional investment that might be required on small projects of this type.

On the basis of this analysis, the major actions required are:

the instigation of further work to compile an exhaustive inventory of food processing wastes in Australia

the initiation of a program promoting and explaining the benefits of ethanol production and encouraging the food processing industry to adopt the technology for ethanol production for the liquid fuel markets

an examination of current waste disposal practices and charges to see if there is scope to change these in such a way as to encourage the adoption of this technology

the initiation of a program to provide financial support for feasibility studies

the support of a project to demonstrate actual construction costs, the benefits of the technology, and waste stream outputs and treatment needs.

Lignocellulose

Ethanol produced from lignocellulose is less competitive than ethanol from food industry wastes. However, the potential volumes are very large, based on the resources presently available from cereal and wood production and from possible future agroforestry wood production.

The cost of ethanol produced from lignocellulose on a large scale (50 to 120 million litres a year) ranges from 70 to 85 cents a litre. This is based on the use of a mix of fully costed cereal residues and agroforestry wood at a price of $40 a dry tonne for cereal straw and $118 a dry tonne for wood, the average price of the mix being $60 to $75 a tonne.

Using agroforestry wood recovered as a residue from pulpwood or sawlog harvesting, or as a residue from eucalyptus oil extraction, ethanol can be produced at between 60 and 70 cents a litre. The cost of the resource in this case ranges from $20 to $36 a dry tonne, resulting in an average price of the mix of between $26 and $42 a dry tonne.

To match the ex-refinery price of petrol at 20 cents a litre, the cost of producing ethanol from lignocellulose must drop by between 30 and 60 cents a litre. To match the price of petrol delivered at the pump of about 50 cents a litre, the cost of production only needs to fall by between 4 and 20 cents a litre.

Sufficient biomass resources could be available to produce 6,000 megalitres of ethanol equal to a third of petrol consumption in Australia. The problem is not total resource availability but the price of this resource.

The potential for employment creation from operating 50 plants is 3,000 persons, with another 1,500 jobs created as an indirect effect of the introduction of these plants. Constructing these plants would cost $8.6 billion .

The technology for producing ethanol from lignocellulose is still in development and likely to produce excise free ethanol competitive with petrol at the pump in the second half of this decade.

The largest cost items in the lignocellulose plant are the feedstock handling and pre-treatment stages (approximately 22% of total facility cost) and the simultaneous saccharification and fermentation stage (approximately 15%). They therefore offer areas for further potential cost reduction.

Construction of the NREL demonstration facility presently underway in the US should help clarify capital and operating costs, as will the design studies being undertaken in Australia by APACE Research. A market opportunity for technologies in this area could exist both in Australia and the USA if the APACE Research process could be proven.

Ethanol costs are more sensitive to feedstock prices and by-product credits than to technological improvements.

The US is targeting the cost of delivered biomass from intensive biomass production at US$34 a dry tonne for later this decade. The biomass costs that closest approach this US target in Australia are those of cereal and agroforestry residues, at between $40 and $55 a dry tonne. There appears to be an opportunity for cost reductions.

Little work has been done in Australia to assess and reduce the cost of biomass production, harvesting and transport for energy.

Potential income from high value by-products reflected significantly and positively on the ethanol price. However, a preliminary investigation did not confirm any immediate potential market for lignin. The review of future opportunities to realise by-product income is important.

Biomass production for ethanol has the potential to contribute to the alleviation of the most pressing environmental issue for agriculture in Australia namely resource degradation through salinity and erosion.

Ethanol from wheat straw would use only 21% of energy used in the production of gasoline and produce only 18% of life cycle CO2 emissions and 26% of life cycle total greenhouse gas emissions compared to gasoline.

It is important to note that the greenhouse gas emissions from the ethanol combustion process in vehicles are similar to those for gasoline combustion but are carbon neutral if the equivalent type and quantity of biomass is regrown to sequester the carbon which is eventually released through fermentation and combustion.

The issues arising from the discussion of the above and requiring action are:

> For Government to confirm that the present tax break for ethanol fuels in Australia will continue, enabling its market as an octane enhancer and fuel extender to develop with confidence
>
> A study be undertaken to assess the impacts of additional lignocellulose harvesting for energy production on the nutrient cycle of multiple use native forests and the attendant long term environmental and economic impacts.
>
> A cross disciplinary study be undertaken to assess the impacts of a lignocellulose market on native forest management techniques and consequent social, economic and environmental impacts.
>
> Further work is required on quantifying and valuing the net benefits of agroforestry biomass production and biomass production for environmental purposes and the extent to which these benefits can be credited to ethanol production
>
> Examine the potential for cost savings arising from the introduction of innovative one-pass techniques for harvesting and transport of wheat straw, forest, wood residues
>
> Assess the potential of multiple product tree crops for energy and other higher value products
>
> Assess the potential benefits and costs of high yield dryland and sewage irrigated coppice farming of energy crops for environmental and energy purposes
>
> Assess the potential for developing and demonstrating a leading edge ethanol from lignocellulose technology able to process a range of feedstocks
>
> Support research aimed at significantly reducing the costs of both the feedstock handling and pre-treatment stage and the simultaneous saccharification and fermentation stage of the process
>
> Investigate innovative high-value opportunities for lignin utilisation

Particular attention should be paid, once a demonstration plant is operational, to quantifying the costs associated with treating the waste streams from this process.

Waste Paper

Ethanol produced from waste paper costs between 78 cents to $1.00 a litre for a plant size of 6 million litres a year using 22,000 tonnes a year of paper. This cost is likely to be significantly less for a larger plant, with a capacity of, say, 30 million litres a year.

The extent to which this technology can be introduced is crucially dependent on how economic it is to recover paper from waste streams. If the price of landfill rises to levels such that this becomes economic, there is a potential resource of some 800,000 tonnes, which can produce 225 million litres. There is a further resource available of about 250,000 tonnes of papers coated with waxes and inks.

The conversion technology utilised in the economic assessment here is the NREL process, and the same problems exist with this as discussed previously.

The feedstock resources are processing waste from waste paper recycling plants and recycled telephone books. There are considerable environmental benefits from the recycling of these waste products, including reduced landfill disposal and a reduction in the need for new forest plantations.

The actions arising out of the investigation of producing ethanol from waste paper are:

a study should be conducted into the impact of landfill charges on the economics of recovering additional paper from waste streams

more information should be obtained on technologies being developed specifically to convert waste paper to ethanol with a view to assessing whether they would be viable in Australia.

Electricity from Biomass

Electricity generation is moving from a situation characterised by monopoly producers in single markets to nationwide markets supplied by electricity generating companies competing with each other. The purpose of government reforms is to increase competition leading to greater economic efficiency and lower prices.

This provides a considerable challenge for biomass-based electricity. However, cost-reflective transmission pricing presently being considered could result in increased prices to end users in remote areas, thus providing a niche market for biomass.

Australian electricity prices are the fourth cheapest in the OECD, averaging out at about 8cents a kWh to commercial and industrial users. Busbar costs i.e. costs where the power station links to the network, are around 3 to 4cents a kWh for existing coal fired stations and 5 to 7cents a kWh for new coal-fired stations, with gas-turbine stations around 6 to 8cents a kWh. Existing production costs can be as low as 1.5cents a kWh, for Victorian brown coal-fired stations.

Studies undertaken by industry interests have identified more than 300 sites around Australia where residues are available or which have problems with the disposal of wastes. These could be utilised for power generation.

The local and export market potential for technology to produce electricity from biomass gasification and anaerobic digestion systems could be significant. Extension of the grid and reliability of supply are also significant issues in the developing Asian economies, offering opportunities. The focus of studies should be Europe and the USA and closer to home, Indonesia, Korea, Philippines and Malaysia.

The increasing costs of water and environmental clean-up from intensive animal rearing facilities and the food industry are catalysts to market development.

Direct Combustion and Gasification

The electricity case studies have electricity production costs at or near competitive prices, at least for replacement of electricity now purchased, and especially at end-of-grid or stand-alone sites.

A study examining the economics of a 10 MW grid-connected direct combustion power plant at Orbost in Victoria reports that biomass feedstock is required to be purchased at $10 a tonne to be viable. The feedstock totalling about 120,000 tonnes a year is expected to be made up of sawmill wastes and forest residues. A second project of capacity 5 MW based on direct combustion of free rice hulls at a rice mill was viable. Another direct combustion project using MSW is being examined for the City of Heidelberg in Melbourne. Under certain achievable scenarios the project is economic being sensitive to gate or burn fees charged by the Council, the cost of landfill and the price chargeable for steam and the return expected by the owner.

An industry-based case study examined a gasification project to cogenerate heat and power from wood wastes for a timber products factory in NSW. The project requires free feedstock to be competitive.

Case studies were examined for gasification processes using an emerging Australian gasifier technology with cotton stalks and gin trash as the biomass resource. Power production costs are in the range 3 to 6cents a kWh at a biomass price of $10 a tonne.

The theoretical maximum generating capacity from wood residues is 1,500 MW (or 150 plants of 10 MW), from cotton stalks and gin trash is 50 MW, and from MSW is 450 MW. This is a total of 2,000 MW or about 5.5% of current installed capacity in Australia. If all these plants were introduced the direct employment created would be about 2000 with a further 1000 jobs resulting from the increased economic activity.

The issue of scale is important for electricity from biomass. The installed capacity of the present Australian electricity generation system is 35,000MW. The largest biomass based plants now under consideration are about 40MW, while the plants in the case studies examined were in the range lOOkW to about 5MW.

Gasifiers, for biomass as for coal, have the potential to achieve higher thermal efficiencies and lower emission levels than combustors.

The SECV in Victoria is developing a large scale gasifier for firing with brown coal as a candidate for the next generation of clean coal technologies for power generation. Given the characteristics of brown coal, this concept could be modified for biomass-firing, including such feedstocks as wood, cereal residues, MSW and other wet wastes. No work has yet been done by the SECV in this area. The early stage of development world wide of this technology, presents a market opportunity for applying this process to biomass.

The BEST/TREElectric small-scale gasifier technology is promising and the local and overseas market for a gasifier able to operate on a range of biomass feedstocks is potentially large. However, it must be emphasised that the project is still at the laboratory stage.

The Heidelberg site is particularly interesting from an environmental viewpoint. On the one hand, landfill is becoming increasingly costly and sites are facing mounting community opposition. Energy from landfill gas is becoming commercial, with apparently little public debate. On the other hand, incinerators are the focus of strong community concern about their environmental impact.

The recommended actions arising from the analysis of electricity produced by direct combustion/gasification are

further work should be undertaken to identify those primary resource processing facilities such as sawmills and cereal processors which have access to wastes at no cost, to promote this technology. This should concentrate particularly on end-of-grid locations

the demonstration of small-scale gasification cogeneration technologies should be supported the development and testing of the gasification of biomass fuels, including MSW, using the SECV process should be supported

export opportunities for demonstrated gasification technologies should be identified and facilitated

further studies of export opportunities, with a focus on Indonesia, the Philippines, Korea and Malaysia should be undertaken

Anaerobic Digestion

The case studies on this technology examined the construction and operation of a regional biogas waste treatment facility to process the putrescible portion of sorted municipal waste, industry wastes from the food processing industry and from intensive animal rearing facilities.

The cost of electricity produced is 5cents a kWh for a 10 MW plant provided the project is paid to dispose of wastes and markets can be found for the cogenerated heat and fertiliser. At larger capacities, such as the plants considered here between 45 and 75 MW, the financial performance is much less dependent on by-product income.

Fertiliser sales are critical to project viability. Whilst there is anecdotal evidence on the use and performance of the fertiliser in Australia the issue of its market value remains unresolved.

The energy potential from MSW totals some 600 million cubic metres of biogas a year, with an energy potential of 90 million GJ, which could be produced in 50 digestor facilities with a capacity of 32,000 cubic meters a day.

This would create directly 250 jobs and around another 125 jobs indirectly.

There are at least 15 to 20 wineries in Australia that are large enough to install anaerobic digestors to treat their wastes, with a total energy potential of more than 70,000 GJ of energy. The potential market is several times this if the food processing industry is considered as a whole.

The case study indicates opportunities in both country regions and in semi urban regions in their early stages of development, such as exists in the Pakenham region.

Such plants should be built at sites to maximise the possible return from process by-products, in particular where there is a ready market for the gas, for the hot water produced in a cogeneration system and for the digested sludge to be used as a fertiliser.

The environmental implications are mainly benefits to the local and regional communities in the provision of a centralised waste treatment facility and the potential for capturing untreated waste water and other waste products presently disposed of on land or to landfill sites.

Other environmental benefits include the reduction in CO2 and CH4 gas emissions from the decay of the solid fraction of the biowastes effluent, and the production of electricity for export to the regional grid. A qualitative analysis would suggest that there is the potential for significant savings in energy and greenhouse gas production. The actions recommended in this area of biomass to energy system development are:

Further work should be done on the price and demand for by-products, in particular organic fertilizer

A plant demonstrating grid-connected regional biogas production from a mixed waste stream should be supported

The potential markets for the application of anaerobic technologies developed in Australia should be identified and demonstration encouraged in key market niches

Export opportunities for demonstrated technologies should be identified and facilitated, with particular emphasis on the US, Korea and Malaysia.

STRATEGIC PLAN

The Strategic Plan sets out a program of activities to develop and promote the biomass-based energy industry in Australia based on the most promising biomass-based energy systems.

These are:

- liquid fuels production from food processing wastes and lignocellulose
- heat and electricity production from a number of waste streams including municipal solid waste, food processing and other industrial wastes, and animal and human wastes.

The activities proposed range from market development both in Australia and overseas, through to research, development and demonstration of promising technologies, depending on the stage of development of each system in Australia. For those that are at the commercial stage or close to it, the major activities required to promote them are industry and market development. For other systems, including leading edge Australian technologies, further research and development is required. Support for demonstration projects would assist the adoption of all these systems in the domestic market and make access to overseas markets easier.

For both conventional and alternative energy systems in Australia, government programs can have a substantial effect on the cost of raw material inputs as well as the price of the final energy product. Government policy stances will be important therefore in determining the short and medium term viability of the biomass-based energy industry in Australia.

This Strategic Plan is organised around three major programs. These are:

1. Industry and Market Development Program
2. Liquid Fuels from Biomass Program
3. Heat and Electricity from Biomass Program

Projects have been developed within the three programs. For each project a set of objectives is identified, a brief description and rationale is given, the key stakeholders are identified and a list of required actions and expected outcomes are provided.

1.0 INTRODUCTION

1.0 INTRODUCTION

The main body of this report comprises seven sections which take the reader through an overview of energy market issues, assessment of biomass resources, conversion technologies, a selection process through which biomass energy systems with most potential are identified, a detailed analysis by case study of these systems and finally the development of an action plan for the industry in Australia, based on the identification and analysis of the main strategic issues.

In addition to the main body of the report there are seven appendices which mainly comprise the detailed reports from individual consultants that support this volume of the report. These appendices provide the opportunity for the reader to gain much more detailed knowledge and analysis, although the main report has been written as a stand-alone document.

While every attempt has been made to draw on the more detailed consultants' reports, the emphasis has been on providing the reader with a comprehensive, readable and accessible document.

2.0 ENERGY MARKET ASSESSMENT

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2.1 INTRODUCTION

This report examines a number of technologies for producing energy from non-traditional sources, as alternatives to oil, natural gas, coal and hydro, which are used to provide transport fuels, electricity and industrial and domestic heating.

Except for some established niche uses such as the use of bagasse in sugar production and methane production from landfill sites, technologies which convert biomass to energy are generally not yet competitive with energy derived from conventional sources. Despite this governments have, over the past 20 years, continued to support the development of biomass to energy technologies and to encourage energy consumers to switch from traditional to biomass-derived energy.

There are a number of reasons for this including:

concerns about the supply and price of traditional energy sources
- mainly oil;
environmental considerations;
economic policy considerations.

The relative importance of these factors vary for example the USA gives strong emphasis to the effect of energy production on the environment while in Europe a lot of the interest rises from the possibility of converting agricultural production from food into energy feedstock.

The oil shortage of the 1970's led to a heightened interest in alternatives to oil. The cost of oil was projected to continue increasing virtually indefinitely, while the available supply was projected to diminish. In the USA, Europe and Japan in particular, governments were also concerned about a projected increasing dependence on oil imports from unstable sources of supply.

This combination of strategic and economic considerations resulted in governments allocating significant resources to the development of alternative energy technologies and in some cases to introduce subsidies to encourage the use of these energy sources. However, the price of oil did not continue to rise, substantial additions to existing reserves were discovered, there was substitution of oil for coal and natural gas, both of which are abundant, energy saving technologies were introduced, and more countries emerged as suppliers on world markets.

Despite this governments have continued to support alternative energy technologies because the supply of oil (and other non-renewable fossil fuels) is finite and the factors driving policy in the 1970's and 1980's will emerge again even if this is in the longer term. As an example, in the USA the Energy Policy Act has among other things, established a program to switch the federal government's transport fleet from gasoline to alternative fuels progressively over ten years.

While the economic and strategic pressures to develop alternative energy technologies have eased somewhat, this has been replaced by an interest driven by environmental considerations. There has been increased concern over the past ten years about emissions to the air arising from the production and use of energy. These emissions are in two categories:

hazardous or noxious emissions from transportation and electricity production such as carbon monoxide, oxides of nitrogen and sulphur, volatile organic compounds, ozone and particulates.

greenhouse gases, principally carbon dioxide and methane, and to a lesser extent, nitrous oxides.

Governments around the world have progressively tightened the environmental regulations covering noxious or hazardous emissions, perhaps the most famous being the standards set in California for emissions from new vehicles with the principal aim being to reduce photochemical smog.

A number of governments, including Australia, have adopted a target to stabilise the emissions of greenhouse gases at 1988 levels by the year 2000 and to reduce these emissions to 20% below 1988 levels by 2005.

The production of energy from biomass sources, in particular the production of methanol and ethanol as petrol substitutes or enhancers, is seen as a way of contributing to the achievement of these greenhouse targets. Firstly, the use of these fuels is believed to be less polluting and secondly, growing biomass resources such as trees, cereal and other crops is believed to be a way of removing carbon dioxide from the atmosphere. The capture and use of methane produced in landfills and from animal and human wastes, is also regarded as environmentally beneficial as it prevents this gas leaking into the atmosphere.

The other main reason for government interest in biomass to energy technologies is because of its implications for agricultural policy. European governments have been under increasing pressure, most notably through GATT, to reduce the subsidies paid for agricultural production in Europe. Part of the response has been a program to subsidise farmers to reduce the amount of land used to grow food. Energy crops are seen as a substitute for food crops. As an example, the European Commission currently is proposing a lower rate of excise duties for motor fuels produced from agricultural sources as a way of stimulating demand for energy crops. There are a number of state and federal subsidies already in existence in the USA for ethanol used as a motor fuel.

While governments continue to encourage biomass to energy technologies a number of recent studies have cast some doubt on the economic, energy and environmental benefits claimed for biomass-based energy.

The International Energy Agency's report on biofuels, the Bureau of Transport and Communication Economics' study of alternative transport fuels, and some US analyses have questioned whether, in light of the generally higher cost of biomass-derived energy, the environmental benefits are any better than using conventional energy sources.

For instance, cars running on natural gas emit unburned methane and methanol produces formaldehyde which is classed as a probable carcinogen in California. More generally the application of life-cycle analysis techniques seem to indicate that energy use and greenhouse gas emissions are least equal to petrol for ethanol produced from cereal crops when oil and coal are used as the process fuels. However, they are significantly less when biomass is used as the process fuel.

2.2 INTERNATIONAL ENERGY MARKETS

The competitive position of energy derived from biomass resources over the next 15 years will be determined to a large extent by what happens to the price of energy produced by traditional means. Clearly, without the benefit of an accurate crystal ball, only general statements can be made about likely international energy market developments over such a comparatively long period.

The level of uncertainty may be illustrated by looking back about 15 years. The second oil shock of 1979 saw the nominal price of crude oil increase from US$13 to US$34.

During this period there also has been steady growth in the estimates of the world's total oil resources, undermining the use of such estimates as measures of scarcity of production potential.

However, there is reason to believe that forecasts are improving. It is not simply because more and better qualified people are engaged in the task. It is also the fact that the oil market today is a freer market that it has ever been. The "Seven Sisters" have gone and OPEC, which was never a very effective cartel has become (and is likely to remain) principally a forum of co-operation between producing country members of very diverse (and often conflicting) interests. OPEC is sustaining a higher price in the market than would be realised without that co-operation but this is a bargain between the very low cost producers, notably Saudi Arabia, who could increase revenue by allowing prices to fall, and the more volatile, principally Arab, Muslim developing countries whose radical prescriptions threaten the long term future markets and other interests of the Southern Gulf states. The arithmetic of this equilibrium is a powerful argument to expect it to be maintained. And the way oil markets behaved over the course of the Gulf War of 1991 was a demonstration of the robustness of the equation.

The present study relies principally on the International Energy Agency (EEA) study "World Energy Outlook" of 1994, which has a time horizon of 2010.

The EEA reference case outlook is based on an average imported crude oil price rising gradually to $28 a barrel by 2005, and remaining constant thereafter (constant 1993 US dollars). A 1993 price of $28 is close to the average price between 1974 and 1992 and just over half the level of the 1980-81 oil price peak of nearly $55 a barrel. To reflect possible capacity bottlenecks, the rise in prices is assumed to be faster in the 1990's.

The above reference case oil price is $2 a barrel below the 1993 "World Energy Outlook" and significantly below that of the IEA's 1991 energy outlook where it was assumed that oil prices would rise to slightly above $38 by 2000 ($35 in 1990), and stay at that level beyond that date. The reduction in the assumed reference oil price reflects, to some extent, a more optimistic supply outlook (ie. geological prospects), as many countries that were closed to Western capital and technology until very recently are gradually opening up.

Biomass-derived energy forms will compete principally with products from crude oil, and electricity. As described above, there is a well-developed world market for crude oil. There is no such market for electricity, although there is a high (and increasing) level of interconnection, especially in Europe and the USA.

Electricity prices to end-users vary widely between countries. IEA data show a range from Japan at 15 cents a kWh to New Zealand at 3 cents a kWh, with Australia about fourth cheapest, at 5cents a kWh (1992 US cents, prices to industry).

Partly as a result of this interconnection and partly as a result of government micro-economic reform policies, the electricity industry worldwide is tending to become more competitive, with consequent downward pressure on prices. There is also rapid electrification growth in many Asian countries. This could provide opportunities for generation from biomass, for example as an alternative to costly grid extensions.

Setting aside political upheavals, the greatest uncertainty surrounding both oil and electricity markets stems from environmental concerns, especially related to the possibility of global climate change. Many governments are contemplating policies aimed at reducing the growth in energy-related greenhouse gas emissions. Some of these changes (eg. carbon taxes), if adopted, could have a significant impact on how energy is produced and consumed - including the relative economics of energy from biomass.

2.3 AUSTRALIAN ENERGY MARKETS

The most recent and comprehensive analysis of future trends in the Australian energy markets was released by the Australian Bureau of Agricultural and Resource Economics (ABARE) in early 1993. The report entitled "Energy Demand and Supply Projections, Australia, 1992-93 to 2004-05" - covers energy consumption and production projections for a range of energy materials classified by industry of use and by State of consumption.

In preparing its energy forecasts, ABARE includes a number of assumptions about economic and demographic trends. ABARE assumes that the price of oil will rise from around US$20 a barrel currently to US$22.30 in 2000-01 and to US$23.45 in 2004-05. This implies an increase of 17.5% over the ten years to 2004-05 or an average annual increase of 1.8%. The ABARE report does not include any assumptions on price movements for coal or natural gas. In a paper presented to the National Agricultural and Resources Outlook Conference in February 1993 however, ABARE in its discussion of coal exports expects the real price of thermal coal to go from US$39.90 a tonne in 1993-93 to US$40.30 in 2004-05 an increase of 4%. By contrast the real price of metallurgical coal is forecast to decline slightly from US$48.90 in 1992-93 to US$48.30 in 2004-05.

Aside from energy prices the other main assumptions made by ABARE are for a relatively steady 3% Australian real GDP growth, a nominal exchange rate of about US$0.78 an Australian dollar and population growth of a little under 1% a year.

Projections for energy consumption in Australia for years 1994-95, 2000-01 and 2004-05 are given in the table. In summary the growth rates for different fuel types are:

	Average Annual Growth Rate		Share in Energy Consumption		
	Historical 1976-77 to 1991-92	Projected 1991-92 to 2004-05	1976-77	1991-92	2004-05
	%	%	%	%	%
Black Coal	3.0	1.8	25.8	29.4	29.0
Brown Coal	3.3	1.2	10.5	12.4	11.3
Net petroleum products	0.2	1.9	48.0	35.5	35.7
Natural gas	6.7	2.6	8.8	16.9	18.5
Renewables	1.0	1.6	6.9	5.8	5.5
Total energy	2.2	1.9	100.0	100.0	100.0
Total final energy	2.0	2.0	69.3	**67.3**	**68.2**
Electricity	4.4	2.2	10.3	14.3	14.9

Coal

Over the period to 2004-05 black coal consumption will grow by 1.8% a year while brown coal will rise by 1.2%. In the case of black coal however production is expected to grow much faster (3.1%) spurred on by a 6.6% a year growth in exports of steaming coal. Domestically, both black coal and brown coal lose market share particularly as brown coal is displaced to some extent by natural gas in the generation of electricity in Victoria.

Oil **and** Oil Products

Australian production of crude oil (including natural gas liquids) is not expected to show much increase over the projection period. In 2004-05 output is expected to be 1206.2 PJ after increasing at about 0.5% per year. To meet the expected rise in consumption of 1.8% imports will grow strongly (3.0%) with exports being roughly unchanged. Petroleum products share of energy consumption is expected to change only slightly.

Consumption of heating oil, kerosene, industrial diesel fuel and fuel oil will drop to quite low levels by 2004-05.

Transport fuels on the contrary are expected to increase with the strongest growth being in aviation turbine fuel (4.8% a year), automotive diesel oil (2.8%) and LPG (3.1%). Aviation gasoline (1.7%) and automotive gasoline (0.9%) will also show increases.

Various non-transport petroleum products will grow at moderate rates

Natural Gas

Natural gas is expected to increase slightly its market share of energy consumed by manufacturing industry but its share of fuels consumed by the electricity generation industry will rise from about 11% to 14.5% over the forecast period although there will be a dip in the late 1990's as coal fired stations are commissioned in Western Australia and South Australia.

Wood, Woodwaste and Bagasse

The use of wood and woodwaste as an energy source declined considerably in Australia over the post-war years before picking up in the late 1970's and is projected by ABARE to rise at a rate of about 1.2% a year until 2004-05.

The share of wood and woodwaste in energy consumption will decline somewhat from around 2.6% to 2.3%.

Wood and woodwaste as an energy source is used mainly for domestic space heating purposes which is responsible for 77% of consumption. The other main uses are in the production of wood and its associated products and for paper production. There is some minor use in the smelting and refining of metals and in the food processing industry.

Wood and woodwaste is most important as an energy source in Tasmania (12.4%) followed by South Australia (3.6%) and Victoria (2.8%). The most important markets in quantitative terms are Victoria and New South Wales. Only in South Australia is wood and woodwaste projected to increase its market share by 2004-05 - in all other States it will decline in importance.

Bagasse is used as an energy source by the sugar processing industry in Queensland and to a much lesser extent in New South Wales. Projected growth of 1.5% a year is linked to expected outcomes for this industry to the year 2004-05.

Electricity

The Australian electricity market is in a period of unprecedented change, spurred on by the quest for greater efficiency.

The first phase of this quest started in Queensland in the mid-1980s, and spread to other states to a greater or lesser extent. This phase consisted essentially of major staff reductions, coupled with substantial improvements in plant availability. As a result of these changes, the Australian electricity industry's real operating costs fell 25% between 1982 and 1991. Total real costs fell only 9% during this period, due to the impact of increasing interest rates on the industry's debt. In 1993, the average Australian price to commercial and industry customers was about 8cents a kWh and continuing to fall. For example, Pacific Power recently reduced its Public Supply Tariff by 8%.

The second phase of the moves toward greater efficiency forms part of the Commonwealth and state governments' micro-economic reform agenda. The policies concerned aim to increase competition through structural change in the industry. Only the "wires" business of transmission and distribution are now regarded as natural monopolies, with generation and retail supply to be made contestable.

The Industries Commission estimated that this introduction of competition could reduce electricity costs by over $2 billion a year, a decrease of about 20%. The electricity industry argues that around $600 million of these savings have already been made, as part of the first phase.

Whatever the precise numbers, it is clear that investors in biomass-generated electricity will have to aim at carefully-selected niches in a market where the well-established competition is already one of the lowest-cost electricity producers in the world.

Such ruches could be facilitated if more cost-reflective transmission prices are introduced. Recent National Grid Management Council publications include examples where the cost of transmission to a load 250km from a power station would be over 8cents a kWh. This could radically improve the relative economics of biomass-fuelled electricity close to that load. Of course, this implies that transmission charges of this magnitude are politically acceptable.

As discussed earlier, the global climate change issue could result in policies aimed at internalisation of externalities. The recent report to the Victorian Government "Externalities Policy Development Project: Energy Sector" includes a worked example of externality values for the Loy Yang A power station. Only the high scenario included a externality value for carbon dioxide, which dominated all other externality values due to the large volumes involved (compared, for example, to sulphur or nitrogen oxides). The carbon dioxide externality value was 3cents a kWh.

Again, there is a strong political dimension to this issue. Environmentalists may wish to see higher prices for electricity from fossil fuels (and even large-scale hydro) but business and domestic consumers generally want their electricity bills reduced.

2.4 ENVIRONMENT AND THE BIOENERGY MARKET

The global interest and quest for renewable energy supplies is mainly in response to a number of broad key attributes of energy derived from fossil fuels, which are listed below:

- the unsustainability of fossil fuel supply;
- the geographic distribution of fossil fuel resources and economies;
- the accelerating rise in Greenhouse gas emissions; and
- the lack of national energy self sufficiency, especially in the third world.

As a consequence of these attributes, considerable attention is being focused worldwide on energy derived from biomass as a renewable energy supply.

There is also wide interest in the scope for the bioenergy cycle to enhance both the local and global environment with positive effects on the existing environmental practices employed in agriculture, forestry and energy production. There is potential for positive impact on the following key global environmental issues and the manner in which energy production from biomass resources could potentially reduce the impact of these environmental issues.

Greenhouse gas emissions and global climate change

A significant replacement of fossil fuel use with biofuels would result in reduced greenhouse gas emissions together with progress towards a carbon neutral fuel resource, where the volumes of carbon emissions are equivalent to those sequestered in the biomass feedstocks.

Deforestation and land degradation caused by erosion, salinisation and desertification

Economic demand for biomass feedstocks would result in dedicated re-afforestation plantations on suitable degraded or marginal agricultural land. This has the potential to rehabilitate large areas of land affected by erosion or salinisation without creating an economic burden to the nation.

Unsustainable land use practices, including forestry

Integrated harvesting of a range of biomass feedstocks has the potential to reverse unsustainable land use practices in Australian forestry and agriculture.

Loss of biodiversity

Re-afforestation and rehabilitation of degraded or marginal agricultural land has the potential to reduce the need or the desire to clear native forests, woodlands and grasslands, which could result in the effective maintenance of Australia's biodiversity. In Victoria alone, between 3000 to 6000 ha of land are cleared of native vegetation each year. The economic cost to revegetate is $1500/ha in 1993. It is estimated that between $7m to $10m is spent on revegetation and land rehabilitation each year across Australia, without a direct income incentive. Much of the re-afforestation is potentially a significant resource for bioenergy production if the appropriate species are planted.

Deteriorating urban air quality

The use of biofuels has the potential to improve urban air quality through the changed chemical composition of vehicle exhaust emissions.

However, if energy produced from biomass is to be environmentally positive in its global and regional impacts, then all life-cycle phases of the plant growth, plant harvesting and conversion must be environmentally sound. The two main existing impacts bioenergy can reduce are: the national life-cycle greenhouse gas emissions, particularly carbon dioxide by displacing fossil fuel use; and unsustainable land use practices by employing sound ecological principles. The bioenergy feedstocks must demonstrate a significant capability in carbon sequestration if bioenergy is to make a strong contribution to the slowing of greenhouse gases and global climate change.

A significant net reduction in national life-cycle greenhouse gas emissions could be achieved by the large scale production and use of, for example, transport fuels such as ethanol from biomass. However, it is important to assess local/regional environmental problems with the siting of such facilities and the treatment and disposal of their waste. As these, if not treated adequately could provide significant barriers to development in the short term.

Whilst food and energy cropping employ similar agricultural methods, there are strong limitations to the improvements bioenergy production can have on environmental impact and sustainable land use. For example, if bioenergy feedstocks were significantly limited to crop residues, we could expect the potential for significant degradation in land use practices as farmers sought to maximise their income between energy, food and fodder cropping, unless strict environmental management policy was enforced.

In addition, any dedicated energy cropping should be established on cleared land and not impact on remaining native vegetation and habitat. This may be difficult to achieve if there is strong competition between biomass feedstocks and food crops for the same parcels of land. There is also the danger of large tracts of land being used for energy crop monocultures which would have significant impacts on the maintenance of biodiversity.

Large areas of degraded land, often marginal agricultural land could be identified suitable for the establishment of plantations, in particular, hardwood plantations. However, there are strong limitations to the extent of available land since much of the land is already intensively used for agriculture. Another limitation to the extent of new hardwood plantations is the reduction of catchment water yields which will need to be balanced against downstream water demands, and possibly salinity control in some catchments.

Changes in land management policy and community attitudes will be required to allow a significant increase in the land application of sewage and industrial effluent. Effluent irrigated plantations are likely to be high yield with short rotations, and located close to regional markets, could make them ideal for the production of bioenergy feedstocks.

The last but not least environmental consideration in selecting suitable bioenergy feedstocks and their geographic locations, is the effect of climate change over the next twenty years. Although, the Australian climate is highly variable, any long-term changes in the rainfall pattern and temperature will have enormous effects on agricultural water balances, including yield, demand, fluctuations in the groundwater table and irrigation suitability.

Significant areas of southern Australia may experience a progressive shift from winter-dominated rainfall to summer-dominated rainfall (Whetton et al. 1992) which will affect crop type suitability, time of harvest and erosion hazard. Consequently, development of biomass feedstocks over the next twenty years will need to be adaptive to increased climate variability and shifts in regular climate patterns.

2.5 ENERGY MARKET ASSESSMENT SUMMARY

While most biomass to energy technologies have still to prove their economic competitiveness, they continue to attract government support because of their assumed benefits in helping to solve economic and strategic problems associated with a perceived increasing dependence on fossil fuels, principally oil.

While the concerns on this front may have lessened over recent years, the emphasis has switched to the role biomass-derived energy may play in meeting increasingly stringent environmental targets for atmospheric pollution and greenhouse gas reduction.

The role of energy crops as a substitute for crops for food has gained support in Europe.

The analysis of international and Australian energy markets indicates that the price of conventional energy sources will rise only mildly on world markets over the next fifteen to twenty years and there appears to be little in the way of supply constraints emerging over this period.

The arguments for supporting biomass to energy technologies in the medium term will therefore rest mainly on environmental concerns rather than economic feasibility in other than niche applications.

Technologies based on using various animal, human, food processing and abattoir wastes may prove the exception.

In the context of the rest of this study, the benchmark Australian energy prices used are those prevailing mid-1994. These are:

- petrol production cost at 20 cents a litre and 50 cents a litre with taxes and excises
- electricity averaging 8 cents a kWh to commercial and industrial users with production cost of 3 to 4 cents a kWh.

3.0 RESOURCES ANALYSIS AND DISTRIBUTION

3.0 RESOURCES ANALYSIS AND DISTRIBUTION

3.1 INTRODUCTION

A review has been undertaken to assess the availability of a wide range of present and future of biomass resources, together with their production volumes and costs in Australia. The purpose of this review was to develop information relevant to identifying biomass resources that might play a major role in the development of a biomass energy industry.

The resource scoping is presented in five sections: field crops for starch and sugar; field crops for vegetable oil; lignocellulose production from forests, crop and forest wastes including municipal solid wastes, animal wastes and waste as by-product from food processing. Information for each of the resources studied provides data on production volumes, land areas being used, composition characteristics of the biomass that are of importance to energy production, and price. Comment on expansion potential is also included.

Appendix 2 provides a much more detailed overview of resources prepared by Read Sturgess and Associates.

The estimates of production levels have been drawn from ABS data, from discussions with experts doing work on this area both in the public and private sectors around Australia and from field studies and trials being undertaken.

In addition, indicative case studies were selected primarily on the criteria of low cost and abundance. Volumes of costs were developed in a series of six resource production case studies, reported in Appendix 2 and 6. These included:

Agro-forestry in salinised dryland and irrigation areas, chosen because of the environmental benefits (disposal of salinised groundwater and/or reduced accessions to groundwater) that would complement the biomass production.

Irrigation of plantations using sewerage effluent, because of the environmental benefits (disposal of sewerage effluent) that would complement the biomass production.

Increasing the area of plantations, because of the environmental benefits (carbon sequestration in order to offset/reduce the production of greenhouse gases) that would complement the biomass production.

Harvesting of 'woody weeds', because of the extremely large volumes available at relatively low cost and impact on graziers.

Cereal straws, because of their extremely large volumes available at relatively low cost.

Saw milling wastes, because of their relatively low cost.

The review has shown that crops used for food are very expensive, costing between $150 and $400 a tonne. Major opportunities exist in residue utilisation from growing field crops and growing trees for wood, pulp and land rehabilitation (agroforestry). Industry, animal and municipal wastes are of particular interest given there is an increasing cost of disposal associated with their production.

Table 3.1 broadly summarises present and potential biomass production in Australia.

3.2 AUSTRALIAN RESOURCE PROFILES

3.2.1 Starch and Sugar Crops

Annual production of starch and sugar cane in Australia is dominated by winter cereals (19 million tonnes) and sugar (25 million tonnes) grown primarily for the food market. Other major crops in this category include rice (0.85 million tonnes), maize (0.2 million tonnes), and grain sorghum and potato (each about 1.1 million tonnes fresh weight).

Energy crops such as sugar beet and cassava which could provide high yields of sugar and starch can also be grown for biomass.

Starch Crops

Cereal crops are grown primarily under dryland conditions with winter rainfall in South Western Australia and on land areas stretching from South Eastern Queensland, through New South Wales and Northern Victoria into Southern South Australia. Small areas of irrigated cereal production exist in New South Wales and Victoria.

Western Australia (5 million tonnes) dominates cereal production, and is responsible for about a third of the national annual total. NSW with 5 million tonnes, South Australia (3 million tonnes) and Victoria (2.7 million tonnes) follow. Southern Queensland produces 1.5 million tonnes, whilst Tasmania has an almost negligible production of only 50,000 tonnes.

Dryland yields of the most prominent cereal crops, wheat and barley, vary between 2.6 tonnes a hectare (Queensland) down to 1.2 tonnes a hectare (Western Australia). The crop has a starch content of around 82-83% (dry weight).

TABLE 3.1: Summary of Biomass Production in Australia

Biomass	Million Tonnes per year (fresh weight) Food Component	Million Tonnes per year Residue and Wastes	Price $/tonne (fresh weight)	Comments
Starch & Sugar				
1. Food Crops				
Cereals, Rice, Maize, Sorghum	21.2		110-195	
Potato	1.1		200-310	
Sugar Cane	24.3		41	
2. Potential energy crops				
Sweet Sorghum	7.16		35	
Jerusalem artichoke}	21-32		40-90	
Cassava, Sugar beet}				
Oilseeds	0~26		210-410	
Wastes				
Industry Wastes		n.a.	n.a.	Too diverse to quantify
Animal Wastes		587	-2	Total solids
MSW		14	40	
Lignoeellulose				
Cereals		30	40-55	
Bagasse		2-3	10	
Wood				
Tree prunings		0.5-0.6/city	-10?	Capital cities only
Sawmill wastes		1.2	7-15	
Residues				
Native forests		15	22-42	
Softwood plantations		5	25-55	Thinnings
Hardwood plantations		3	20-73	
Irrigated (sewage) plantations		0.3-1.4	35-145	In development
Agroforestry		1.1-1.3	45-167	Pilot programs
Stalks from potential energy crops				
Kenaf		6-7.5	10	
Woody Weeds		large	78-140	
Cotton Ginning Wastes		0.3	3045	Total resource 290 million tonnes
		1.6	15-33	

Harvesting of the cereal crops takes places between October (Southern QLD and Northern NSW) through to February - the bulk being harvested over the first two months of the year in the main producing areas.

The delivered cost of cereals lie between $170-$195 a tonne (harvest weight), and is fixed by commodity prices for crops sold for human and animal consumption.

Any significant expansion in the future of the area presently under cereal production will be limited by competition for grazing land and concerns about land degradation.

Rice and maize are both grown under high rates of irrigation in Australia in the high rainfall areas of North Eastern Queensland, in the semi-arid regions of Southern New South Wales, and along the Northern coastal regions of New South Wales and Victoria.

Yields of these crops vary from 3-6 tonnes a hectare for rice down to 0.7-4 tonnes a hectare for maize. Both have a grain starch content similar to the cereals.

Harvesting occurs between November and April, with the crops fetching $175 a tonne in the commodity markets. A market exists for 'broken rice' at about $110 a tonne.

The expansion of rice production is severely limited by the availability of irrigated water. Maize production could be expanded if land used for the production of pasture or other food crops is used.

Grain sorghum is a dryland crop in Australia grown in the lower rainfall, less fertile soils of sub-tropical Queensland and NSW. Harvested between February and June, it is presently used mainly for stock feed. Yields are 22-26 tonnes a hectare and it costs $110 a tonne (harvest weight) delivered to a biomass processing facility. The starch content is similar to wheat, and its production can be expanded if other crops grown in the sub-tropics are replaced.

Potatoes are the major vegetable crop of Australia and grown in all States. Annual production totals about 1.1 million tonnes fresh weight. Production in Victoria and Tasmania dominate, each with a share respectively of about a third and a fifth of the total production. The rest of production is approximately equally distributed across the other states except for the Northern Territory, which is not a significant producer.

The potato tuber has a high moisture content (approx 80%) and high dry weight starch content of 72%. Harvested over a period of 4 months in different regions of Australia, potatoes are produced all year round at yields of between 25-50 tonnes a hectare (fresh weight) and cost $200-$310 a tonne delivered as prime product in the food market. Production can be expanded, if required, on land presently used for pasture production in high rainfall areas.

The potato growing industry produces surplus and waste potato tubers amounting to about 10% of total crop. These wastes are deposited in the fields and can be recovered for energy production

A starch crop not presently commercially grown in Australia is cassava. Cassava can be grown as an energy crop in tropical latitudes in the higher rainfall regions or under irrigation at yields between 40 and 60 tonnes a hectare.

This agronomic requirement limits possible land production areas to approximately 225,000 ha, which are situated roughly congruent with the present sugar growing belt along the east cost of Queensland.

The potential production lies between 9 and 13.5 million tonnes a year fresh weight.

The crop can be grown as an annual or perennial, producing a tuber containing about 62% water and 35% carbohydrate year round at a delivered cost of $50-$80 a tonne fresh weight.

Sugar Crops

The dominant sugar crop presently grown in Australia is sugar cane. Grown best in warm, sunny and frost free climates with high rainfall, production is mainly situated in Queensland (23 million tonnes) and Northern NSW (1.4 million tonnes) of cane (fresh weight). Around 80% of Queensland production is exported.

Harvesting takes place from June to December at yields of 60-80 tonnes a hectare.

A total of about 406,500 hectares are under sugar production in Australia, with an estimated expansion potential of between 50-70%, to potentially provide an additional 14 million tonnes of sugar cane.

Sugar cane on average has a moisture content of 45% and a fresh weight sugar content of 16%. Molasses can provide a further 3% fermentable substrate. Total delivered costs are calculated at $41 a fresh tonne of cane.

Sugar could also potentially be produced by growing new crops like Jerusalem artichoke and sugar beet. Offering high yields in trials conducted in Australia, these crops require copious and expensive summer irrigation water and can be grown on land presently used for dairy farming that provides farmers with high margins. The total estimated area suitable for production in the irrigated districts of Southern Australia is 300,000 ha.

Jerusalem artichoke produces a copious crop of both above ground (stem and leaves) and below ground (tubers) biomass. If grown for the sugar in the stem, the plant can be treated as a perennial crop that can be forage harvested. Tubers are harvested annually. Sowing, which can be staggered, takes place in September/October and harvesting can occur from February and staggered into June or July. Yields on trial plots have indicated 40-70 tonnes a hectare for tubers and 20-25 tonnes a hectare for stems with the tubers producing around 75% sugar and the stalks about 30% hemicellulose on a dry basis. Stored tubers lose mass and sugar through winter that may total up to 30% of harvested weight.

The delivered biomass costs have been estimated to be $40-65 a tonne for tubers and $10 a tonne for stems, both fresh weight. The total potential production is in the range 12-18 million tonnes a year of tuber or 6-7.5 million tonnes a year of stalk and leaves, fresh weight.

Sugar beet is another potential sugar yielding crop that can be widely grown in the high rainfall or irrigated regions of Victoria and Tasmania. Irrigation is required to achieve consistent yields.

Under these conditions, yields of 30-70 tonnes a hectare can be expected. The tuber contains 83% moisture on harvest, and 73% sugar on a dry basis.

The crop is best sown in October and harvested after May. Staggered sowings are possible to supply roots from mid January to early October with little need to stockpile other than to provide supply when it is too wet to harvest.

Total delivered costs range from $40-90 a tonne fresh weight, depending on yields achieved.

Sweet sorghum is a plant grown in Australia as a forage crop. It has a shorter growing season than sugar cane and has been grown successfully in Northern Queensland and North Eastern Victoria in regions of high summer rainfall and/or irrigation. In the warmer climates it is grown all year round. The stem contains about 37% sugar on a dryweight basis.

Potential land areas of 200,000 hectares are estimated to be available as a complement to sugar cane production. With yields estimated to be 60-80 tonnes a hectare, a total potential production of 12 to 16 million tonnes fresh weight annually at a delivered cost of $35 a fresh tonne may be possible. Commercial availability would extend sugar supply to a processing plant using cane by about three months.

A summary of present and future biomass crops for sugar and starch production is presented in Tables 3.2 and 3.3.

3.2.2 Oilseed Crops

Australia presently produces 800,000 tonnes a year of oilseeds, of which cotton seed oil accounts for 630,000 tonnes and about 259,000 tonnes a year of soya, canola, sunflower and safflower seeds.

Oilseeds in the latter category are grown both in summer and winter, with annual production dominated by canola in winter (91,400 tonnes) and sunflower in summer under irrigation (140,000 tonnes). Other major crops include safflower (22,000 tonnes, winter) and linseed (5,000 tonnes, winter). Total production is split fairly evenly over summer and winter.

Major production regions include New South Wales and Queensland, which produce roughly 80% of Australia's entire crop, followed by Victoria (roughly 15%) and South Australia (roughly 4%). Western Australia accounts for about 2%.

Australia is has ample land for expansion of oilseed production. Yields vary from 1-3 tonnes a hectare and at harvest the seeds contain about 10% moisture. The oil content varies from 39-44% of dry matter, depending on the variety.

Delivered costs, depending on the seed yield and irrigation requirements, vary from $210-$410 a tonne (harvest weight). Table 3.4 summarises oilseed crop production in Australia.

3.2.3 Lignocellulose

The potential sources for lignocellulose production in Australia are both varied and large. Resources falling under this category include:

(i) Residues from field crops.
(ii) Residues from harvesting timber from native forests.
(iii) Wood and thinnings from softwood and hardwood plantations.
(iv) Sawmill wastes.
(v) Tree prunings from gardens.

: Summary of Biomass Production, Starch and Sugar (existing)

Starch and Sugar (existing)	Approx. Area of Production C000 ha)	Yields (t/ha)	Present Annual Production ('000 tonnes)	Moisture Content % Composition (% DryWeight)	S/Tonne Delivered	Harvest Period	Likely Constraints on Increasing Production	Comments
1 Winter Cereals	12,500	1.2-2.6	19,000	10% Moisture 82-83% Starch	155-195 Possibly 110*	October (S.Qld) February (other regions)	Soil degradation in WA & Murray Darling Basin	* Spoilt grain
Rice	140	3-6	850	13% Moisture 79% Starch	175	Dec-Jan (NSW) April-May (Qld)	Availability of irrigation water	
Maize	55	0.7-4	214	10% Moisture 77% Starch 2% Sugar	175	Nov-April	Commodity Prices	
Grain Sorghum	560	2.2-2.6	1,130	10% Moisture 82-83% Starch	110	Feb-June	Commodity Prices	
Potato	40	25-50	1,135	80% Moisture 70% Starch 2.5% Sugar	200-310	* Year round	Commodity Prices	* Available year round, but individual regions have harvest season of four months
Sugar Cane	400	60-80	24,370	45% Moisture 34% Sugar	41	June-December	Only 200,000 ha of land available for expansion	

TABLE 3.3 : Summary of Biomass Production, Starch and Sugar (Future)

Starch and Sugar (future)	Approx. Area of Potential Production ('000 ha)	Yields (t/ha)	Potential Annual Production ('000 tonnes)	Moisture Content % Composition (% DryWeight)	Cost $/Tonne Delivered	Harvest Period	Likely Constraints on Increasing Production	Comments 1
Sweet Sorghum	154*	60-80	7,700* 12,000-16,000	65% Moisture 34% Fermentable	35	January-March	Only 200,000 ha suitable land available	* Presently grown for stockfeed
Jerusalem Artichokes				78% Moisture			Would replace existing pasture. Requires irrigation	Stored tubers can lose up to 30% of fermentables over several months
Tubers	300,000	40-70	12,000-18,000	75% Sugar	40-65	February - June		
Stems		20-25 stems	6,000-7,500	83% Moisture 30% Hemicellulose	10	Dec-January		Forrage harvested as as perennial crop
1 Cassava Tubers	225,000	40-60	9,000 -13,500	62% Moisture 92% Carbohydrate	50-80	Year-round	Suitable land: where sugar is grown	
1 Sugar Beet 1 Tubers	Ample	30-70	n.a.	83% Moisture 73% Sugar	40-90	January-October	Requires high rainfall or irrigation	

TABLE 3.4 : Summary of Biomass Production, Oilseed Crops

Oilseed Crops	Approi. Area of Production ('000 ha)	Yields (t/ha)	Present Production ('000 tonnes)	Moisture Content % Composition (%DryWeight)	Cost $/Tonne Delivered	Harvest Period	Likely Constraints on Increasing Production	Comments
Oil Seeds		**1-3**		**10% Moisture**	**210-410**	Varies regionally- usually 3 months	Commodity prices	Expansion will use land presently used for cereal and pasture
Other	250		259	**35-40%** Oil				
Cotton Seed			630	**24%** Oil				

(vi) Woody weeds.
(vii) Agroforestry.
(viii) Wood from irrigated plantations using effluent.
(ix) Crops grown for lignocellulose.

Categories (i) to (vi) are resources that are already available in Australia, whilst categories (vii) to (ix) are potential resources, some of which are being developed and others of which are being studied.

Table 3.6 summarises the present and future potential of lignocellulose production.

(i) Residues from Field Crops

The field crops dealt with in the previous sections are grown and harvested for food and animal feed. However, the harvested portion generally represents less than half the total biomass produced when the crop is grown, the remaining portion being made up of lignocellulose residue. A measure of the quantity of grain or tuber yield as a percentage of the total above ground biomass is called the Harvest Index. Table 3.5 provides an estimate of the residual biomass left in field after harvesting the commercial crop.

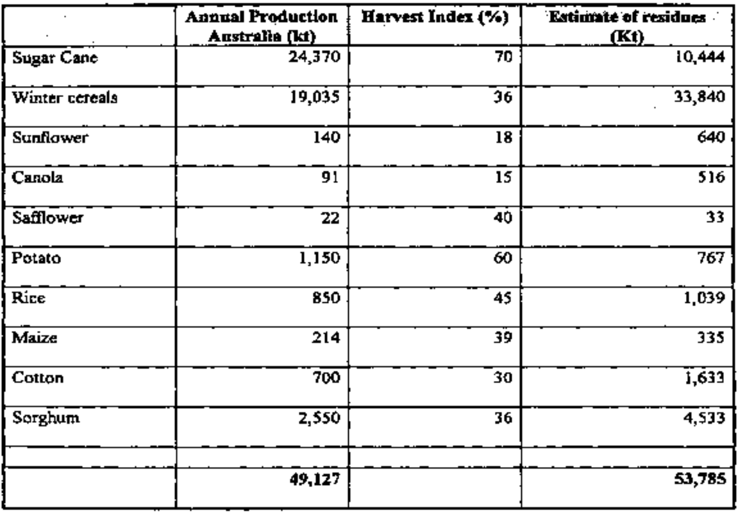
The table shows that the major residues produced are those from winter cereals, sugar cane and sorghum. Whilst totalling nearly 54 million tonnes annually, the table represents a gross underestimate of the total residues produced, as it excludes pastures, tree crops and grain legumes.

Farming practice in Australia presently ploughs back these residues into the soil or they are grazed, burnt or left to decompose in the field with the advantage of returning nutrients and organic matter to the soil.

However, a number of agricultural and biomass studies have concluded that it might be appropriate to remove and utilise a portion of the crop residue for energy production - particularly cereal residues - which would provide large volumes of low cost material.

Environmental and agricultural studies have indicated that retention of enough straw to provide 50% ground cover would meet the needs of erosion protection and nutrient return. This means leaving about 1 tonne a hectare of residue.

TABLE 3.5 : Summary of Field Crop Residues **in Australia**



	Annual Production Australia (kt)	Harvest Index (%)	Estimate of residues (Kt)
Sugar Cane	24,370	70	10,444
Winter cereals	19,035	36	33,840
Sunflower	140	18	640
Canola	91	15	516
Safflower	22	40	33
Potato	1,150	60	767
Rice	850	45	1,039
Maize	214	39	335
Cotton	700	30	1,633
Sorghum	2,550	36	4,533
	49,127		53,785

TABLE 3.6 : Summary of Biomass Production, Lignocellulose

Lignocellulose	Potential Area of Production ('000 ha)	Yields (t/ha)	Potential Production ('000 tonnes)/y	Moisture Content % Composition (% DryWeight)	Cost $/Tonne Delivered	Harvest Period	Likely Constraints on Increasing Production	Comments
Cereal residues	20,000	2	54,000 produced 30,000 removable	10% Moisture 40% Cellulose 20% Hemicellulose 10-15% Lignin	40-55	October-February	Environmental requirements mean approx. 1t/ha retained in the field	Existing resource
Bagasse	n.a.	n.a.	3,500 produced 2,000-3,000 available	50% Moisture 50% Fibre	10	June-March		Existing resource. Presently used for energy in sugar mills.
Wood from irrigated plantations (sewage effluent)	10 minimum 26 likely, up to 81 possible	11-45/y	341-1,400	50% moisture	35-145			Potential resource. Complementary benefit in disposal of sewage effluent (809,000 Ml/y)
Woody weeds	15,000-20,000	5.5-27	300,000 (total resource 290 million tonnes)	n.a.	30-45	Year round	Extremely dispersed and variable densities	Slow growth rates and dispersed nature assume "one-off" harvesting in areas studied.
Kenaf	Large	5.40	Large	14% Moisture 51% crude cellulose 7% lignin	78-140	Year round	Commodity Prices	Potential resource.
Residues from hardwood harvesting of native forests	?	?	Total of about 20,000 produced. Estimate that 15,000 available	50% Moisture 35%-45% Cellulose 15-25% Hemicellulose 15% Lignin	22-42	Year round	Environmental concerns	Resource decreasingly available.
Thinnings and wood from softwood plantations	600 planted	90	Total of 5,300 (1990) and 7,500 (2030)	As above	25-55		Potential increases in capacity for alternative uses (eg pulp mills)	Estimates exclude Queensland which has planted 21% of national area.
Hardwood plantations	18,500 total* 3,000 realistic potential	1000	3,000	As above	20-73		*Includes highly productive ag land	Large scale potential availability outside 15yr study time frame

TABLE 3.6 (Cont'd): Summary Of Biomass Production, Lignoceliulose

Lignocellulose	Potential Area of Production ('000 ha)	Yields (t/ha)	Potential Production ('000 tonnes)	Moisture Content % Composition (% DryWeight)	Cost $/Tonne Delivered	Harvest Period	Likely Constraints on Increasing Production	Comments
Agroforestry on salinized irrigation farms	45	11-30	1,100-1,300 or 337-405	As above	45-167	Year round Short rotation as residual wood.	Increasing land & water degradation in WA & Murray Darling Basin likely to lead to increased planting	Complementary benefit in disposal of salinized ground water. Near term potential on irrigated land
Agroforestry in high and low rainfall areas	460-20,000	7.5	75,000-150,000		45-59		Using marginal ag land	Longer term potential Residual coss $18/tonn (green)
Tree prunings	n.a.		Approx 500-600 in major cities	As above	Minimal		Unknown. Rising cost of alternative disposal likely to reduce cost of acquisition	Estimates made for Sydney and Melbourne
Sawmill Wastes	n.a.		1,250	10-50% Moisture Dry weight composition as above	7-15	Year round	Scope for increased timber production lies with future increases in plantation forestry	
Cotton ginning wastes			1,633	10% Moisture	15-33			

This being the case, the straw could be harvested after grain removal by raking, windrowing and producing large half-tonne square bales.

At a Harvest Index of between 0.25 - 0.45, depending on the variety of cereal crop, there would be between one and three tonnes of straw produced for each tonne of food crop. Typical compositions are 35 - 45% cellulose, 15-26% hemicellulose and 10-15% lignin. The volume of cereal residue available nationally would therefore be as high as 10 million tonnes a year.

Harvested during summer, baled straw has a storage life of more than a year if the moisture content is appropriately low at the time of baling. Bales can be stored on-farm or at a processing site to provide year round feedstock. The cost of delivery of biomass in this form would range from $40-55 a tonne.

The other major crop residue produced in Australia is bagasse from the sugar industry.

Australia produces about 3.5 million tonnes of bagasse each year, which is currently burned for steam and electricity at sugar mills. The energy needs of sugar mills is equivalent to only about half the quantity of bagasse available, making between 2.5 and 3 million tonnes of bagasse (dry weight) available for other energy and industry use.

Produced between June and March each year, bagasse has a composition of 50% water and 48% fibre, with 2% soluble solids. The delivered cost to a plant would be about $10 a tonne dry weight

(ii) **Residues from Harvesting Timber from** Native Forests

Residues were considered from native forests, excluding old growth forests. The various methods of harvesting wood result in forest residues being available in many forms - from standing dead and green trees, to dry or wet timber bulldozed into piles adjacent to logging roads, or residue wood scattered on the forest floor.

Australia presently produces about 5 million m3 a y pulp wood, and demand from Australian supplies is expected to grow.

Only about one third of the aerial weight is logged and taken to the mill, suggesting that the level of residue in native forests is about 20 million m^3 a y, excluding the backlog of residue form past harvesting. A substantial portion of the 6 million m^3 of wood presently used for industrial, commercial and domestic heating in Australia would be derived from native hardwood forests, the remainder coming from agricultural land.

It is therefore estimated that up to 15 million m^3 a y wood might be available from native forests, subject to sufficient residues being left to maintain soil fertility. Given royalty levels to State Governments of \$3-\$5 a m^3, harvesting and collection costs of between \$2 and \$20 a green tonne, the total delivered cost of native forest residue would range from \$22-42 a tonne fresh weight (50% moisture) in chipped form.

The National Forests Policy Statement may restrict the amount of wood harvested from native forests.

(iii) **Wood and** Thinnings **from** Soft **and Hard** Wood Plantations

Increasing demand for wood for pulp and paper and environmental concerns relating to wood removal from native hardwood forests has seen the development of softwood and, lately, hardwood plantations, over the last 15 years.

These plantations are managed under long rotations for both sawlogs and pulp and are increasingly being studied for their potential to "lock-up" atmospheric carbon in order to reduce or offset the production of greenhouse gases.

Studies, which exclude Queensland, have estimated a total of nearly 600,000 hectares of softwood plantation (mainly Radiata pine) in Australia today, with two thirds of this area split almost equally between New South Wales (232,400 ha) and Victoria (203,000ha). South Australia, Tasmania and Western Australia have between 92,000 and 54,500 hectares each. Approximately two thirds of the total area is under 20 years old, requiring a first thinning (normally occurs after about 14 years) to remove half the standing wood at yields of about $90m^3$ a hectare. Subsequent thinnings are required at about year 21 and 28, with clear fell at year 35.

A major surplus of wood for pulp and fuel has deferred thinnings in recent years.

Estimates made of wood availability from softwood plantations indicate rising volumes from 5.3 million m3 in 1990 to 6.3 million m3 in the year 2000 and to an estimated 7.5 million m3 in 2030. These estimates exclude more recently developed softwood plantations in Queensland which now comprise about 21% of the planted area in Australia.

Softwood plantation wood could be delivered in chip form, with an average moisture content of 50%. Chips can be stored in bulk or in silo-like structures and trucked to appropriate markets.

Delivered costs would range from $25-55 a fresh tonne, with the lower cost relevant to situations where the plantation owner provided free access to harvested thinnings on the forest floor, and the upper cost to the situation where the biomass processor had to pay a royalty of $20 a tonne and use more complex collection and harvesting procedures.

Land suitability studies for the establishment of hardwood plantations (E. Globulus) for carbon sequestration have recently been completed in Australia for sites in New South Wales, Victoria, Tasmania and Western Australia. They showed a total available area of 18.5 million hectares on land the majority of which is presently used for medium to high agricultural production. However, a portion of this, nearly 3 million ha, was identified as marginal agricultural land with a capability of high wood production and close to a potential processing site.

Long rotation (100 year) wood production would be expected to yield about 500 tonnes a hectare in logs and double this volume in harvesting residues.

In the longer term, towards the end of next century, there could be large volumes of wood available from this type of development.

(iv) Sawmill Wastes

Sawmilling of hardwood logs in Australia results in the production of saleable timber product (45%), wood chips (30%) and sawdust and chip rejects (25%). The last two products of the log do not generally find a use other than in the horticulture industry, and must be disposed of by the sawmill as waste by burning.

The 2,000 saw mills across Australia produce about 5 million m3 a year of sawlogs, suggesting that about 1.25 million tonnes a year ends up as sawmill waste. Some sawmills have indicated that they have arrangements for the removal of sawdust and residues with the contractors, whom they pay in some instances to remove the material. The extent to what agreements are in place and clarification of the opportunity cost of the resource needs further investigation.

Collection of these wastes for biomass energy production would entail assembly at a single point in the mill by conveyor, truck loading bays and transportation to a site for energy production if this is not located at the sawmill.

Delivered costs would therefore vary depending on whether wood royalty charges were passed on or not, the form of the wood, the distance over which it would need to be transported, and the opportunity cost of selling the wood into other markets (such as garden mulch).

Calculated costs would vary from $7 - 15 a tonne fresh weight.

(v) Tree Primings

Restrictions on the use of urban incinerators and increasing charges for landfill disposal is leading to large quantities of tree prunings being available in chipped form. As landowners presently pay to dispose of garden wastes they might be available in chipped or shredded form at little or no cost to an energy producer. A Sydney tree pruning company believes that a supply of 300,000 - 500,000 tonnes (fresh weight a year) would be available in Sydney. This is not inconsistent with an estimate by the Environment Protection Agency of Victoria that about 600,000 tonnes a year of garden wastes were being disposed of at landfill sites in Victoria.

(vi) Woody Weeds

Native shrubs and bushes that occupy large tracts, estimated at 15-20 million ha, of semi-arid regions of Australia could be harvested on a "one-off" basis to provide lignocellulose for conversion to energy. Large scale harvesting of this inedible biomass would enable replanting of these areas by grasses for animal (beef, cattle) pasture. Areas covered by these weeds include north western New South Wales and southern Queensland.

Studies by the NSW Government indicate the main varieties of biomass are narrow and broad leaf hopbush, budda and turpentine. Biomass yields of these plants range from 5.5 tonne a hectare in low density to 27 tonnes a hectare in high density areas.

It is estimated that New South Wales and Queensland could provide a total of 290 million tonnes of biomass from this resource. A typical area could yield 300,000 tonnes annually over 20 years, providing a year-round feed stock supply.

The cost of harvesting and transporting the biomass to a processing plant is estimated as $30 - 45 a tonne, depending on royalties and the harvesting method used.

The harvesting of woody weeds can be carried out sustainably by employing short rotation coppicing methods together with partial clearance to provide land management and a sustainable supply of biomass.

(vii) Agroforestry

There has recently been a great deal of renewed interest in the production of trees from farmed agricultural land because of the potential to improve agricultural productivity, diversify and increase farm income, conserve land, maintain biodiversity and contribute to the national timber supply.

It is estimated that about one million hectares of land which is marginal for intensive agricultural purposes is suitable for plantation establishment in Australia, about 460,000 hectares of available land has been identified within a 200-kilometre radius of existing timber and pulp processing facilities. These estimates were restricted to high rainfall areas.

Estimates for the low rainfall areas suggest that there is the potential to plant trees on 10 to 20 million hectares of the 100 million hectares of dry farmland across Australia, where yields of 7.5 tonne a hectare a year could provide 75 to 150 Mt of timber annually.

Studies of Western Australia indicate that agriculture simply will not survive without substantial increase in tree plantings on farms, with a number of forms of land degradation providing an 'ecological imperative' for revegetation with trees in the low rainfall areas there.

Agroforestry in Australia to date, however, has been restricted mainly to high rainfall sites. A review in this study of agroforestry in salinised irrigation areas calculated the cost of production of used wood from tree plantations established on 50% of farms over 10% of farm area with a minimum area of 20 hectares on each farm in the Murray Goulburn irrigation district in Victoria.

The costs of producing the wood biomass and the opportunity cost of the income foregone by not using the land for agricultural enterprises provided a break even price that the farmer would have to be paid to provide that level of return.

With the high yield and a (low) gross margin forgone of $325 (dairying on annual pastures) the delivered cost of woodchips would be about $45 a tonne. At the lower yield, the cost of woodchips could be as high as $167 a tonne delivered, suggesting that agroforestry on salinised farms could only be justified if a processor could pay at least $50 a tonne for wood chips delivered to the processing plant.

A possible scenario that could provide biomass at lower prices might involve farmers segregating their timber production according to particular quality attributes and selling it into a number of markets. This might involve farmers selling a portion of harvested timber not suitable for other markets (e.g. for oil extraction or timber products) to an energy processor at prices considerably lower than achieved for the timber with attributes suited to the higher value markets.

Other resource studies have identified about up to 10 to 20 million hectares of land which is marginal for agriculture but suitable for plantation establishment in low rainfall agricultural regions. This could provide 75 to 150 million tonnes of wood, assuming a yield of 7.5 tonnes a hectare a year. The delivered price of biomass from these dryland regions is estimated at between $18 a tonne (green) for residues and $44 - $59 a tonne (green) for logwood.

Despite the benefits, there has been very little penetration of agroforestry in Australia, primarily because of the unproven financial viability to farmers for going into this type of resource allocation.

(viii) Wood from Irrigated Plantations Using Effluent

Environmental pressure on the major water authorities in Australia is forcing them to examine the option of establishing irrigated plantations for the disposal of sewage effluent. Some trial plantations have been established and considerable research is taking place on irrigating Pinus Radiata and Eucalypt species with primary treated municipal effluent and food processing waste water. Health guide-lines only allow the reuse of primary treated effluent on wood and not food production, resulting in an overall positive impact on the environment.

Only about 4% of the total sewage outflow is recycled in Australia. Provided the water balance is positive and does not contribute to increasing ground water levels as indicated, use of this water would be ideal for energy biomass production.

Estimates made for southern Australia, mainly Victoria and South Australia, indicate a potential of 5,000 hectares and 4,000 hectares respectively for irrigated plantations, with a further considerable potential in New South Wales. Review of these estimates suggest these land areas are conservative, and that much larger areas could be dedicated to this type of effluent disposal and biomass production.

Typical wood yields achievable with coppiced eucalypts offering 6 coppicings before replanting vary in the range 11-45 m3 a hectare, depending on the degree of optimism projected from the many trials being conducted around Australia at present.

The 10,000 hectares identified above would produce between 110,000 and 450,000 tonnes of green wood a year.

The cost of wood chip production from effluent irrigation schemes depends on yield and the value of the land used. Variation of these parameters provides a range of $35-145 a tonne of green wood. Until experimental yields are achieved close to the more optimistic estimates, costs will be at the high end of these estimates.

Land disposal of effluent waste water has a positive environmental impact as long as discharge of nutrient rich water is controlled.

(ix) Crops Grown for Lignocellulose

Kenaf is a fast growing herbaceous annual crop that can be best grown in warm climates when given access to large quantities of irrigation water or summer rainfall.

The most favourable areas for production in Australia would be the irrigated areas of Northern Australia, where year round production would be possible. These include the Ord River Irrigation and the Burdekin River Irrigation areas, where yields could be as high as 30 -40 dry tonnes a hectare.

The crop can also be produced in dry land areas over much of the north of Australia and along the east coast as far south as western Victoria and Tasmania, where yields might drop to as low as 5 tonnes a hectare. High production potential is proven up to now only in the Northern Territory, where yields range from $5 - 25 tonnes a hectare. Wherever Kenaf might be produced under irrigation it would compete against existing land uses, or bear the costs of development if the vast areas of semi-arid and dryland in Northern Australia were especially developed for its production.

Based on average dryland farm yields of 10 tonnes a hectare of dry stems, the cost of production is calculated as $69 a dry tonne. Irrigated costs are estimated at $135 a dry tonne, resulting in a range of delivered costs to a biomass plant of between $78 - 140 a dry tonne.

3.2.4 Municipal Solid Wastes (MSW)

The availability of landfill sites varies widely from city to city depending on population size and density and the geology and topography of the region. It is a much more pressing issue in Japan and parts of Europe and the USA than in Australia but is regarded as an imminent problem for Sydney.

The total amount of waste collected by councils across Australia in 1989 was 8,581 million tonnes of which some 6,090 million tonnes (71%) comes from households. The other sources are industrial (7%) commercial (20%) and government premises (2%). The composition of MSW varies according to location and the type of collection service.

The average composition is 46% putrecibles, 24% papaer, 26% plastic, glass and metal and 4% "other".

The biomass resources comprise putrescibles, paper and plastic and together these make up on average 80% of the waste although this figure varies among cities.

Disposal costs vary across Australia and lie between $6 and $45 a tonne.

Estimates of the energy content of MSW range from a gross calorific value of 9 to 12 GJ a tonne for unsorted waste which includes non-combustible elements through to 14 to 18 GJ a tonne for waste without these elements, determined in part by the extent to which paper and plastic materials are removed for recycling.

The report estimates that the total Australian waste stream of around 14 million tonnes with a calorific value of 9 GJ a tonne converted at an efficiency of 70% would yield about 29 PJ.

The distribution of MSW correlates closely with that of the human population so the opportunities for energy conversion technologies will be in population centres of sufficient size to make facilities based on these technologies viable.

3.2.5 Animal Wastes

Pigs

Information on the distribution of pig farms has been derived from ABS agricultural census data which reports on pig production in terms of statistical local areas (usually local government areas) and from the Australian Pork Corporation.

Pig farms are located throughout Australia but are concentrated in the larger States (NSW, Victoria, Queensland, South Australia). Around 29.6% of production is from 28 farms with herd sizes of 1000 sows or more.

Pig Herds : 1000 Sows or More

	Number of Herds	*Number of Pigs*
NSW	*5*	321,000
Victoria	**6**	150,500
Queensland	**8**	169,440
South Australia	**5**	115,000
Western Australia	**4**	53,500
AUSTRALIA	**28**	**809,440**

Source: Australian Pork Corporation Database. July J 993.

In New South Wales large pig farms are located (i) in Corowa which accounts for 9% of Australian production, (ii) in the northern coastal region, (iii) in the southern region around Cowra and Parkes and (iv) in the Southern Highlands around Gundagai and Narrandera. In Victoria there is a concentration of production in the region extending from around Ballarat through to Shepparton. In Queensland, Western Australia and South Australia pig farms are mainly located in the regions surrounding the capital cities.

Until recently wastes from pig farms have been disposed of by discharge to the environment. The main potential use for pig wastes is as a fertilizer or soil conditioner. As this is a by-product of the anaerobic digestion process when viewed as an energy system there is currently no other competitive use for the resource. Its price as a feedstock for anaerobic digestion or other energy conversion technologies is therefore zero or negative as its disposal is driven by environmental regulation.

Chickens

Information on the distribution of chickens for meat and for egg production is derived from ABS data and data provided by the Chicken Meat R&D Corporation. While chicken production occurs in all States it is concentrated in just a few regions and in the case of Queensland, South Australia and Western Australia on the outskirts of the capital cities. In Queensland production is in Beaudesert, Albert, Laidley, Caloundra and Redland Bay. For South Australia farms are mainly in the Adelaide Hills, and Murray Bridge regions while in Western Australia, chicken production is concentrated in the northern and southern suburbs of Perth.

In New South Wales the main locations for chicken farms are the outer western suburbs of Sydney (Liverpool, Camden, Wollondilly, Penrith, Baulkan Hills, Blacktown); around Gosford and Wyong; and in the Hunter Valley. There is also significant production in Griffith in southern NSW.

For Victoria there are chicken farms in the Bendigo, Wimmera and Geelong areas but the bulk of production occurs on the Mornington Peninsula south-east of Melbourne and in the north eastern outskirts of the city.

Each of these major chicken producing regions has a chicken slaughtering facility. According to the Chicken Meat R&D Corporation all chicken farms are within 2 hours drive of a slaughtering facility.

The biomass resource from chicken farming is twofold - litter refuse and offal. Litter refuse is the waste obtained from cleaning out chicken sheds and the amount varies among growers according to how frequently this cleaning is done. In most cases the litter is removed at no cost to the chicken farmer with the collector processing and selling it as a fertiliser. The largest supplier of fertiliser based on chicken waste is Dynamic Lifter which charges $340 a tonne wholesale.

The offal produced from chicken slaughtering facilities is converted to a meal which is costed at $600 to $800 a tonne.

One unexplored waste product is spent and dead hens from the egg laying side of chicken farming. Spent hens currently fetch $0.20 a bird and are used in pet food. Dead hens are those that die in production and represent around 4% of the flock or about 16,000 tonnes a year.

Cattle in Feedlots

While free range cattle are not an economic source of waste material, cattle in feedlots may represent an opportunity for waste to energy processes. According to a survey by the Australian Lot Feeders' Association the number of cattle in feedlots has been growing strongly over recent years with a 42% increase over a 12 month period to November 1993.

As at the end of that month numbers in feedlots were:

NSW	130,316
QLD	234,024
VIC	32,307
OTHER	4,841
AUSTRALIA	*401,538*

While feedlots are fairly widespread throughout NSW and Queensland, about one third of the total capacity is concentrated in Tamworth, Baradine, Delungra and Cootamundra in NSW and Beaudesert, Toowoomba and Dalby in Queensland. Throughput numbers are not currently available so it is not possible to estimate the potential waste available from this source.

Abattoir Wastes

As described in Appendix 3 Section 3.11.2.1 abattoir wastes are an ideal feedstock for anaerobic digestion. The amount of waste available from an abattoir will depend primarily on the numbers of each type of animal killed.

Information on throughput for abattoirs is very difficult to obtain for commercial confidentiality reasons although some information is available from the Australian Quarantine and Inspection Service.

Complete information is available for Queensland and more aggregated data for Northern Territory, South Australia and Victoria, no estimates of waste production however, were available to this study.

Industry Wastes

Food processing is the largest single industry in Australia, covering the production of meat, dairy products, fruit, vegetables, cereals, bread and baked products, sugars, confectionery, processed seafoods, and alcoholic and non-alcoholic beverages and cooking oils.

There is potentially a large number and variety of sources of food processing residues and by-products that could be used for biomass energy production purposes.

Many of the individual parts of the food processing industry are seasonal in nature, resulting in highly variable waste streams and different types of waste being discharged throughout the year. Wastes of interest for energy production are primarily the solid and liquid wastes.

Solid wastes from food processing arise from the wide variety of products, processes and procedures associated with the industry. Final disposal is usually to a landfill.

Typical solid wastes include peelings and scraps from fruit and vegetables, pieces of food product that do not meet quality control standards, peel and pips from fruits and vegetables, pulp and fibre from the sugar and starch extraction industries, filter sludges, coffee grounds, and wastes from the canning industry.

In general, food processing requires large volumes of process water and water for removing dirt and contaminant, cooking, cooling and heating, washing down equipment and work areas and for incorporation into the product. The waste waters can contain sugars, starches and other dissolved and solid organic matter.

Sources of liquid wastes include water from washing meat, fruits and vegetables, blanching fruit and vegetables, precooking meats, poultry and fish, cooking and other processing operations.

The general characteristics of these waste waters are high biochemical oxygen demand (BOD), high suspended solids levels, high fat levels and ready biodegradability.

While there is a paucity of information about most food processing wastes, most have an important advantage as biomass resources: and that they would not otherwise be sold or retained. In many cases food processors incur net costs in disposing of them. As such, an energy processing plant utilising those wastes would not be likely to have to pay any price or royalty in order to obtain the wastes from the food processing companies.

Molasses

Molasses, a by-product of sugar production, is currently used for the production of industrial ethanol, some is exported and some is sold for stock feed. Molasses production is about 700,000 tonne a year, with about 250,000 tonne presently being used for ethanol production.

Molasses consists of 20% water, 35% sucrose, 7% glucose, 9% fructose, 17% other organics and the rest is ash.

Storage of molasses is not a problem, as it does not degrade and it can therefore be used to smooth out supplies from its 9 month production period (June-March).

The largest distillery is a CSR operation at Sarina consuming some 180,000 to 200,000 tonnes of molasses annually for the production of 45 to 50 million litres a year of ethanol.

About 615,000 tonnes of the total is produced in Queensland, with the remainder from Northern New South Wales. Production could theoretically reach over a million tonnes with a 50% expansion in the area of cane planted. The total potential could therefore be 1,050,000 tonnes annually. Given the presumptions about new areas for sugarcane most of this expansion will be in the Burdekin and Northern regions.

Market prices for molasses vary considerably due to the influence of export market returns. Observed unit values for molasses in recent years have been around $25 to $30 a tonne but advice from industry is that $50 a tonne is a typical current market price. The delivered cost of molasses to an ethanol production facility is therefore between $35 and $60 a tonne.

Potatoes

About 50% of Australia's potato crop is processed into either "french fries" or crisps, with the former accounting for about two-thirds of the processed crop. In Tasmania, however, about 90% of the crop is processed into french fries.

Recent expansion of the Edgell-Birds Eye plant at Ulverstone in Tasmania will permit it to nearly double its annual production to about 220,000 tonnes. About 45% of the national crop is sold on the fresh market and about five percent is used for seed.

It is estimated that for every fresh weight tonne of tuber entering a factory for french fries, only about 0.5 tonne emerges as chips. Not all of the residue is wasted, however, as some may be turned into dehydrated products. Nevertheless, if it is assumed that about 500,000m tonnes of potatoes are processed each year, then the potentially utilisable waste material is equivalent to about 167,000 tonnes freshweight. In addition there will be starch in waste water which might be recovered.

Some processing firms dispose of waste for stock feed.

The wastage produced in a crisp factory appears to be less than for french fries. Peeling waste (emerging as a fine slurry) appears to range between 2 and 5% while wet scrap waste is about 2 to 3%. There may also be a small wastage, 1 to 2% of tubers on the production line. An estimate of the starch content of waste water which suggested that 100 tonnes of potatoes might produce about 8,000 litres of starch. At least one crisp factory recovers starch from wastewater. If about 167,000 tonne of potatoes enter crisp factories each year, then the solid wastes might total between 5,000 tonne and 12,000 tonnes, including soil. If the above estimate of starch in waste water is reasonable, then about 13 million litres of starch might also be produced.

Whey From Milk Processing

Whey is the liquid by-product derived from the manufacture of cheese, casein and co-precipitate. The volume of whey produced from the manufacture of these products in Australia has been estimated at about 1,560 million litres a year with about 68% produced in Victoria.

It is estimated that at present, about 50% of whey produced in Australia is utilised in further processing to whey powder, lactose and protein products and about 50%, say 780 million litres, requires disposal.

Most of the whey disposed of is sprayed onto land, some is fed to pigs or disposed of by ocean outfall and to the sewers.

Dairy companies are under increasing pressure from environmental bodies to improve their methods of whey disposal and most difficulties appeared to lie with the smaller plants.

Disposal costs are estimated at $2,000 to $3,000 a million litres if transport is not required. Transport, say, a round trip of 40km, could increase this cost to $4,000 to $5,000 a million litres.

Pineapples

Australia produces between 120,000 to 150,000 tonnes of pineapples annually with virtually all production being in Queensland.

The majority is canned. The only company active in this field being Golden Circle Canneries, located in Northgate, Queensland. That company's intake of pineapples has recently been between 100,000 to 120,000 tonnes annually. Canning produces pineapple wastes consisting of the skin and the core (the tops are left in the field at harvest). The company currently has a contractual arrangement for the disposal of these and other wastes (they process other fruit and vegetables) for stockfeed for pigs and dairy cattle.

At an estimated 15% waste, the estimated quantity of pineapple waste would be 18,000 tonne a year.

Pineapples are harvested on the south Queensland coast between January to August, and on the central Queensland coast they are harvested between December and May. Availability of canning wastes would therefore be seasonal, extending from December into the middle of the year.

Citrus Juice Processing

Citrus fruits are grown in all Australian states except Tasmania and the Northern Territory. The main areas are the Murray River regions of Victoria, South Australia and New South Wales, the Murrumbidgee Irrigation Area, the central coast of NSW and the Burnett region of Queensland. NSW and South Australia account for about 75% of production. About 60% of production is sold for processing, a little over 40% is sold on the local fresh market and about 10% is exported as fresh fruit.

The citrus processing industry produces large quantities of waste, principally in the form of skins. An estimate provided by industry sources suggests about 0.5 tonne of waste for every 1.0 tonne of oranges which enter the factory. In 1988-89, about 324,000 tonne of citrus were processed in Australia, resulting in about 162,000 tonnes of waste material. The waste skins are produced in two distinct types depending on whether sugars and other soluble solids have been extracted. Skins from which sugar have been removed are estimated between 10 and 50%.
Common forms of disposal of citrus waste at present are by burying, or sale for stock feed or fertiliser. Some processors pay to have the waste removed. If the practice of removing sugar is not allowed to continue, there could be some 160,000 tonnes of fermentable material available each year. If the practice continues, the best estimate is that the amount of fermentable material might lie between 16,000 tonnes a year and 80,000 tonnes a year.

Tomatoes

Tomatoes are Australia's second largest vegetable crop, with about 45% produced in Victoria. With the expansion of the industry into northern Queensland and Western Australia year-round supply is now available.

Roughly 80% of the crop is processed but the quantity of solid waste, mainly skins, is small and the content of soluble solids is low. A similar situation seems to prevail for most other vegetables. Sold waste may be fed to pigs, buried or otherwise dumped. It is estimated that about 6 to 7% of tomato intake for processing goes out as waste. With roughly 220,000 tonne of tomatoes used for processing annually, this estimate of wastage suggests only about 14,000 tonne of waste over the entire crop. Most tomato processing is highly seasonal but some storage takes place in semi-processed form, such as paste.

Fruit Canning

The production of fruit from deciduous trees takes place in most States but there are some notable concentrations. About 80% of pear production takes place in the Goulburn Valley of Victoria which is also a major producer of peaches. In total, the Goulburn and Murray Valleys produce about 70% of the canned deciduous fruits. Apple production is more widespread with major producing areas in New South Wales, Victoria and Tasmania, and to lesser degrees in Western Australia, Queensland and South Australia.

Peaches, pears and apricots are the main canning fruits in temperate Australia. Apart from the stones, peach processing produces little waste - about 1-2%. Peach and apricot stones find a variety of uses in nurseries and in septic systems.

Apples and pears (whether for canning or juicing) yield about 10 to 15% waste in the form of skins and cores In juice manufacture, these will be squeezed to obtain the greatest yield of juice. One estimate put the yield of soluble solids from the cores and skins of canning pears at 10 - 12%. This would suggest a total quantity of apple and pear waste of the order of 15,400 tonnes to 23,000 tonnes a year.

Wine Industry Wastes

The wine industry in Australia processes about 500,000 tonnes per year of grapes.

About 80% of the fresh grapes are processed by the three largest wineries, two in SA and one in NSW. Wastes account for about 10% of total input. The bulk of this as marc (skins, seeds and excess pulp from fermentation) is discarded and processed to recover remnant sugars and other components such as ethanol, tartaric acid and other by-products. Solid remnants are used as fertiliser after 12 months of composting.

Roughly 0.5-1% of the grape input is removed as products in cleaning operations, and ends up in the waste water stream. Wineries produce a total of about 1,500 million litres of waste water with 4,000-6,000ppm BOD.

Starch Processing Wastes

Of the 19 million tonnes of cereal grain grown in Australia, approximately 4 million tonnes are consumed domestically and of this about 1 million tonnes is processed annually to starch, gluten and other food and industrial products.

Yield losses from flour processing are typically up to 15% of raw material input. About 60% of the losses consist of starch and fermentable solids, amounting to approximately 72,000 tonnes a year.

These fermentable are carried in the high volume, high strength water effluent that emerges from starch processing facilities. Typically, the fermentable solids would from between 1 and 2% of the waste stream, suggesting total volumes for the industry of about $800m^3$ an hour or between 6 and 7 m^3 a year.

TABLE 3.7: Summary of Industry Processing Wastes

Type of Processing Waste	Estimated Annual Production
Potato Processing	
Peel wastes (fresh weight)	27,500-82,000 tonnes
Starch in waste water	13 million 1
Milk (whey)	1,560 million 1 (50% unutilised presently)
Pineapples	18,000 tonnes
Citrus	
Present	16,000-80,000 tonnes
Potential	160,000 tonnes
Tomatoes	14,000 tonnes
Fruit Canning	15,000-23,000 tonnes
Wine (waste water)	1,500 million litres
Starch Processing (waste water)	7 million m^3 (1-2% fermentable)

3.3 SUMMARY

Table 3.1 summarises present and potential biomass and wastes production in Australia.

Winter cereals and sugar cane dominate anthropogenic biomass production in Australia, with grain and sugar going into the food chain.

The use of food crops for energy production is expensive. Costs are in the range $150-300 a fresh tonne for the cereals and $210 - $410 a tonne for oil seeds. Sugar cane costs $41 a tonne delivered for fresh cane.

Residues available from food crops total 30 million of the 54 million tonnes of crop residue produced in Australia. Delivered costs range between $10 a tonne for bagasse and $40-$ 5 5 a tonne for cereal residues depending on the complexity of collection and transport distances.

Starch and sugar crops grown specifically for energy, (such as sorghum, sugar beet, cassava) can be grown and delivered for costs ranging from $35 to $90 a fresh tonne, providing a relatively expensive biomass feedstock. Production areas, and hence volumes, of these crops are expected to be limited by their need for irrigation water and the need to displace land used for other more lucrative farming activities.

Wood residues from native forests, thinnings from soft and hardwood plantations, sawmill wastes and urban tree pruning provide resource opportunities from the forest industries. Total volumes are estimated at more than 22 million tonnes a year, and delivered costs vary from $7 a tonne at sawmills to $22 - $55 a fresh tonne for residues from native forests and softwood plantations. Up to 500,000 tonnes a year (green) wood may be available in each major metropolitan area at no or little cost as a result of tree pruning activities.

Future potential supplies of wood from hardwood plantations and agroforestry could provide additional massive volumes of 75 - 150 million tonnes annually at a cost of between $20 and $167 if environmental issues catalyse the development of wood production on salinized or degraded land.

There are major opportunities to utilise sustainably woody weeds growing in the semi-arid areas of New South Wales. Annual volumes of 300,000 tonnes over 20 years are estimated as a feasible resource supply option out of a total estimated resource volume of 290 million tonnes. Delivery costs are estimated at between $30 and 45 a tonne.

Australia's largest single industry is the food industry. Solid and liquid wastes containing lignocellulose, sugars, starches and other carbohydrates are produced in converting crops and fruits to edible foodstuffs. A biomass energy processor can access these at no or little cost. In some cases the food industry will pay to have them removed. The cost, availability and volumes of these wastes has been difficult to acquire.

Municipal Solid Wastes produced annually in Australia total 14 million tonnes. The biomass portion comprises putrescibles and paper which, on average, make up around 80% of the waste stream. About 71% is derived from households. Disposal costs currently range from $20 to $40 a tonne.

Animal waste production in Australia was reviewed. Pig wastes, produced mainly on the North Coast of NSW, Corowa in Southern NSW and Northern Victoria have no alternate use and therefore are available for biomass energy production. In the main chicken wastes are currently used as fertilizer.

Table 3.8 following illustrates approximate energy production capacity from the biomass presently produced and future possible energy crops. Whilst the numbers reflect the total potential from lignocellulose, the energy from starch and sugar would require use of all food crops for this purpose.

TABLE 3.8 : Examples of Potential Biomass Energy Production in Australia

Biomass	Million Litres Ethanol per year (approx)	MW Power Equipment	Million Litres of vegetable oil/year	Comments
Starch & Sugar				For illustrative purposes only, energy volumes are calculated from all business biomass produced, including that presently used for food.
1. Food Crops				
Cereals, Rice, Maize, Sorghum	7,535			
Potato	99			
Sugar Cane	1,700			
2. Potential energy crops				
Sweet Sorghum	2,000			
Jerusalem artichoke}	1,334-2,048			
Cassava, Sugar beet}				
Oilseeds			91	
Lignocellulose				
Cereal residues	10,125	4,500		
Bagasse	526	300-400		
Wood	4,125	3,300		
Tree prunings				
Sawmill wastes				
Residues				
Native forests				
Softwood plantations				
Hardwood plantations				
Irrigated (sewage) plantations				
Agroforestry (irrigated)	14,060-28,125	11,250-22,500		
Residues from stalks from potential energy crops	1,125-1,400	900-1,125		
Kenaf	large			
Woody Weeds	55-100	45		
Cotton Ginning Wastes				

4.0 CONVERSION TECHNOLOGIES

4.0 CONVERSION TECHNOLOGIES

4.1 INTRODUCTION

This overview of conversion technologies is structured to provide information on the state-of-development of each biomass to energy conversion route, together with the key technical and economic parameters required to calculate the cost of energy products over a range of capacities.

The technologies being reviewed fall into two broad categories for the biomass, municipal and animal waste feedstocks to be processed; thermal/chemical and biochemical conversion routes.

Included in the first category are; direct combustion, gasification, pyrolysis, cogeneration, methanol production, vegetable oil extraction and esterification and oxygenates production.

The second category includes biochemical conversion to ethanol and anaerobic digestion to biogas.

Where possible, Australian developments are identified.

4.2 COST ESTIMATE BASIS

A major part of the work undertaken in reviewing the major thermal and biochemical technologies was to reliably identify their capital and operating costs.

Where possible, information on capital and operating costs have been taken from plants that have been built and are commercial. Care is taken where this has not been possible to follow up on the best available estimates that have been derived from pilot plant and engineering studies for energy technologies.

Capital costs include all costs associated with building a grass roots facility, including utility and waste treatment plant and start-up costs. Operating costs include labour, auxiliary chemicals and maintenance.

The costs were all brought to a 1993 A$ equivalent, with appropriate contingency depending on the perceived degree of information reliability.

Representative examples of each technology were selected and used to document the required data on capital and operating costs, process inputs and outputs, major waste streams and overall process energy balances. There was consideration of by-products when these were an integral and important part of the process.

The capital and operating costs developed in the study should be used with discretion. While a $\pm$10 - 20% accuracy may be possible for green field sites using commercially operating technology, it is much more difficult to cost emerging technology accurately for a prototype, first of a kind, plant. Accuracy here is typically ± 20-35%.

4.3 CONVERSION TECHNOLOGY OPTIONS

4.3.1 Direct Combustion

Direct combustion technologies are well established in domestic, commercial and industrial applications.

Domestic solid fuel heaters, cookers and boilers are available in standard designs with combustion efficiency at the technical limit of about 70% in the domestic equipment range. In addition, the industry is coming under increasing pressure to produce cleaner burning systems by legislation. Attention in this market segment is therefore presently focussed on increasing the reliability and life of domestic heaters and improving environmental performance. The introduction of long-life catalysts to clean up particulates and other emissions will probably be the direction taken in the future.

A variety of companies in Australia sell a range of small to medium scale combustors for process heat and steam production in small scale commercial applications (100-lOOOkw thermal). These include BEST, Maxitherm and Pyrotherm. Waterwide produces these systems in New Zealand.

Biomass burners for larger industrial or commercial applications are produced in a number of designs. The trend is to move away from the older style pile, stoker grate and moving grate systems to fluidised bed systems, which allow compact design, higher turn-down ratios and a large variability in feed type, shape and moisture content. More efficient combustion at lower temperatures and less NO_x and So_x emissions will be achieved by incorporating the control of these in the combustion unit itself.

California has a $2 billion investment in 850MW of biomass direct combustion power capacity. Nearly all solid waste combustion projects have had "deposit" fouling problems causing excessive downtime. This slagging is caused by alkali carried in the leaves and small limbs of most woods. There are major activities underway to analyse and resolve these problems.

Sandia Labs and consultants are investigating new boiler designs and suggesting additives to reduce the problem. Work is also progressing on increasing heat rates and lowering handling requirements, contributing to lower system capital cost. The overall conversion to heat and power efficiency, typically 25% at present, is expected to be raised to over 35% in the next few years.

TABLE 4.1: Cost Data : Steam Production by Direct Combustion from Biomass

Product	Process	Feedstock(s)	Plant Capacity	Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements	Raw mtl Cost	By-Product	Value
High pressure steam	Wellons	Biomass	10 MWth (18.15 t/h)	9.0	0.45	7.57/dry tonnes per MW			
			50MWth (90.7 t/h)	30.5	2.55				

TABLE 4.2 : Cost Data : Power Production from MSW Neutralysis Process

Product	Process	Feedstock(s)	Plant Capacity	Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements	Raw mtl Cost	By-Product	Value
Electric power	Neutralysis	MSW (unsorted)	48.6 GWh/y	86	10.6	216,000 t/y		building aggregate	$40/t
		liquid waste				52,000 t/y	-$70/t	steel	$35/t
		ash				37,000 t/y	-$35/t		
		clay				129,000 t/y	-$15/t		

Substantial increases in efficiency are being achieved by fluidized bed combustion technologies, in which carbon is utilised close to 100%. Various versions of this technology have been adapted for biomass from coal-based developments, and several large units from 10-50MWE have been built and are operating in the US to provide heat and electricity.

Fluid bed systems come in two major designs. They are the bubbling and circulating bed types. The latter design has a higher operation efficiency and requires lower excess air levels than the bubbling bed, but has the disadvantage of requiring more input power to operate the significantly larger fans and a greater capital cost in the smaller (15 - 30MW) size range.

Developments in Australia for commercial application include the testing of a 350kWth circulating fluidised bed combustion system by the Electricity Trust of South Australia for pulverised coal applications. The technology could be applicable to a large range of solid fuels, including biomass In addition, the Sugar Research Institute is developing a pilot swirl burner firing system for bagasse that shows excellent performance and stability over a wide range of feed moistures. This development, however, is only expected to increase efficiency by about 2%.

In the US a project is underway with financial support by EPRI to develop and test the whole Tree Burning Concept, which aims to reduce costs of energy production. The entire tree is harvested and burnt without chipping, after being dried in a cheap tent-like installation to about 25% moisture using waste heat from a high pressure steam turbine. To be economic, plant capacity must be 100MW. It is claimed the furnace will have an efficiency of around 85%.

The combustion of municipal solid waste for heat and power is also established technology.

There are about 60 mass burning plants and about 20 plants burning refuse derived fuel (the combustible component that comes out of a waste sorting facility) operating in the US. Presently approximately 19% of all municipal wastes are burnt.

Emissions are not clean, and requirements to install chlorine, mercury, NO_x and particulate removal equipment are increasingly severe. There is strong community opposition to this type of technology as it is now established that pollutants, in particular dioxins, attach to particulates less than 10 microns in size and so can be ingested into the lung.

A novel process to dispose of municipal wastes, called the Neutralysis Process, has been developed in Australia. It produces both a lightweight building aggregate and electrical energy via direct combustion as by-products. No plants have yet been built.

Two technologies have been selected to demonstrate the economics of direct combustion. They are the Wellons technology for high pressure steam production at 10 and 50MW capacity and the Neutralysis process. The capital cost data for both is shown in Tables 4.1 and 4.2. Further data for direct fired cogeneration plant is given in Table 4.6

4.3.2 Gasification

Gasification is the conversion of biomass to a combustible gas through combustion in a controlled atmosphere of air or oxygen, either at atmospheric pressure or under pressure.

All large scale commercial gasifiers operating on biomass to date are atmospheric pressure designs, with pressurised units for electricity and fuel applications under development from coal-based technologies. The small scale systems developed for this application are reviewed in the cogeneration section.

Directly heated gasifiers utilise air or oxygen to partly oxidise the feedstock and provide heat for the gasification process. There are two basic types: the fixed and fluidized bed.

Fixed bed systems are designed to be up, down or crossflow draft configurations. The technology is commercial, and is suited to both wood and biomass fuels with a high ash content, like rice hulls. Installed capacities of between 1 and 6 MW exist in Finland, the US, Malaysia and Brazil.

Fluid bed systems are generally side fed, using a bed fluidised by steam or oxygen with an inert material (such as sand) to facilitate the gasification process. The technology, which can be operated either at atmospheric or higher pressures, was originally developed and commercialised as the Rheinbraun/Uhde High Temperature Winkler process for coal and has now been adapted for biomass.

Systems being developed and in commercial, operation include:

* *the bubbling bed fluidised system:* Sizes built range from 10-50 MWe, fired on a range of materials including wood, agricultural residues, MSW and pulp and paper wastes. The Renugas gasifier developed in the US by the Institute of Gas Technology, is an oxygen blown system developed specifically for biomass.

- *the circulating fluid-bed system:* Significant research is going into the development and commercialisation of different variations of this type of gasification system. This system, which can be atmospheric or pressurised, utilises a high ratio solids recirculating system and has low solids inventory due to very efficient gas/solid contact. The process can gasify a wide range of biomass materials.

- *entrained bed gasification:* This system, originally developed for coal, requires grinding the feedstock to a very fine particle size and as it doubles the feed preparation costs, has not been pursued for biomass applications. Recent indications are that using specially designed chamber and a tangentially blown feed system sawdust, rice husks, cotton trash and other biomass may be gasified without grinding.

Table 4.3 summarises the major developments underway in directly heated gasifiers.

Indirectly heated gasification systems, presently in the development phase at pilot scale, are designed to take advantage of the high reactivity of biomass to produce gas undiluted with nitrogen and without the addition of costly oxygen. Heat is provided indirectly using sand or heat exchangers. Their disadvantage lies in the fact that the gas tends to have higher levels of methane and other light hydrocarbons, which requires costlier downstream processing if the gas is to be converted to methanol.

Major research programs on atmospheric and low pressure systems are underway at Battell - Columbus Laboratories, MTCI (Manufacturing Technologies Co Inc) of Baltimore and TEES, all in the US. They are summarised in Table 4.4.

Australian work on an integrated combined cycle gasification process for brown coal at the SECV's Herman Research Laboratory in Melbourne involves a novel process for drying and then gasifying the moisture rich coal. The SECV believe the process, a pressurized fluid bed system using air, is suitable for lignocelluiose biomass and test facilities, including a 0.5MW pilot plant, are available to investigate this.

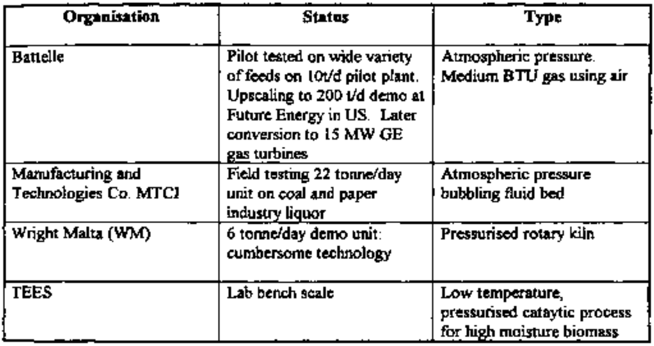
Work is also underway to apply gasification to municipal wastes.

Southern California Edison is presently working with Lurgi to develop and test a circulating 0.8 MW fluid bed gasifier in Frankfurt to produce low BTU gas. The unit will operate at atmospheric pressure using air to produce gas from sorted undensified refuse. A key part of the technology will be a water scrubbing system to take out ammonia, chlorine, tars, heavy metals and particulates. Tars, oils and particulates will be recirculated to the gasifier.

TABLE 4.3 : Major Directly Heated Gasification Technologies

Process	Company	Status	Type
Renugas	IGT	• In development • 11t/d pilot plant • 70 t/d demo on bagasse, start up late 1994 in Hawaii using hot gas cleanup and 5MW turbine from Westinghouse	O_2 blown fluid bed, pressurised
High Temperature Winkler (HTW)	Uhde	Bench and pilot testing	Pressurised fluid bed
Circulating Fluid Bed	Lurgi and several Scandanavian companies	Commercial units built up to 75MW	Atmospheric circulating fluid bed
	Ahlstrom, Sweden	30MW demo project in operation with hot gas cleanup	Pressurised circulating fluid beads
	Lurgi/Uhde and others	In development for a wide variety of biomass	Pressurised
	Shell Texaco Kopers-Totzek	Established for coal. Not very active in development because of high feedstock preparation costs	Entrained bed gasification

TABLE 4.4 : **Major Indirectly Heated Gasification Technologies**



Organisation	Status	Type
Battelle	Pilot tested on wide variety of feeds on 10t/d pilot plant. Upscaling to 200 t/d demo at Future Energy in US. Later conversion to 15 MW GE gas turbines	Atmospheric pressure. Medium BTU gas using air
Manufacturing and Technologies Co. MTCI	Field testing 22 tonne/day unit on coal and paper industry liquor	Atmospheric pressure bubbling fluid bed
Wright Malta (WM)	6 tonne/day demo unit: cumbersome technology	Pressurised rotary kiln
TEES	Lab bench scale	Low temperature, pressurised cataytic process for high moisture biomass

Heavy metals will be combined with ash and this, with the salty scrubber water run off, will be suitable for disposal to sewer and is the only discharge to the environment. The hot gas cleaning system, to prepare the gas for turbines, is the only component requiring prove-out.

The design has been completed for a 5 MW (200 tonnes a day feed) demonstration plant. Construction of the demonstration plant is scheduled for late 1995 at an existing power plant and the company expects the technology will be commercial in 1998.

Italy has a working MSW gasifier in the Chianti region South of Florence. It has been operating for approximately one year. There is also an updraft gasifier using MSW operating at Crefeil in France.

TPS of Sweden (formerly Studsvik) is building a densified RDF gasification unit using an air blown circulating fluid bed gasifier originally developed for wood. The gas is not cleaned and goes to two 3MW water wall boilers both feeding a 6 MWe generator. The company has also developed and tested a 2MW thermal circulatory fluid bed gasifier.

In the area of small-scale gasification, several companies, particularly in Europe and the US, are involved in the development and sale of gasifiers for producing low value gases, mainly to developing countries.

A comprehensive review into the status of commercial small scale units was undertaken by Monenco Consultants of Canada in 1988, and the study concluded that there did not appear to be any successful commercial installations of significant rating in operation at the time.

Despite that, companies in France (Duvant and Ets Touillet who manufacture under the brand name Martezo), Germany (Imbert), the US (Kansas State University, Power Generating Inc) and Brazil (Gasogenio do Brasil) all claim to have developed and in some cases, commercialised and installed, biomass units between 5kW and 3.5MW using various forms of biomass from wood to agricultural residues and corn stover.

The small scale gasifiers, manufactured in France under the brand name Martezo, operate on wood or agricultural wastes in the range 5-500kW and can be used to feed thermal engines to drive alternators, pumps, vehicles and cogeneration sets producing 2kWh thermal. Plants are claimed to have been built and operating in France, Belgium, French Guyana, Costa Rica and the Congo, with 20,000 operating hours demonstrated.

The Brasilian company claims to have built and sold over 300 units.

Another detailed survey on gasifiers for the ERDC and for UN Habitat, carried out by BEST in Australia, disagrees with the Moneco report.

System Johansen in South Africa, Chevet in France, a company in China (based on a design developed and tested by the Indian Institute of Science at Bangalore) are producing and selling gasifiers, mainly in the range of 10 to 200kW. System Johansen offer a 160kW (electrical) gasifier and cleanup system.

See [illegible] at page 273 *

Development work in this area is also taking place in Australia on a 150KWe downdraft unit with flue gas cleaner that will be translated into a commercial package for the 0.5-4 MW range. Developed by Biomass Energy Services and Technology and TREElectric, they report some success in tests to date using sawmill wastes, achieving a cold gas efficiency of 70%. Problems are presently being addressed that relate to improving the rotary biomass feeder.

The economics data for power generation from gasification technologies is provided in Section 4.3.4, Cogeneration.

4.3.3 Pyrolysis

Pyrolysis is the transformation of biomass into charcoal, gas or liquids by heating in the absence of oxygen or with only a very small amount of oxygen.

Pyrolysis process can be categorised as fast or slow depending on the heating and reaction rates. Products include gases, liquids and solids, depending on the reaction rate. The product gas contains carbon monoxide, carbon dioxide and hydrogen and can be cleaned to provide a combustible fuel. The liquid phases consist of an aqueous phase containing water with a range of low molecular weight organic compounds and an organic phase containing mainly aromatics and heavy molecular weight products. This phase is generally referred to as "bio-crude". A solid phase of charcoal can also result from the process. The product mix depends on the process - the slow process producing more solids and the fast process more biocrude and gas.

The choice of pyrolysis process primarily depends on the form of the biomass available. In powder or fine form, a fast or flash process is employed in a fluidised reactor, whereas for large particles conventional pyrolysis on a moving bed or rotary kiln may be employed.

Pyrolysis of biomass is currently not commercialised. However interest in the technology is spurred by the possibility of producing biocrude that would be suitable for oil companies to use as a feedstock for oil refineries.

A review of processes has revealed that there has been substantial development activity in this area and that preliminary testing of pyrolysis oil products indicate positive results in both performance and emissions in small diesel engines.

Veba Oil in Germany and Ensyn Technologies of Canada have developed processes for biomass pyrolysis, the latter has a 30kg an hour pilot facility and a 25 tonnes a day demonstration plant running on wood chips and producing high value chemicals.

Processes developed by Georgia Tech (the AFP process) and the University of Arizona, (the LIPS process) were recently assessed by the IEA. Both processes have been run on laboratory scale equipment to date and designs upscaled to feed rates of 1000 tonnes a day to determine economics.

Amongst the leading technologies in development is that of the National Renewable Energy Laboratory in the US, which is developing a process to produce crude oil by high efficiency pyrolysis with the Polymer Research Consortium. The technology, presently at a pilot scale at a feedrate of 1.36 tonnes a h, is being scaled up to a 36 tonnes a day demonstration unit to prove yields and economics. They expect to produce a product that costs $20-$25 a barrel. Work is underway to test burn these oils in several applications including gas turbines in a joint EEC/Canadian/Hawker Siddley proof-of-concept project; large medium speed diesel engines; and in boilers, in a joint project with Sandia Labs. Present problems include acidic and unstable biocrude oil products.

Other developments include the ENCEL project, which has a 20 tonnes a d process development unit with Red Arrow in Wisconsin and the Interchem/Energy Conversions project, which is presently upscaling technology to a 100 tonnes a day (design completed) unit with the aim of developing standard 240 tonnes a day modules for commercial application.

Municipal Solid Wastes (MSW) are not the easiest feedstock for use in pyrolysis or gasification processes, as the inorganic material and plastics can interfere, forming slags and corrosives. If unsorted waste is pyrolysed or gasified, the process must be designed to provide sufficiently long residence time at a sufficiently high temperature to destroy potentially toxic air contaminants such as dioxins. Air pollution permit conditions in the US often require the use of an auxiliary fuel (natural gas or fuel oil) during startup and shutdown in order to maintain furnace temperatures greater than 870°C.

A number of gasification/pyrolysis processes have been developed specifically for MSW. Whilst there are around 20 commercial processes in development the best known is the Andco's Torrax pyrolysis. Union Carbide

(Purox process) and Occidential Research Corp. have abandoned the commercialisation of their process, developed 20 years ago.

The Andco-Torrax process was developed by Carborundum Environmental Systems, Inc. and was demonstrated from 1969 to the early 1970's on a 68 tonnes a day pilot plant in New York. It was designed for MSW conversion into a fuel gas for firing boilers and kilns. The first commercial plant (200 ton a day) was built in Luxembourg, and appears to be one of the few MSW pyrolysis plants operating successfully.

The technology chosen to demonstrate process economics is the NREL fast pyrolysis process. The data is given in Table 4.5.

4.3.4 Cogeneration

Cogeneration, the conversion of a single energy source into electrical energy (power) and useable heat energy (steam or hot water), can be achieved either by the direct combustion of biomass or its gasification.

In the former, the fuel is used to raise heat and steam, which in turn is used to drive a steam turbine for power. In the latter, the gas derived is combusted directly in an engine or turbine and the waste heat is recovered to provide steam or hot water. At smaller generating capacities, the reciprocating engine is used (0.5 - 1MW), whilst gas turbines are generally of interest at capacities in excess of this.

Cogeneration via the direct combustion route is commercially well established, with operating efficiencies around 30% for capacities in the range 15 -50MW. Capital and operating cost date for selected technologies and capacity ranges are given in Table 4.6.

In Australia, BEST and Strathsteam manufacture a small engine co-generation system with power outputs up to lOkW and heat outputs up to 60kW, with 4 systems having been sold to date. The Australian National University has developed a high pressure, high efficiency small steam engine with power outputs up to lOOkW. There are manufacturers of biomass fired co-gen systems (up to 200kW electrical) in Brazil, Thailand and Switzerland.

Biomass integrated gasification/gas turbine systems (BIG/GT), combining advanced gas turbine power and cogenerating cycles which have already been developed for natural gas and clean liquid fuel applications, offer promising alternatives to direct combustion with higher efficiencies of between 33 and 45% and lower emissions. Already mature and commercialised for natural gas and coal, the combined cycle systems for biomass are in the development/ demonstration stage.

TABLE 4.5 Cost Data : NREL Fast Pyrolysis Process

Product	Process	Feedstock(s)	Plant Capacity	Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements (dry wt)	Raw mtl Cost	By-Product	Value
Diesel Oil	NREL/Interchem (present)	Biomass	95MW (71.3 ml/y)	83.9	11.6	1,000 t/d			
	NREL/Interchem (improved)	Biomass	117 MW (87.8 ml/y)	81.0	9.2	1000 t/d			

TABLE *4.6 Cost Data :* Cogeneration via Direct Combustion

Product	Process	Feedstock(s)	Plant Capacity	Capital Cost SM	Operating Cost SM/Y	Raw Mtl requirements (dry)	Raw mtl Cost	By-Product	Value
Electric Power	Kvaerner Generator AB	Biomass	15 MW/th 5.3 MWe	36.8	0.3	4.1 t/d per MWth			
			30 MWth 10.5 MWe	61	0.61				
			50 MWth 17.5 MWe	91.4	1.01				
			70 MWth 24.5 MWe	117.6	1.42				
Electric Power	Gratefired Condensing turbine	Wood chips, sawdust	10 MWe	18	0.3	60,000 t/y			

Work is focussed on improving gasification technologies, gas cleanup, and developing aeroderived turbines for higher combustion pressures and high exhaust temperatures.

The first generation biomass integrated gasification/gas turbine technology is likely to involve steam injection of the gas turbine (BIG/STIG)to produce efficiencies of between 33 and 40% in simple cycle. Improvements likely to increase efficiency are underway. These include increasing turbine inlet temperatures and modifying cycle configurations.

Application of the technology is limited to those processes which have a steam requirement equal or more than that produced by heat recovery, otherwise the efficiency of the system drops off significantly.

An advanced version of STIG involves a 2-stage compression and intercooling of intake air that is projected to increase efficiency if the STIG system by 25%. Presently under development for natural gas, the technology is expected to be demonstrated for the clean fuel by 1997 and thereafter for biomass.

The only complete demonstration of the advanced biomass integrated gas combined cycle (BIG/IGCC) plant in the world has been built by Ahlstrom in Sweden, linked to their demonstration wood fed pressurised fluid bed gasification process mentioned earlier in the gasification section of this report. The capacity is 6 MWe and 9 MWth with a design efficiency of 82% for the cogeneration plant and a 32% net electrical efficiency. The plant has cost US$39 million.

Other commercialisation activities include a number of projects in the 18-90 MWe range using a variety of biomass gasification technologies integrated with gas turbines.

Development work underway to improve technical performance and system efficiencies is concentrated on gas clean-up to ensure emission levels are met and to reduce erosion, corrosion and deposition problems. The alkali metals found in biomass are known to cause corrosion in high temperature gas turbines.

Work in the US and Europe indicates that ceramic filters would be the best choice for this and Westinghouse, in a project underway since early 1993, are developing a hot gas clean-up system for installation and testing with the IGT Renugas gasifier demonstration project in Hawaii. Westinghouse are also utilising emathlite clays to remove alkalis in the system. General Electric in the US are also developing a hot gas clean-up system for coal gasifiers |- which will later be adapted to biomass.

Studsvik in Sweden and Battelle Columbus Laboratory in the US are both developing a dolomite based system for the catalytic cracking of tars. In the Studsvik process, tars and ammonia are converted into gases suitable for firing in reciprocating engines. Details of the BCL system have not been disclosed.

Power and cogeneration plant for small scale gasification units typically burn gas produced from gasifiers in the internal combustion engine, either alone or in dual fuel mode. These engines, adapted mainly from diesel and spark ignition automotive engines, including Fiat, Mercedes Benz and Dorman, typically show thermal efficiencies between 27 and 35%. Major operating problems occur from tars and carbon build-up in the valves and combustion chamber.

Substantial work is underway to properly adapt gas turbines from the jet engine industry to use the low energy gas produced in gasifiers. Of interest is the work being carried out by PGI of the US, in developing a direct fired gas turbine system for biomass derived gas. The compressor section of the gas turbine pressurises the combustion air for biomass gasification. The hot gases are then directed through a cyclonic separator which it is claimed reduces entrained particulate matter sufficiently to provide extended gas turbine operation. Exhaust gases can be used for thermal drying or to raise steam. The system is being developed on a full scale 391 kWe demonstration plant and is expected to be commercialised in about 3 years for capacities between 500kWe and 3.5MWe.

The Australian company Energy Developments Ltd is developing a small lOOkWe engine/generator set. The technology will incorporate proprietary gas clean-up technology developed from landfill gas utilisation. A suitable site is presently being investigated for first demonstration project.

Capital costs data for a range of capacities and processes is given in Table 4.7.

4.3.5 Fuel Methanol

Biomass gasification to a synthesis gas consisting of CO, H2 and CH4, provides opportunities for methanol production.

All the technology stages after syngas production are well known and proven through the conventional natural gas process route.

The production of methanol from biomass requires the production of a clean syngas from a gasification process. Whilst biomass has the advantage over conventional fuels of having a low sulphur content, it also has a high oxygen content.

TABLE 4.7 Cost Data : Cogeneration via Gasification

Product	Process	Feedstock(s)	Plant Capacity	Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements (dry)	Raw mtl Cost	By-Product	Value
Electric Power	BJG/STIG	Biomass	5.4 MWe 53 MWe 110 MWe	16 107 174	0.23 1.6 3.14	5.4 t/d per MWe			
Electric Power	BEST/EDL *See Email on page 273	Woodchips, sawdust	0.5 MWe 1.0 MWe 4.0 MWe	0.4 1.8 3.4	(?)	1.0 t/d per MW			
Electric Power	Southern Cal Edison	MSW	83 MW gas (2.34 mGJ/y) 250 MW gas (7.07mGJ/y)	234 548	30.5 60.6	1000 t/d RDF 3000 t/d RDF			

As a result, the biomass derived gas will have ratios of hydrogen to carbon oxides significantly lower than the optimum (2:1) required for efficient synthesis and the process for must therefore be modified.

Two routes are available for achieving this: direct oxygen blown gasification which requires an air separation plant or indirect steam- blown gasification, which produces a syngas rich in hydrogen and utilises a portion of the syngas produced to supply heat to the reactor. Both routes end up with a syngas with too much carbon monoxide and need a shift reaction step to adjust the chemical ratios. In addition, all gasifiers generate about a 20-40% energy loss due to the formation of methane and higher hydrocarbons in the gasification process. These compounds must be removed before or in the methanol synthesis plant. Overall efficiencies of conversion lie in the range 57 - 65% for biomass to methanol, with the higher conversion relating to indirect gasification processes.

Typical methanol plants using natural gas as feedstock, operate at relatively low pressures (50 - 100 atm) and at capacities of 1500 - 2500 tonnes a day to be commercially viable. Technology for more that 90% of these commercial facilities has been supplied by ICI of the UK and Lurgi of Germany.

A new ICI methanol synthesis route, called the Leading Concept Methanol process, is to be demonstrated in a BHP project in Victoria Australia for the first time. This 160 tonnes a day methanol plant will utilise an oxygen fired reformer instead of the conventional large direct fired reformer. Methanol synthesis will also take place at relatively high temperatures of 1200-1500°C. It is expected that this new technology could reduce the economical size of methanol plants to 1000 tonnes a day or less.

Lurgi has also developed a low pressure process quite different from the ICI route, and over 20 plants using this technology have been built since 1969 using natural gas feedstock in the capacity range 22 to 2200 tonnes a day methanol.

The Hydrocarb process, originally developed by Brookhaven National Laboratories, is now being developed by the Hydrocarb Corp in the US. It comprises three stages: hydrogasification of the biomass, pyrolysis of the methane to hydrogen and carbon, and methanol synthesis. In the process natural gas is added to enhance the production of synthesis gas, excess hydrogen is recirculated to the gastfier, energy is recovered from the high temperature step and the shift conversion, and the cold gas clean-up to remove C02, sulphur and alkalis has been eliminated. Alt of these process components have, to some extent, already been proven in various applications and testing of the concept on a bench-scale plant is presently underway in Southern California.

Work being carried out at the National Renewable Energy Laboratories and Batelle Columbus in the US to demonstrate catalysts for hot gas cleanup and methane conversion to useful syngas components. Prove out of long term performance is underway.

Improved methanol synthesis routes are also under investigation, and a major improvement would be the development of a "once through" system to eliminate recycle loops. Brookhaven National Laboratory has developed a low temperature liquid phase catalyst that can convert 90% of the CO in a single pass, combined with an efficient heat recovery system. Other technologies are looking at methanol removal on synthesis and development of a single step synthesis gas/ methanol conversion process.

Reviews by the USDOE indicate optimism to substantially increase efficiencies and yields from the present 51 to 62% and from 575 to 704 litres of methanol a tonne respectively by the year 2000, thereby almost halving the cost of methanol production by that date.

Cost data for ranges of methanol process technologies are given in Table 4.8.

4.3.6 Fuel Hydrogen

Capital and operating cost data for the leading gasification routes to hydrogen are given in Table 4.9.

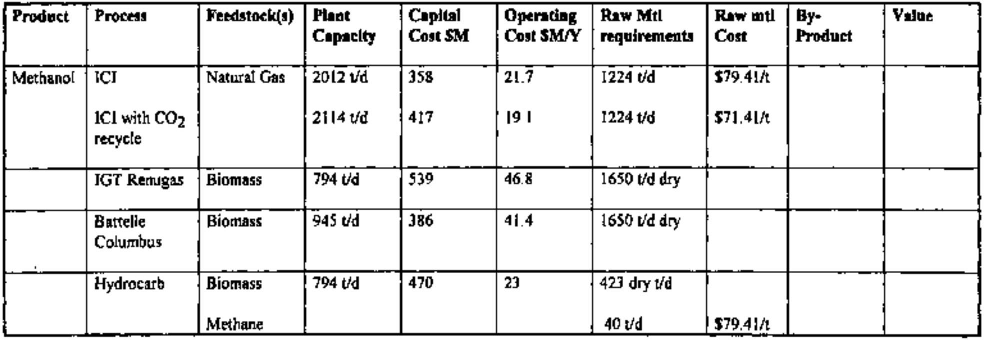
Hydrogen can be produced as a fuel gas from biomass utilising the indirect gasification process, followed by conditioning and a shift reaction step to convert as much as possible of the carbon monoxide to carbon dioxide, removal of water from the gas now containing some 60% hydrogen, and then finally a purification step, usually achieved by a pressure swing adsorption unit, which produces 99.9% purity hydrogen.

Biomass to hydrogen conversion efficiency will range from 68% (direct gasification) to 78% (indirect gasification).

No commercial facilities for hydrogen production from biomass are currently in operation, the major barrier being the development of a viable gasification process. All other process steps are commercially proven.

In the only demonstration of its kind, Veba Oel of Germany is in the process of developing a 1 tonne an hour plant to produce hydrogen from elephant grass using fluidised bed gasification.

TABLE *4.8 Cost Data* : Methanol from Biomass



Product	**Process**	**Feedstock(s)**	**Plant Capacity**	**Capital Cost $M**	**Operating Cost $M/Y**	**Raw Mtl requirements**	**Raw mtl Cost**	**By-Product**	**Value**
Methanol	ICI	Natural Gas	2012 t/d	358	21.7	1224 t/d	$79.41/t		
	ICI with CO_2 recycle		2114 t/d	417	19 1	1224 t/d	$71.41/t		
	IGT Renugas	Biomass	794 t/d	539	46.8	1650 t/d dry			
	Battelle Columbus	Biomass	945 t/d	386	41.4	1650 t/d dry			
	Hydrocarb	Biomass	794 t/d	470	23	423 dry t/d			
		Methane				40 t/d	$79.41/t		

TABLE 4.9 Cost Data : Hydrogen from Biomass

Product	Process	Feedstock(s)	Plant Capacity	Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements (dry)	Raw mtl Cost	By-Product	Value
Hydrogen	IGT Renugas	Biomass	247.3MW (890GJ/h)	425	64.7	1650 t/d			
	Shell	Biomass	291.4 MW (1049GJ/h)	506	65.1	1650 t/d			
	Wright Malta	Biomass	314 MW (1129GJ/h)	383	71.8	1650 t/d			
	Battelle Columbus	Biomass	301.1 (1084GJ/h)	285	61.5	1650 t/d			

In a more advanced development, a laboratory scale process is being evaluated to produce hydrogen from wet biomass by gasifying in supercritical water. The University of Hawaii is studying hydrogen production from a marine derived biomass as feedstock.

4.3.7 Fuel Ethanol

Fuel ethanol can made by fermentation of sugars derived from biomass containing sugar, starch and cellulose and from industrial wastes containing these products such as lactose in milk whey, molasses from sugar processing and liquors from pulp and paper manufacture.

Potential sources of sugar include sugar cane, sugar beet, sweet sorghum, milk whey and molasses; starch and more complex sugar sources include the cereals, sago, cassava, potatoes and Jerusalem artichokes; and lignocellulose includes wood, crop stalks and residues, paper and grasses.

Both acids and enzymes are used commercially to hydrolyze starch itself and the starch contained in cereals to fermentable sugars.

The production of ethanol from sugar, cane, sugar tubers, molasses, grain and starch is well established technology and commercial plants are operating in many countries around the world. Processes for this are offered by a wide range of companies. The ethanol is produced at more than 99% purity if it is to be used as a blend with petrol, or at 95% if used as a neat fuel.

The production of ethanol from lignocellulose is emerging technology.

The capital and operating costs of biomass to ethanol processes are provided in Table 4.10.

Lignocellulose biomass is generally made up of cellulose (45-50%), hemicellulose (20 -25%) and lignin (15-20%), together with soluble solids and ash. Cellulose and hemicellulose are carbohydrate polymers, which when hydrolysed by acids or enzymes break down to give hexose sugars (glucose) from the former and a mixture of glucose and pentose sugars (xylose) from the latter. The lignin does not contain sugars and is used as boiler fuel or sold as a by-product. The hexose sugars are easily fermentable by yeasts and other organisms, whilst rapid and efficient fermentation of the pentose sugars is much more difficult.

TABLE 4.10 Capital Costs : Ethanol Production from Biomass

Product	Process	Feedstock(s)	Plant Capacity		Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements	Raw mtl Cost	By-Product	Value
			m^3/d	Ml/y						
Ethanol	Vogelbusch	Grain	20	6,8	8	2.5*			Animal feed (DDG)	$200/t
			100	34	42	12*				
			300	102	96	36*	394 l/t grain			
			400	136	125	47*				
	Chematur	Molasses	20	6.8	11	2*				
			100	34	34	9.5*	281 l/t molasses			
	TVA dil acid	Lignocellulose	102	34.7	150	9.8	205 l/t dry wood			
	TVA conc acid		120	40.8	102	17.5				
	NREL (present)	Lignocellulose	350	119	195	17.5	341 l/t dry wood			
	NREL (future)	Lignocellulose	Not available				372 l/t dry			
	Atkins Tasmania	Beet	110	37.4	35	5	90 l/t fresh beet		Animal feed	$15/t
			225	76.5	50	6				

* Includes raw material costs

Companies in the US are claiming to be building demonstration plants as a prelude to the commercialisation phase. Organisations at the forefront in this area include Iogen and StakeTech in Canada (steam explosion route) and the National Renewable Energy Laboratory (enzyme hydrolysis and fermentation), the Tennessee Valley Authority (dilute and concentrated acid hydrolysis) and Arkenol in the US.

Stake Tech have three pilot plants processing waste paper at capacities between 0.5 and 6 tonnes an hour in Canada and the US, and in France they have a 30 cubic meter facility to trial enzyme production and fermentation. They also claim to have demonstrated single stage hydrolysis and fermentation.

The TVA has tested its dilute and concentrated acid hydrolysis process on hardwood at 2 dry tonnes a day and 6 dry tonnes an hour respectively. TVA are in the process of scaling up a new concentrated acid process with acid recovery and recycle, which they say they have demonstrated at laboratory scale. The fermentation step uses yeasts in these processes.

Arkenol are developing a concentrated sulphuric acid process and their first two commercial scale plants due to start up over the next two years. The first project will be a combined grain/cellulosic plant in Texas producing 13% of its ethanol from cellulose initially, increasing to 55% over 5 years. The second will be a plant utilising waste heat from a 148.5 MW cogeneration plant. The Arkenol process is a 2-stage acid hydrolysis system in which the acid and sugars are separated by ion exchange. The acid is recycled and a yeast will convert both glucose and xylose to ethanol.

No information was received from Iogen on their process.

The National Renewable Energy Laboratory is developing a single stage sacharification and fermentation process using enzymes. A first generation demonstration project is presently under construction near Denver, with the participation of AMOCO. The project, due for start-up this year will have a capacity of 1 tonne a day lignocellulose feed and utilise state of the art technology blocks as developed to date by NREL. Further work is being carried out on a lab and pilot scale on the pretreatment and single stage hexose and pentose fermentation systems. The program has the objective of achieving a production cost of ethanol of US$1.00 a gallon using the present technology system and US$0.70 a gallon by the year 2000.

The yields of ethanol for the various technologies are shown below The large differences between the TVA and other technologies are mainly due to pentose conversion.

NREL	372 litres a tonne dry wood
ARKENOL	363
STAKE TECH	320
TVA cone acid	240
dilute acid	205

A two million litre a year lignocellulose to ethanol demonstration plant using a Zymomonas process under development at the University of NSW, is at the design stage in a feasibility study presently being conducted by Gorton Timber of Grafton, New South Wales, Australia.

The Australian non profit company APACE Research has developed a combined ethanol recovery/waste treatment process. The developers indicate that the process is energy self-sufficient and lower cost than conventional technology, and is being included in the demonstration plant design.

No details of the technology or capital and operating costs were made \ available in time for a thorough evaluation.

Process development work is focussed on :

- facilitating hydrolysis through pretreatment of the biomass by size reduction and/or extracting the cellulose and hemicellulose, or making it more accessible to enzymes or acid hydrolysis through steam explosion;
- improved acid or enzyme hydrolysis through lower temperatures, less product degradation, faster reaction times and acid or enzyme recovery and recycle;
- improved fermentation processes through faster fermentation, simultaneous hydrolysis and fermentation, and the genetic engineering of enzymes and yeasts that will increase yields by allowing the fermentation of pentose sugars.

4.3.8 Vegetable Oils and Esters

Vegetable oils and their methyl or ethyl esters have been used as diesel engine fuels both in their crude form and fully refined state. They have been used neat and in a range of blends as they are fully miscible in all proportions with diesei.

The technologies for extracting vegetable oils and their esterification are mature.

The original process for extracting oil for vegetable seeds was by expeller The process is used on both a large and small scale. The oil can be squeezed out of the seeds leaving a 5-7% oil in the residual meal. This meal is suitable for pigs and chickens and may be suitable as a partial diet for cattle. The crude oil produced is suitable both for use as a fuel and for esterification.

Almost all modem world plants now produce vegetable oil on a large scale by solvent extraction. The oil is then filtered and is suitable in this crude form as a liquid fuel.

Low glycerol content is a prerequisite for any biodiesel process because traces of the chemical can clog injection nozzles during combustion. Austria has been the first to set a national biodiesel standard with a maximum of 0.25% and 0.03% for total and free glycerol, respectively. In 1993, these limits will be tightened to 0.24% and 0,02%. A similar proposal is currently being reviewed in Germany. US companies are informally following Austria's lead.

A process developed by Vogel & Noot GmbH of Austria using a potassium hydroxide catalysed process meets these standards. Other processes are lowering glycerine content by more closely controlling the phase separation step. Oelmuhle Connemann GmbH of Germany plans to use a centrifuge in a 60,000 tonnes a year plant, which will come onstream in 1994. Meanwhile, Sofiporteol SA's Compiegne plant uses a patented process called Esterfip, developed by the Institute Francais du Petrole.

Typical capacities for an esterification plant are between 8,000 and 60,000 tonnes a year with plans for 100,000 tonnes a year methylated vegetable oil facility under consideration.

Vogel & Noot claim to have built five esterification plants. Three of them have a capacity of 1,000 tonnes oil a year, one of 15,000 tonnes oil a year and one of 30,000 tonnes oil a year, with its start up scheduled for early 1994.

More than 200,000 tonnes a year of esterified vegetable oil production capacity has been installed in Europe, with a further 500,000 tonnes a year planned by 1995. The largest producer is the Novamont subsidiary of Italy's Ferruzi-Montedison Group, which has just started up a 60,000 tonnes a year plant at Livorno. A second 100,000 tonnes a year biodiesel plant is planned.

By 1994, Interchem Industries plans to market between 30 and 60 million gallon of biodiesel in the US. The company has contracted Proctor & Gamble's Industrial Chemicals Div. to produce 15 million gallons a year of biodiesel at its plants in Massachusetts and California.

Both the extraction of vegetable oils and the esterification of vegetable oils can be done on farm at any scale using simple technology. The raw material may be seed which is contaminated or otherwise unfit for human consumption.

The esterification process can also be used to convert waste oils, e.g. cooking oils, into a useful fuel.

At the very low technology end, CSIRO and ANU in Australia have combined to produce a processing unit for $200 which will extract oil from coconuts. A commercial prototype has been built.

Cost data for large and small scale plant is given in Table 4.11.

4.3.9 Anaerobic Digestion

Anaerobic digestion is the breakdown of organic material to methane and ; carbon dioxide by bacteria in the absence of air.

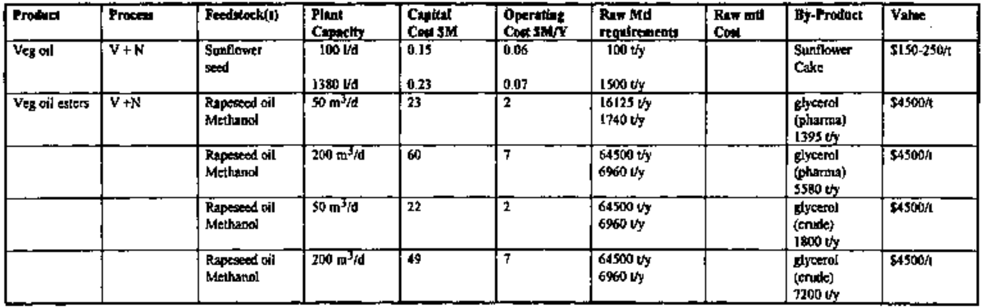
The process can be applied to a wide range of raw materials including sewage sludge, animal wastes and wastes from abattoirs, industrial and food processing wastes and municipal solid waste. Plants can be built on a large or small scale.

The evolution of technologies for anaerobic digestion began with digesting low solid sewage sludges (5% solids), through animal waste slurries (15% solids) and then on to municipal solid wastes in landfill sites (+50% solids) and in specially designed reactors (35% solids). All of these applications, except the very last perhaps, are commercially demonstrated and well established over many hundreds of projects, with technologies being offered that have been developed in Europe, Japan and the US.

Digestion can occur in three temperature ranges: ambient; 37-40°C (mesophilic); or at around 55 °C (thermophilic). This temperature affects the rate at which the digestion process occurs, but not its conversion efficiency, Generally 25-45% of the feed solids are destroyed, producing 0.5m^3 of biogas (50-80% methane, 30-50% carbon dioxide depending on the feed type) for every kg of COD converted. Some designs operating at the higher temperatures can consume 20 - 30% of the gas generated to maintain the required temperature regimes.

Some wastes, particularly industrial wastes, require nutrients to be added, usually nitrogen and phosphorous, to support the digestion process.

TABLE 4.11 Cost Data : **Vegetable Oil and Esterification Technologies**



Product	Process	Feedstock(s)	Plant Capacity	Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements	Raw mtl Cost	By-Product	Value
Veg oil	V + N	Sunflower seed	100 l/d 1380 l/d	0.15 0.23	0.06 0.07	100 t/y 1500 t/y		Sunflower Cake	$150-250/t
Veg oil esters	V +N	Rapeseed oil Methanol	50 m^3/d	23	2	16125 t/y 1740 t/y		glycerol (pharma) 1395 t/y	$4500/t
		Rapeseed oil Methanol	200 m^3/d	60	7	64500 t/y 6960 t/y		glycerol (pharma) 5580 t/y	$4500/t
		Rapeseed oil Methanol	50 m^3/d	22	2	64500 t/y 6960 t/y		glycerol (crude) 1800 t/y	$4500/t
		Rapeseed oil Methanol	200 m^3/d	49	7	64500 t/y 6960 t/y		glycerol (crude) 7200 t/y	$4500/t

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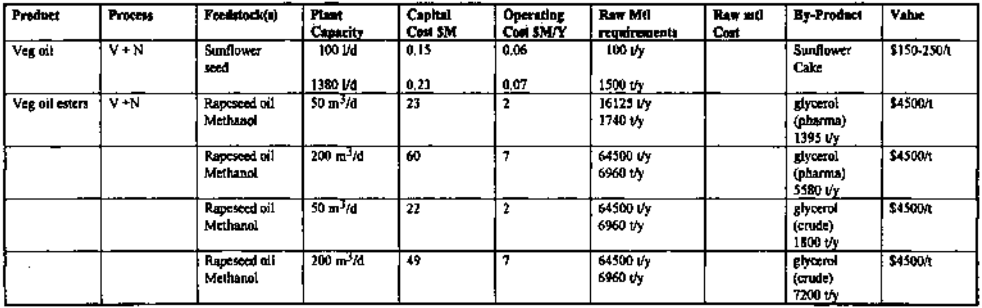

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		Rapeseed oil Methanol	50 m^3/d	22	2	64500 t/y 6960 t/y		glycerol (crude) 1800 t/y	$4500/t
		Rapeseed oil Methanol	200 m^3/d	49	7	64500 t/y 6960 t/y		glycerol (crude) 7200 t/y	$4500/t

There are a range of technologies employed for the various situations and these can be categorised into three main types. They are the suspended growth processes, best suited for the treatment of wastes with a high particulate matter content; the supported growth processes, suited to wastes in which almost all the organic matter is dissolved; and hybrid processes for wastes that fall between these categories.

Suspended growth systems include conventional completely mixed digestion systems and the anaerobic contact process. This type of system is generally applied to animal wastes.

Supported growth processes utilise technologies to hold the organisms in place in the reactor as they are designed for higher flow rates. They can be of the fixed and fluidised bed type. Inert packing materials are used on which the organisms attach themselves and which are heavy enough to resist being washed out by the flow of effluent. Mainly suited to industrial wastes, these systems are unsuitable for animal wastes with a high solids content.

Hybrid systems include the upflow anaerobic sludge blanket (UASB), the UASB a fixed bed and the anaerobic lagoon. In the UASB process, the organisms themselves clump together to form large, high concentration granular floes in a relatively dense bed in the reactor. High efficiencies are achieved at high throughputs of lower concentration wastes. More than 200 of these plants have been built worldwide to treat a large variety of industry wastes, from chocolate factories to soft drink plants. Reactor volumes have been as small as 280 m^3 and as large as 67,000m^3. Anaerobic lagoons are simple pond systems with long residence times. Recent innovations include trends to construct deeper ponds with smaller surface areas in order to efficiently collect the biogas released.

No major new developments are expected in the areas of industrial and animal waste treatment in the foreseeable future, although in Europe there has been a trend to installing large centralised or regional biogas plants that will process wastes from a variety of sources.

Biogas systems are slowly beginning to penetrate the market in Australia Bunge operates a UASB process to treat starch wastes at Altona, in Victoria, achieving a 65-90% BOD reduction and recovering biogas containing 65-70% methane. McCain Foods at Ballarat, Victoria operate a mixed tank digester for potato processing wastes and more recently UASB digesters have been installed at a paper mill, two confectionary plants, a fruit cannery, a brewery and a chemical company. Environmental Services International in Perth has developed technology applicable to a range of industry wastes.

A large two-stage animal waste processing plant has recently been built at the Charles EFE piggery near Ballarat for 12,000 pigs. The technology is Italian based, but modified for local conditions by BioResources Australia using Australian developed proprietary technology. The 1700m^3 a day gas is used to cogenerate heat and power in Fiat Totem engines and a caterpiller engine producing 4300kWh of power and 8,000 kWh of hot water. It exports 85% of the energy generated. The plant, the first demonstration in the Asia Pacific region, has the capacity to process waste from 25,000 pigs.

The CSIRO has developed at two-stage anaerobic biofilm/floc reactor, demonstrated 10 years ago at 120 litre scale. Piggery wastes have been successfully tested at loading rates up to 23 kg COD a m^3 a day, producing methane at 0.3m^3 a kgCOD. The technology is being redesigned to be a single stage process and is being marketed by Bioplus Technologies of Melbourne.

4.3.10 Anaerobic Digestion of MSW

The collection of gas from landfill sites has been underway commercially since 1980, and the technology is now well established and relatively well understood. More than 150 tips worldwide were identified in a 1987 survey that have been fitted with wells and extraction and collection systems for gas recovery.

Power was generated at 56 of the sites at a total capacity of 170MW, 13 projects supplied pipeline gas to the grid and in the rest the gas was used to direct fire boilers and kilns.

The average gas yield over the life of a tip is 135m^3 a tonne. Theoretically, this could rise to 400m^3. Systems have been developed to allow gas collection to begin early on in the life of the tip, to ensure there is no oxygen penetration during gas extraction and to maintain optimum moisture levels in order to maximise gas yields. The collected gas, which consists approximately of 50% methane and 50% carbon dioxide and trace components of sulphides and other unwanted poisonous or corrosive compounds, can be burnt directly to provide heat or fed to cogeneration equipment for power generation. The gas is scrubbed and cleaned before being fired in internal combustion engines or gas turbines to provide heat and power.

Councils and companies are actively installing cogeneration systems at tips in Australia. In Victoria a total of about 40MW of power generating capacity has been installed or is under construction at tip sites. Energy Developments Ltd of Brisbane are now operating 10 projects around Australia, at a total capacity of over 50MW.

Newer technology for digesting MSW in digesters is presently being developed, demonstrated and commercialised. A variety of processes using unsorted and sorted MSW alone in raw form, hydrolysed and neutralised or mixed with sewage sludge are being planned and tested both in Europe and the US at capacities from 10 to 200 tonnes a day feedrate.

No larger-scale plant has yet been built in the US. However plants exist in Europe using the Belgian DRANCO (Dry Anaerobic Composting) process, the German BTA process, the French Valorga process and the WABIO system developed in Finland. A fifth plant, using a process developed by Uhde in Germany, is under construction. Their sizes and technology status is summarised in Table 4.12.

Data on the capital and operating costs of the range of technologies discussed above is given in Table 4.13.

4.3.11 Oxygenates

Methanol and ethanol can be converted to MTBE (methyl tertiary butyl ether) and ETBE (ethyl tertiary butyl ether) respectively, both having a more favourable set of properties as a gasoline additive than the original alcohols They can both be produced in the same reaction system and production of MTBE versus ETBE is dependent almost solely in the price differential between ethanol and methanol. Some additional distillation equipment is required in an ETBE production facility over that designed for MTBE alone.

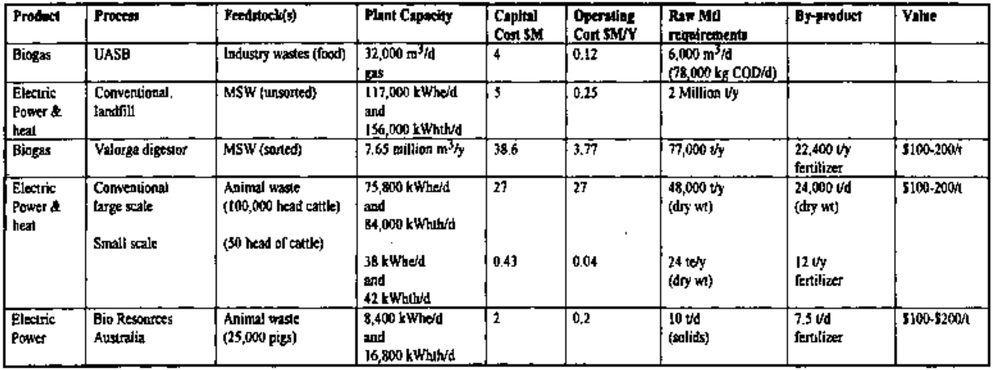
Production of MTBE requires a supply of iso-butylene as regent for the catalytic etherification of the alcohols. This may be obtained directly from in-refinery sources or from sources external to the refinery, primarily, from mixed field butanes. For the former case, only the etherification reaction is required and the scale of production is ultimately limited by the refinery catalytic cracking capacity producing the isobutylene. Production from field butanes is carried out at much larger processing capacities but requires additional isomerisation and (high cost) dehydrogenation stages. There are, therefore, two different levels of cost of production of MTBE/ETBE with in-refinery production being the lower capital cost.

Chevron and ARCO are the largest producers of MTBE in the US, and ETBE is currently not produced commercially, although ARCO have run their plant to produce small batches. Phillips Petroleum Co of the US also offer proven technology for production of MTBE from iso-butylene rich feed streams.

TABLE *4.12 : Status of* MSW Digestion Technologies

Process	Status	Capacity	Sorted/ Unsorted	Site	Residence	Yield	Temperature	COD Reduction	Comment
REFCOM	Demo	10t/d	U	Bergen, NJ US	12-18 days		35°C		
DRANCO	Comm	10,500 t/y	S	Munich, Germany	14-21 days	2.2 m^3 CH$_4$/m^3/d 120 m^3 gas/tonne MSW	55°C	53%	
	Planned	10,500 t/y	S	Salzburg, Germany					
BTA	Comm	20,000 t/y	S	Munich	9 days				MSW is hydropulped and hydrolysed
	Comm	20,000 t/y	S	Nuremberg					
	Comm	22,000 t/y	S	Helsingor Denmark		137 m^3 gas/tonne MSW	38°C		
	Under Const	70,000 t/y	S	Newmarket					
Valorga	Comm	27,400 t/y	S	Amiens		236 m^3 gas/tonne VS	35-40°C		Source separated waste
	Comm	8,000 t/y	S	La Buisse, France					
	Comm	90,000 t/y	S	Tahiti					Residue mixed with wood chip for fertilizer
	Under const	52,000 t/y	S	Tilburg, Holland					
WABIO	Comm	2,100 t/y org waste and 1,200 t/y sewage sludge	S	Stormossen Finland and Mustasaari Finland	18-21 days			55-60%	Wet bio-fraction used as feed mixed with dewatered sewage sludge 9-13% solids
UHDE	Under const	72,000 t/y	S		14 days				2 stage digestion 10% solids in feed

TABLE 4.13 Cost Data : Anaerobic Digestion of Biomass Processes



Product	Process	Feedstock(s)	Plant Capacity	Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements	By-product	Value
Biogas	UASB	Industry wastes (food)	32,000 m^3/d gas	4	0.12	6,000 m^3/d (78,000 kg COD/d)		
Electric Power & heat	Conventional, landfill	MSW (unsorted)	117,000 kWhe/d and 156,000 kWhth/d	5	0.25	2 Million t/y		
Biogas	Valorga digestor	MSW (sorted)	7.65 million m^3/y	38.6	3.77	77,000 t/y	22,400 t/y fertilizer	$100-200/t
Electric Power & heat	Conventional large scale	Animal waste (100,000 head cattle)	75,800 kWhe/d and 84,000 kWhth/d	27	27	48,000 t/y (dry wt)	24,000 t/d (dry wt)	$100-200/t
	Small scale	(50 head of cattle)	38 kWhe/d and 42 kWhth/d	0.43	0.04	24 te/y (dry wt)	12 t/y fertilizer	
Electric Power	Bio Resources Australia	Animal waste (25,000 pigs)	8,400 kWhe/d and 16,800 kWhth/d	2	0.2	10 t/d (solids)	7.5 t/d fertilizer	$100-$200/t

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No Australian refineries currently produce MTBE or ETBE and their capacity to do so depends on the size of the refinery, particularly its catalytic cracking capacity and on whether the catalytic cracker is operated to maximise olefins production.

The range of potential MTBE production capacities in Australian refineries is numbered to be from 20,000 - 80,000 tonnes a year. A large number of Australian refineries could produce MTBE at around 50,000 tonnes a year with some adjustment of catalytic cracker operating conditions.

Production of ethers from field butanes is based on facilities using Engelhard and Phillips technology.

Typicial world-scale plant capacities are between 500,000 and 600,000 tonnes a year MTBE. Recent installations as low as 180,000 tonnes a year of MTBE have been completed. The range of capacities considered to be of relevance to Australia for plants using mixed butanes is 200,000 - 500,000 tonnes a year of MTBE.

The CSIRO's Division of Coal and Energy Technology has developed a new process to produce, at the laboratory scale, fuel octane enhancers/oxygenates directly from biomass. This process converts hemi-cellulose and cellulose using hydrolysis and hydrogenation steps to methyl furan and dimethyl furan respectively. These compounds, relative to MTBE, have high blending octane numbers, low vapour pressure and similar oxygen content. Economic studies have indicated that methylated furans can be expected to be valued around 25% higher than MTBE on a tonnage basis valued as octane enhancer and equivalent to MTBE if valued as oxygenate. Direct testing of vehicle emissions using methylated furan gasoline additives has not yet been undertaken. Their recent studies have focused on production of methylated furans from bagasse.

Capital and operating costs for this process have been developed from conceptual design studies. These studies have also identified where significant reductions in capital and operating cost can be made in future.

They also suggest that plant capacities will probably need to be greater than about 150,000 tonnes a year furans, equivalent to around 600,000 dry tonnes a year bagasse. Maximum plant capacities are likely to be around 350,000 tonnes a year furans, equivalent to around 1.4 million dry tonnes a year.

Capital and operating cost data for ETBE, MTBE and furan production is given in Table 4.14.

TABLE 4.14 Cost Data : Oxygenate Processes

Product	Process	Feedstock(s)	Plant Capacity	Capital Cost $M	Operating Cost $M/Y	Raw Mtl requirements	Raw mtl Cost	By-Product	Value
In- refinery production									
MTBE	Phillips	Methanol	50,000 t/y	17	1.5	18,200 t/y	$1215/t		
		Isobutylene				33,000 t/y			
ETBE		Ethanol	57,000 t/y	17	1.5	26,200 t/y	$1215/t		
		Isobutylene				33,000 t/y			
Grass roots plant									
MTBE	Phillips	Methanol	20,000 t/y	190	16.7	72,800 t/y			
		Mixed Butanes				132,000 t/y	$258/t		
		Ethanol	232,000 t/y	190	16.7	104,800 t/y			
		Mixed Butanes				132,000 t/y	$258/t		
MTBE	Phillips	Methanol	500,000 t/y	400	31	182,000 t/y			
		Mixed Butanes				357,000t/y	$258/t		
		Ethanol	580,000 t/y	400	31	261,600 t/y			
		Mixed Butanes				357,000 t/y	$258/t		
FURANS	CSIRO	Bagasse	176,850 t/y	260	21.9	700,000 dry t/y	$20/t fresh		

4.4 SUMMARY

The conversion technologies have been reviewed to provide an overview of the state-of-development of each biomass to energy conversion route, together with the key technical and economic parameters required to calculate the cost of energy products over a range of capacities. These are summarised in Table 4.15.

Direct combustion technologies are well established in domestic, commercial and industrial applications. Domestic solid fuel heaters cookers and boilers are available in standard designs with combustion efficiency at the technical limit of about 70%. Attention in this market segment is now focussed on environmental performance. Increased efficiency is being sought in industrial equipment through improvements to grate and combustion chamber design.

Simple boilers have an efficiency of around 20-25% and capacities vary from around 100KW up to 30MW. Steam production from these systems are typically around 150-2250 tonnes an hour .

A technology improvement under development in Australia is the swirl burner being developed for bagasse by the Sugar Research Institute in Queensland. It would improve boiler efficiency only minimally.

Substantial increases in efficiency are being achieved by fluidized bed combustion technologies, in which carbon is utilised close to 100%. Various versions of this technology have been adapted for biomass from coal-based developments, and several large units from 10-50MEW have been built and are operating in the US to provide heat and electricity. Whole tree combustion systems are being developed, claiming efficiencies of over 85%.

Gasification is the conversion of biomass to a combustible gas through combustion in a controlled atmosphere of air or oxygen, either at atmospheric pressure or under pressure.

All commercial gasifiers operating on biomass to date are atmospheric pressure designs, with presssurisesd units for larger scale electricity and fuel applications under development from coal-based technologies. Efficiencies of 75-85% are being achieved. Processes can be directly (oxygen/air) or indirectly heated. Large scale directly heated technologies are being demonstrated in several major projects in the US and Europe for biomass. The technology is also being applied to MSW.

No commercial facilities have been built using indirect biomass gasification, although there are several pilot scale units in operation.

The SECV in Victoria is developing a fluidized bed gasification system for brown coal which could be applied to biomass. This technology needs to be investigated in detail.

Of interest is the work going on in the area of small-scale gasification. Small scale power plants, manufactured in several European countries, operate on wood or agricultural wastes in the range 5-500kw and can be used to feed thermal engines to drive alternators, pumps, vehicles and cogeneration sets.

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Work in this area is also taking place in Australia on a 150KW unit to develop a commercial package for the 0.5-4MW range. Developed by an Australian company Biomass Energy Services and Technology Pty Ltd, the units will be linked to power generating systems being developed by another Australian company Energy Developments Limited.

Pyrolysis is the transformation of biomass into gases or liquids by heating in the absence of oxygen.

A review of processes has revealed that there has been some activity in this area and that preliminary testing of pyrolysis oil products indicate positive results in both performance and emissions in small diesel engines. The National Renewable Energy Laboratory in the US, Veba Oil in Germany and Ensign Technologies of Canada have developed processes for biomass pyrolysis, the latter two have a 30kg an hour pilot facility and a 25 tonnes a day plant running on wood chips.

First generation systems for the cogeneration of electricity and heat from steam and fuel gases are proven with biomass feedstocks. Operating at lower steam pressures than conventional coal-fires electric utility plants, they also have lower efficiencies (14-18% vs 35%). The lower steam conditions arise from a dependence on the use of steam turbines for plants of capacity less than 100MWE.

R & D is therefore being carried out to improve the efficiency of cogeneration systems based on integrated gasification combined cycle systems (IGCC) offering relatively high levels of efficiency compared to the combustion technologies. Process developments included steam injection to gas turbines, and this technology could be commercial in the next 2-3 years. In a recent development, Ahlstrom in Sweden has just built the world's first IGCC demonstration plant using biomass. It will produce 6MWE and 9MWTH at a net total design efficiency of 82% and a net electrical efficiency of 32% using a pressurised fluid bed gasifier and gas turbine cycle.

Other commercialisation activities include a number of projects in the 18-90MWE range using a variety of biomass gasification technologies integrated with gas turbines. Work is continuing to develop hot gas clean-up systems and more efficient directly fired gas turbines developed from jet aircraft engines.

Biomass gasification to a synthesis gas consisting of CO, H2 and CH4, provides opportunities for methanol production. All the technology stages after syngas production are well known and proven through the conventional natural gas process route. Oxygen blown pressurised fluid bed gasifiers can be used to produce syngas from biomass.

Typical methanol plants using natural gas as feedstock, operate at capacities of 1500-2500 tonnes a day to be commercially viable. New technologies (one of which is being demonstrated in Australia) and cheaper gas could reduce this to 1000 tonnes a day or less.

Work being carried out at the National Renewable Energy Laboratories in the US and reviews by the USDOE indicates optimism to substantially increase efficiencies and yields from the present 51 to 62% and from 575 litres of methanol a tonne to 704 litre a tonne respectively by the year 2000.

Fuel ethanol production from molasses, grain and starch is well established technology. Processes for this are offered by a wide range of companies.

Technology for ethanol production from lignocellulose biomass is developing, with some companies claiming to be in the commercialisation phase. Organisations at the forefront of ethanol recovery in the US are Stake Tech (steam explosion route), the Tennessee Valley Authority (dilute and concentrated acid routes), National Renewable Energy Labs (enzyme single stage sacharification and fermentation) and Arkenol (acid route).

The former has pilot plants processing waste paper at up to 6 tonnes an hour and the latter has tested its processes at 2 dry tonnes a day and 6 dry tonnes an hour respectively. Fermentation processes of both companies use yeasts. NREL is building a 1 tonne an hour R & D plant in Denver. Many of these organisations now claim a capability to co-ferment glucose and xylose.

A lignocellulose to ethanol process using Zymomonas is under development at the University of NSW in Australia, and a process design for a 2 million litre a year demonstration plant incorporating this technology and other technology blocks from overseas is presently underway for the Federal Government by Gorton Timber of Grafton.

APACE Research in Australia have developed novel technology for ethanol separation and waste treatment. This will be incorporated in the above design.

No information was available to this study on the Gorton Timber technology and the Zymomonas fermentation process.

Vegetable oils can be used as a fuel for diesel engines either directly, as a blend with diesel, or chemically modified esterified oils. Technology for producing oils and esters is mature on both large and small scale plants. Unrefined, waste and contaminated oils may be used for ester production. Glycerols are produced as a by product.

By 1995, there will be over 700,000 tonnes a year of boidiesel produced in Europe and 250,000 tonnes a year produced in the US.

Anaerobic digestion technologies for treating sewage waste, industrial waste and the organic fraction in municipal solid waste is essentially mature. Specially designed reactors for processing the MSW to biogas and fertiliser have been developed and demonstrated.

Methanol and ethanol can be chemically converted to MTBE and ETBE respectively which have more favourable properties as gasoline additives than alcohols. Both MTBE and ETBE may be produced using proven technology.

Production of MTBE requires a supply of iso-butylene which may be obtained from in-refinery sources. The range of potential MTBE production capacities in Australian refineries is 20,000 - 80,000 tonnes a year.

MTBE and ETBE may also be produced from field butanes. Typical world scale plant capacities are 500,000 tonnes a year MTBE with some recent installations as small as 180,000 tonnes a year. Cost data is presented to cover the 200,000 - 500,000 tonnes a year MTBE range considered to be of relevance to Australian conditions.

CSIRO has demonstrated the direct production of furan fuel octane enhancers/ oxygenates from biomass at a laboratory scale. This process converts lignocellulosic feedstock to methyl furan and dimethyl furan respectively. Preliminary testing in vehicle engines and economic studies indicates that they are equivalent to MTBE if valued as oxygenates.

To be competitive with MTBE production, furan plant capacity will need to be greater than 150,000 tonnes a year, requiring 600,000 tonnes a year of dry bagasse.

TABLE 4.15 Summary of the Status of Biomass Conversion Technologies

Technology	Market Segment	Status	Comments/Directions
Direct combustion	Domestic	Commercial	Improved emissions required.
	Medium and large scale	Commercial	Problems arising from slagging. Improve efficiency from 20-25% to 30-35%. Fluidized bed ETSA development of interest
Gasification	Small scale	Commercial	In demonstration phase. Australian technology in development. (BEST) Atmospheric fluid beds commercial. Pressurized fluid beds in deveopment. Gasification of MSW developments in US of interest, as is an Australian development at the SECV.
	Large scale		
	Directly heated	Commercial Emerging	
	Indirectly heated	Emerging	
Pyrolysis		Emerging Commercial	Of interest due to liquid biocrude products.
Cogeneration	Small scale		BEST/TREElectric development work inAustralia of interest
	Direct combustion	Commercial	
	Gasification	Emerging	
	Large scale		
	Direct combustion	Commercial	Hot gas clean up and development of integrated combined cycle systems underway. Direct fired gas turbine systems being developed.
	Gasification	Emerging	
Methanol	Gasification	Emerging	As in gasification above.
	Methanol synthesis	Commercial	Small capacities possible through new catalysts. "Once through" systems under development.
Ethanol	Sugars, starch	Commercial	Minor improvements in unit operations underway.
	Lignocellulose	Emerging	Acid processes - recycling developments underway. Enzyme processes and single step hydrolysis and fermentation being developed. Xylose fermentation organisms being developed and tested. Australian technology in development - no information yet available
Anaerobic digestion	Animal & Industrial wastes	Commercial	Little improvement expected
	MSW (landfill)	Commercial	
	MSW digestors	Emerging	Some technologies demonstrated.
	MSW Neutralysis	Emerging	Australian development of interest.
Oxygenates	ETBE. MTBE	Commercial	
	Furans	Emerging	Australian development of interest (CSIRO)

5.0 SYSTEMS SELECTION

5.0 SYSTEMS SELECTION

5.1 INTRODUCTION

The most promising biomass to energy systems are selected on the basis of a series of selection criteria.

The selection will be made using information developed in the review of biomass resources, energy costs, market opportunities and general environmental issues relating to each system.

5.2 BIOMASS ENERGY COSTS

5.2.1 Introduction

A model has been developed to enable an initial comparison of energy production prices for the range of biomass to energy technologies considered in Section 4, and test sensitivities to various relevant economic parameters.

The resource price ranges, together with the capital and operating costs of the various processes are inserted into the model which then calculates an energy production price for given discount rates.

5.2.2 Methodology

The energy price is expressed in Australian dollars and represents an average yield a litre, KWh or GJ or product sold at the level of demand defined as the plant capacity over the 20 year plant life to allow an investor to achieve a return on investment equal to the discount rate used. Full plant output capacity has been assumed from year one. No inventory or variation in sales volume are included.

The calculation does not include any allowance for inflation, and the corporate income tax used is the Australia company tax rate of 33% over the project life.

The capital investment consists of the initial plant capital cost and a further ongoing investment of 5% on sales level, which is over and above maintenance. Included in investment costs are all engineering, purchasing, construction and start-up costs, with utilities and waste treatment plant to produce the environmental discharges defined in the Conversion Technologies report.

Data on operating costs were provided to include all auxiliary fuels utilities, chemicals, labour and maintenance. The model adds a 10% factor to cover general and administrative (G and A) expenses.

(i) The scenarios assumed by the model are:

A mature world class energy company with a P/E of 15.3 was analysed and based on that analysis, it was calculated that such a company would have a cost of capital of 8.75% on company funds employed, ie the company requires to earn a notional afer tax return of 8.75% prior to debt financing to satisfy deb providers and ordinary shareholders.

(ii) A 15% discount rate has also been used in the model to reflect; level of risk about current operations of that mature company, o another company, that may be required to induce the investor to invest in such a project as compared with other alternativ projects. The model can calculate on any discount rate.

5.2.3 Biomass Energy Costs

The following graphs summarise biomass energy costs at returns o investment of 15% (shaded bar) and 8.75% (unshaded bar).

Fig. 5.2.1 summarises the energy production costs of heat (high pressure steam) and electricity from direct combustion of biomass. Steam from standard boilers using Wellons technology is produced at between $7 and $14 a GJ for the capacity range 10-50MW plant. Power production from a gratefired/condensing turbine system at 10MW capacity can t produced from between 7cents and 11 cents a kWhe.

The energy prices of electricity and heat production (cogeneration) fro biomass using small and large scale gasification technologies are shown Fig. 5.2.2. The prices from large scale plant, using the integrate gasification process with steam injected gas turbines are shown for 5 MWe, 53 MWe and HOMWe capacities over the biomass price range $20 - $50 a dry tonne. Electricity prices, as expected, decrease wi capacity from 11 cents down to 3.5cents a kWh for the large scale plant Given that a small scale facility will most likely be constructed at a site low cost biomass supply (eg sawmill) prices for biomass have been tak in the range $15 down to zero cost a dry tonne. Using estimates of capicity and operating cost given for Australian small-scale technology being developed by BEST, power costs in the range 0.5 MWe up to 4MWe *z* expected to be between 9 and 3 cents a Kwhe.

Pyrolysis technology economics are shown in Fig. 5.2.3. Products that fall into the category of crude diesel oil biocrude or aromatic gasoline is produced in the price range 35cents to 85cents a litre, depending on 1 technology used.

The cost of production of hydrogen energy from biomass by gasificati is shown in Fig. 5.2.4. Whilst competitive with coal, the biomass co ($10-28 a GJ) are significantly higher than from natural gas ($5-8 a *GJ,*

Methanol production costs from biomass are shown in Fig. 5.2.5. 1 figure shows, for comparison, the calculated production costs methanol from both natural gas and coal at typical capacities for the feedstocks. Whilst not competitive with natural gas, biomass methano the lower biomass costs (down to $5 a dry tonne) compare favours with coal. The costs of methanol from biomass between the resource costs of $100 and $5 a tonne range from 30cents to 75cents a li depending on the technology.

The prices derived from newly developed Hydrocarb technology and indirectly heated gasification indicate the potentials of those technical advances.

Biomass to ethanol production costs are shown in Fig. 5.2.6, ranging from the established starch and sugar processes to emerging lignocellulose technologies. Ethanol from starch and sugar substrates results in alcohol between 3 Scents and $1.15 a litre.

Grain to ethanol looks relatively attractive despite very high grain prices because of the value of animal feed by-product. By-product credits have also been included in the sugar tuber (beet scenario).

The price of ethanol from lignocellulose based on the existing state of development of the TVA dilute and concentrated acid processes is surprisingly high, at between $1.15 and $1.90 a litre. TVA indicate that they are developing a more efficient technology with acid recycle and xylose fermentation. The NREL enzyme technology at its present state of development results in ethanol between 40cents and 75cents a litre. Insufficient information was available to test the NREL process on innovations expected over the next few years. All ethanol from lignocellulose technologies have been calculated without by-product credits.

The price of liquid fuels from oil seeds are shown in Fig. 5.2.7 at both small and large scale capacity without animal feed cake by-product credits. The technology results in a high price of vegetable fuel oil of between $1.00 and $1.80 a litre.

The economics of esterified vegetable oils is heavily dependant on by-product credit contributions. Without by-products, esters will cost between $1.15 and $1.45 a litre. If markets are found for the glycerol by-product, the price drops significantly to between $1.00 and 65cents a litre at the market price of oil seeks of $800 a tonne. On a farm scale, vegetable oils can be produced for between 75 cents and $1.20 a litre assuming $50 a tonne for low quality oil seed.

The economics of energy production from wastes are shown in Figs. 5.2.8 and 5.2.9. Landfill gas will produce thermal energy under $1.40 a GJ if power is sold at between 3 and 7cents a kW from an attached cogeneration facility. If MSW is digested in custom made anaerobic digestion plant rather than landfill, the cost of energy will rise well above $10 a GJ unless MSW disposal credits approach the $70 a tonne at the same range of electricity prices. The new gasification process for MSW being developed by Southern Californian Edison will produce gas at between $2.3 and $8.5 a GJ assuming present disposal credits of $40 a tonne. However at $70 a tonne, the price drops to between $1.8 and $5.1 a GJ.

The Neutralysis process will only produce power competitively at MSW disposal credits of $100 a tonne.

Biogas from industry and animal wastes will produce heat at less than $5 a GJ if credits can be realised from fertiliser sales and waste disposal company would have a cost of capital of 8.75% on company funds employed, ie the company requires to earn a notional after tax return of 8.75% prior to debt financing to satisfy debt providers and ordinary shareholders.

(ii) A 15% discount rate has also been used in the model to reflect a level of risk about current operations of that mature company, or another company, that may be required to induce the investor to invest in such a project as compared with other alternative projects. The model can calculate on any discount rate.

5.2.3 Biomass Energy Costs

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The energy prices of electricity and heat production (cogeneration) from biomass using small and large scale gasification technologies are shown in Fig. 5.2.2. The prices from large scale plant, using the integrated gasification process with steam injected gas turbines are shown for 5.4 MWe, 53 MWe and llOMWe capacities over the biomass price range $20 - $50 a dry tonne. Electricity prices, as expected, decrease with capacity from 11 cents down to 3.5 cents a kWh for the large scale plant Given that a small scale facility will most likely be constructed at a site of low cost biomass supply (eg sawmill) prices for biomass have been taken in the range $15 down to zero cost a dry tonne. Using estimates of capital and operating cost given for Australian small-scale technology being developed by BEST, power costs in the range 0.5 MWe up to 4MWe are expected to be between 9 and 3cents a Kwhe.

Pyrolysis technology economics are shown in Fig. 5.2.3. Products that fall into the category of crude diesel oil biocrude or aromatic gasoline are produced in the price range 35 cents to 85 cents a litre, depending on the technology used.

The cost of production of hydrogen energy from biomass by gasification is shown in Fig. 5.2.4. Whilst competitive with coal, the biomass costs ($10-28 a GJ) are significantly higher than from natural gas ($5-8 a GJ).

Methanol production costs from biomass are shown in Fig. 5.2.5. The figure shows, for comparison, the calculated production costs of methanol from both natural gas and coal at typical capacities for those feedstocks. Whilst not competitive with natural gas, biomass methanol at the lower biomass costs (down to $5 a dry tonne) compare favourably with coal. The costs of methanol from biomass between the resource costs of $100 and $5 a tonne range from 30cents to 75cents a litre, depending on the technology.

The prices derived from newly developed Hydrocarb technology and indirectly heated gasification indicate the potentials of those technical advances.

Biomass to ethanol production costs are shown in Fig. 5.2.6, ranging from the established starch and sugar processes to emerging lignocellulose technologies. Ethanol from starch and sugar substrates results in alcohol between 35cents and $1.15 a litre.

Grain to ethanol looks relatively attractive despite very high grain prices because of the value of animal feed by-product. By-product credits have also been included in the sugar tuber (beet scenario).

The price of ethanol from lignocellulose based on the existing state of development of the TVA dilute and concentrated acid processes is surprisingly high, at between $1.15 and $1.90 a litre. TVA indicate that they are developing a more efficient technology with acid recycle and xylose fermentation. The NREL enzyme technology at its present state of development results in ethanol between 40cents and 75cents a litre. Insufficient information was available to test the NREL process on innovations expected over the next few years. All ethanol from lignocellulose technologies have been calculated without by-product credits.

The price of liquid fuels from oil seeds are shown in Fig. 5.2.7 at both small and large scale capacity without animal feed cake by-product credits. The technology results in a high price of vegetable fuel oil of between $1.00 and $1.80 a litre.

The economics of esterified vegetable oils is heavily dependant on by-product credit contributions. Without by-products, esters will cost between $1.15 and $1.45 a litre. If markets are found for the glycerol by-product, the price drops significantly to between $1 00 and 65 cents a litre at the market price of oil seeks of $800 a tonne. On a farm scale, vegetable oils can be produced for between 75cents and $1.20 a litre assuming $50 a tonne for low quality oil seed.

The economics of energy production from wastes are shown in Figs. 5.2.8 and 5.2.9. Landfill gas will produce thermal energy under $1.40 a GJ if power is sold at between 3 and 7cents a kW from an attached cogeneration facility. If MSW is digested in custom made anaerobic digestion plant rather than landfill, the cost of energy will rise well above $10 a GJ unless MSW disposal credits approach the $70 a tonne at the same range of electricity prices. The new gasification process for MSW being developed by Southern Califomian Edison will produce gas at between $2.3 and $8.5 a GJ assuming present disposal credits of $40 a tonne. However at $70 a tonne, the price drops to between $1.8 and $5.1 a GJ.

The Neutralysis process will only produce power competitively at MSW disposal credits of $100 a tonne.

Biogas from industry and animal wastes will produce heat at less than $5 a GJ if credits can be realised from fertiliser sales and waste disposal costs and power is sold at between 3 and 7cents a Whe. Small scale biogas plant for animals sized for around 50 head of cattle looks particularly attractive.

Fig. 5.2.10 shows the economics of oxygenate production from biomass derived ethanol and methanol for in-refinery and grass roots sites. In-refinery costs lie between 75cents and $1.05 a litre, whilst large scale plant using mixed butanes at a greenfield site will result in a cost range 35cents - 70cents a litre.

Initial estimation of the cost of producing furans from biomass in the newly developed CSIRO process indicate a furan price of between 40cents and 60cents a litre in a very tight price range

5.2.4 Summary

Energy production costs from biomass for various technologies at small and large capacities and a range of raw material prices have been calculated at two rates of investment to provide a relative measure of attractiveness.

These have been summarised on Table 5.2.1

Sensitivities are apparent to the return on investment required and raw material prices and or by-product opportunity.

The calculations serve as a basis for the selection process, both for the biomass-to-energy technologies and the biomass resources.

TABLE 5.2.1 : Summary of Biomass Energy Production Costs

Biomass Energy	Heat and/or Gas ($/GJ)	Power (cents/kwh)	Liquid fuels $/litre
Direct combustion, biomass	7 - 13	7- 12	
Gasification biomass			
Large scale		3.5 - 11	
Small scale		3 - 9	
Pyrolysis			0.85
Anaerobic Digestion			
Animal Wastes			
Large Scale	25-<3	3 - 7	
Small Scale	<3	3 - 7	
MSW			
Landfill	<1.40	3 - 7	
Digesters	10	3 - 7	
Gasification	1.80 - 8.50	-	
Ethanol			
Sugar/Starch			0.35 - 1.15
Lignocellulose, acid			1.15 - 1.90
enzyme			0.40 - 0.75
Methanol			
Lignocellulose			0.30 - 0.75
Hydrogen	10 - 28		
Vegetable Oil			
Large Scale			1.00 - 1.80
Small Scale			0.75 - 1.20
Vegetable Esters			0.65 - 1.45
Oxygenates			
MTBE, ETBE			
In refinery			0.75 - 1.05
Grass Roots			0.35 - 0.70
Furans			0.40 - 0.60

BASUM2- HPS

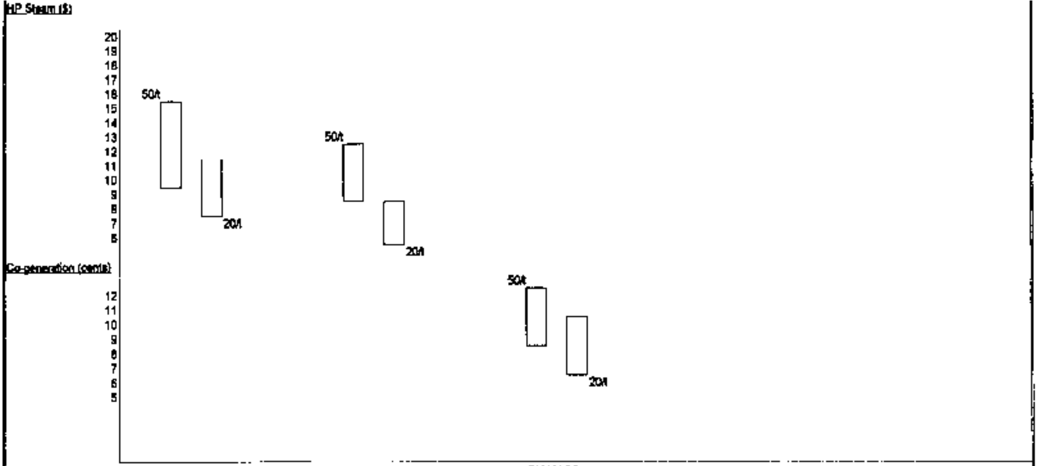
15% ROI
8.75% ROI
PRICE: GJ & kWh($)

BIOMASS STUDY

FIGURE 5.2.1 HP STEAM & CO GENERATION • ROI DERIVED PRICE

WITHIN RANCB Of RAW MATIRIAL PRICK («)

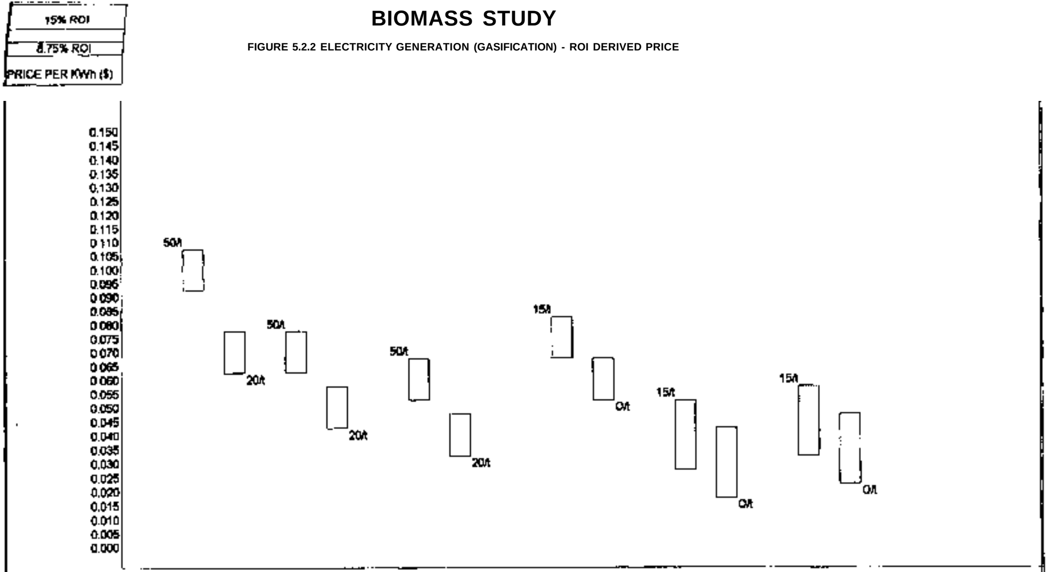
(Each of HP Steam and Co-generation has a different price unit and scale)
HP Steam Price Unit Is GJ and Co-generation Price Unit Is kWh)
(The scale for HP Steam Is In dollars and the scale for Co-generation Is cents)



FEEDSTOCK:	BIOMASS	BIOMASS	BIOMASS
TECHNOLOGY:	WELLONS DIRECT DIRECT COMBUSTION	WELLONS DIRECT DIRECT COMBUSTION	GRATEFIRED CONDENSING TURBINE
CAPACITY:	10 MWth	50 MWth	10 MWe
COMMENT:	H P STEAM	H P STEAM	CO-GENERATION

BIOMASS STUDY

FIGURE 5.2.2 ELECTRICITY GENERATION (GASIFICATION) - ROI DERIVED PRICE

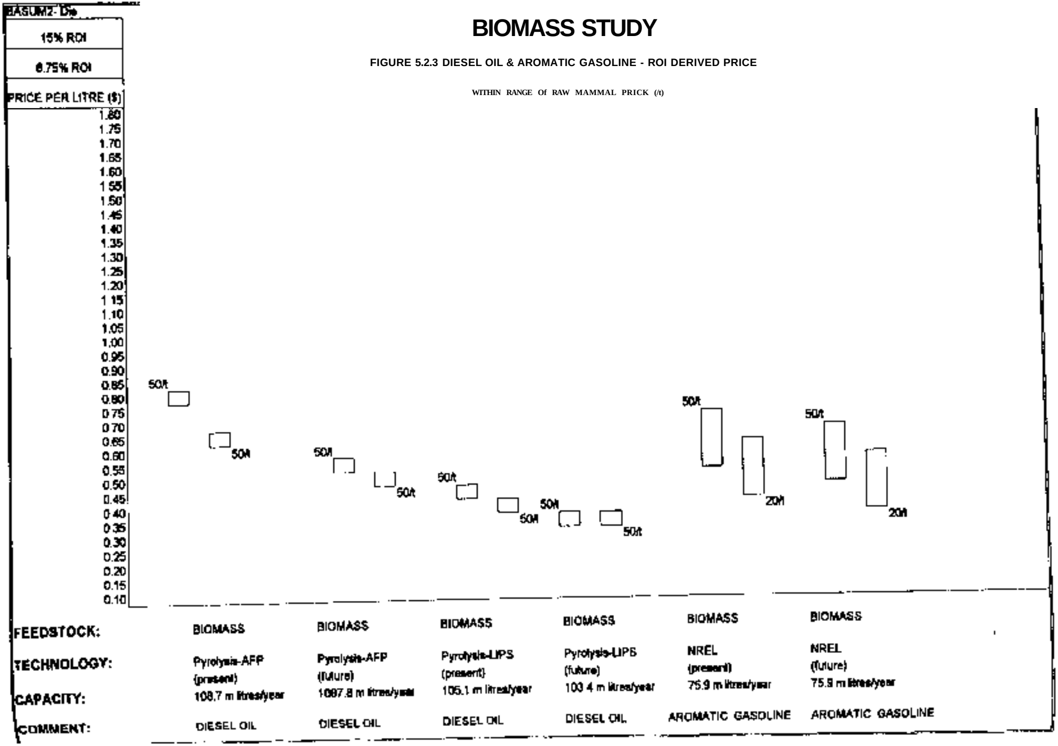


FEEDSTOCK:	BIOMASS	BIOMASS	BIOMASS	BIOMASS	BIOMASS	BIOMASS
TECHNOLOGY:	BIG/STIG	BIG/STIG	BIG/STIG	BEST	BEST	BEST
CAPACITY:	5.4MWe	53MWe	110MWe	0.5MWe	1MWe	4MWe
COMMENT:						

BIOMASS STUDY

FIGURE 5.2.3 DIESEL OIL & AROMATIC GASOLINE - ROI DERIVED PRICE

WITHIN RANGE Of RAW MAMMAL PRICK (/t)



BIOMASS- Hyd

15% ROI

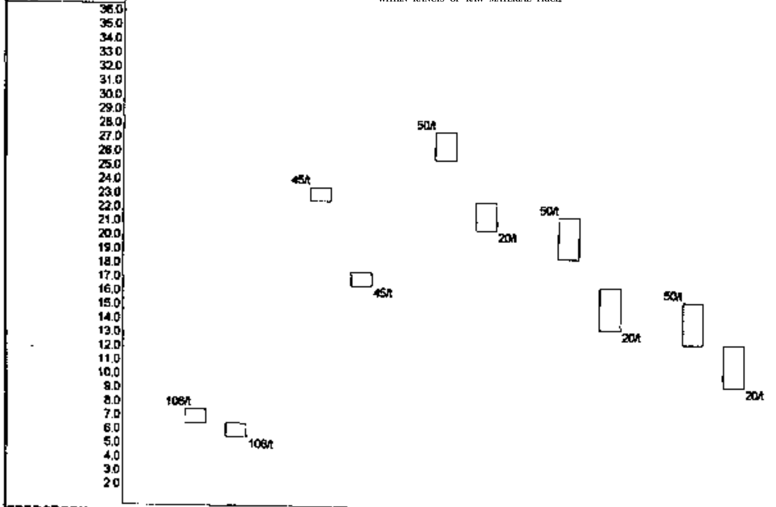
8.75% ROI

PRICE PER GJ ($)

BIOMASS STUDY

FIGURE 5.2.4 HYDROGEN - ROI DERIVED PRICE

WITHIN RANGES OF RAW MATERIAL PRICE.



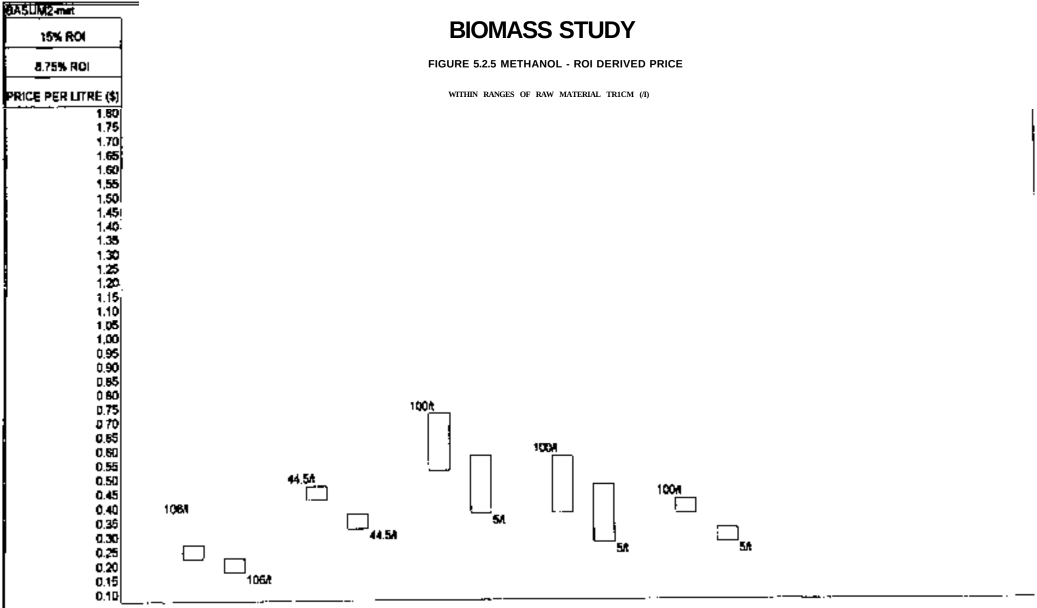
FEEDSTOCK:	NATURAL GAS	COAL	BIOMASS	BIOMASS	BIOMASS
TECHNOLOGY:	CONVENTIONAL	SHELL	RENUGAS	SHELL	BCL
CAPACITY:	8.2 m GJ/year	8.2 m GJ/year	7.3 m GJ/year	8.2 m GJ/year	8.2 m GJ/year
COMMENT:					

BASUM2-met

BIOMASS STUDY

FIGURE 5.2.5 METHANOL - ROI DERIVED PRICE

WITHIN RANGES OF RAW MATERIAL TR1CM (/I)



FEEDSTOCK:	NATURAL GAS	COAL	BIOMASS	BIOMASS	BIOMASS
TECHNOLOGY:	CONVENTIONAL	GENERIC	IGT RENUGAS	BCL	HYDROCARB
CAPACITY:	412 5 m litres/year	2,063 m litres/year	327.5 litres/year	412 litres/year	327.5 Litres/ year

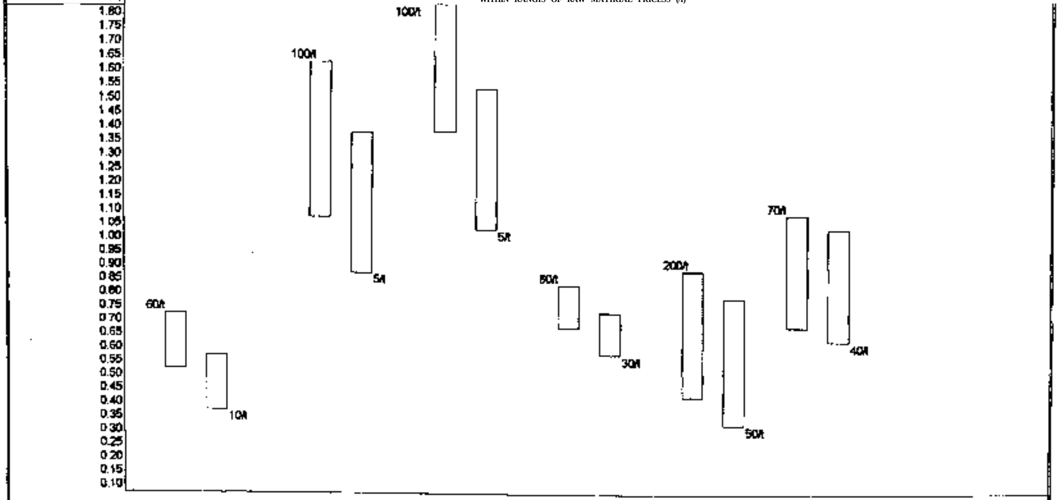
COMMENT:

BASUM2- EFI

BIOMASS STUDY

FIGURE 5.2.6 ETHANOL - ROI DERIVED PRICE

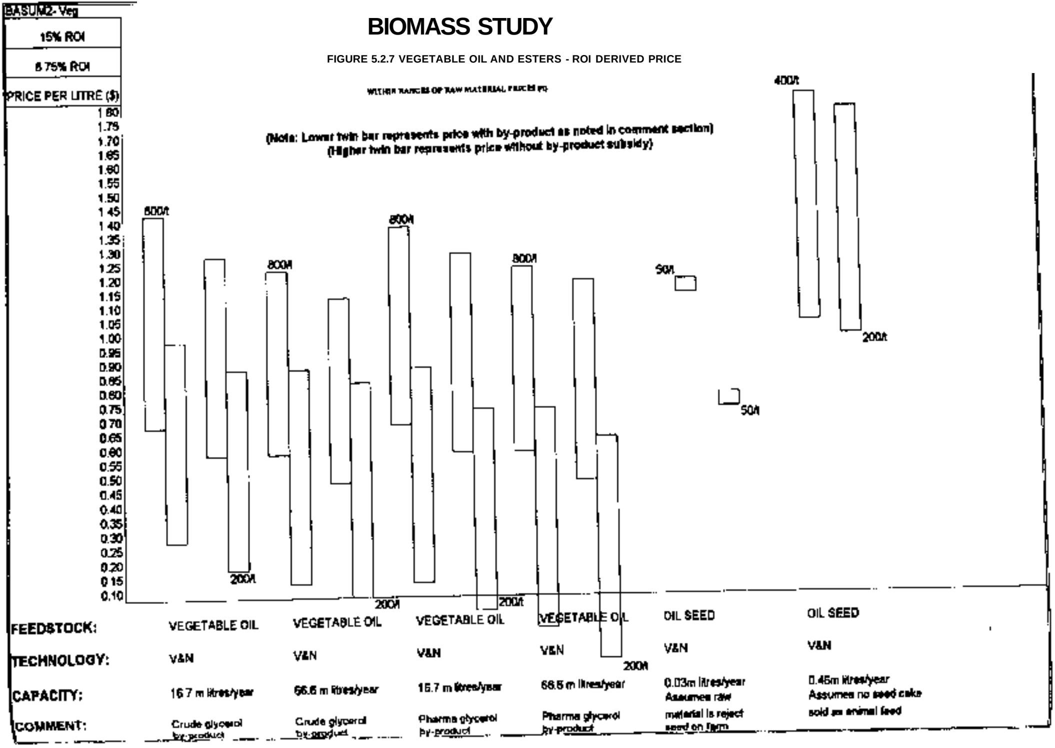
WITHIN RANGIS OF RAW MATIRIAL PRICESS (/I)



FEEDSTOCK:	BIOMASS	BIOMASS	BIOMASS	MOLASSES	GRAIN	BEET
TECHNOLOGY:	NREL - present	TVA - conc.	TVA - dil. acid	Chematur	Vogelbusch	Tasmania
CAPACITY:	119 m litres/year	40.8 m litres/year	34.7 m litres/year	34 m litres/year	136 m litres/year	76 5 m litres/year
COMMENT:	No by-product	No acid recycle	No acid recycle		Animal feed by-product	Animal feed by-product

BIOMASS STUDY

FIGURE 5.2.7 VEGETABLE OIL AND ESTERS - ROI DERIVED PRICE



BASUM2- Eph

15% ROI

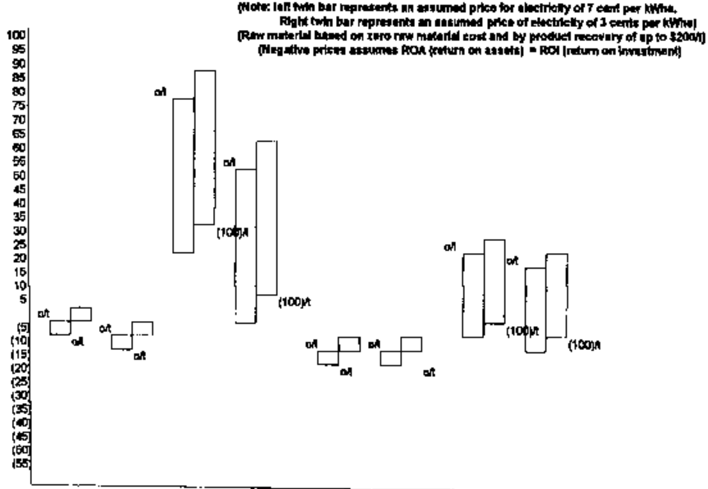
8.75% ROI

PRICE - HEAT GJ($)

BIOMASS STUDY

FIGURE 5.2.8 ELECTRIC POWER AND HEAT (ANAEROBIC DIGESTION) - ROI DERIVED PRICE

WITHIN RANGESS OF RAW MATERIAL PRICES *(It)*



(Note: left twin bar represents an assumed price for electricity of 7 cent per kWhe.
Right twin bar represents an assumed price of electricity of 3 cents per kWhe)
(Raw material based on zero raw material cost and by product recovery of up to $200/t)
(Negative prices assumes ROA (return on assets) = ROI (return on investment)

FEEDSTOCK:	MSW (UNSORTED)	ANIMAL WASTE (100,000 CATTLE)	ANIMAL WASTE (50 CATTLE)	ANIMAL WASTE (25,000 pigs)
TECHNOLOGY:	CONVENTIONAL (LANDFILL)	CONVENTIONAL DIGESTOR	CONVENTIONAL DIGESTOR	Bio Resources Aust DIGESTOR
CAPACITY:	117,000 Kwhe/d 158,000 kWhth/d	75,600 Kwhe/d 84,000 kWhth/d	38,000 Kwhe/d 42,000 kWhth/d	8,400 Kwhe/d 16,800 kWhth/d
COMMENT:				

All cases assume fertilizer by-product from $0 to $200 per tonne

BASDM2- Eph2

15% ROI

8.75% ROI

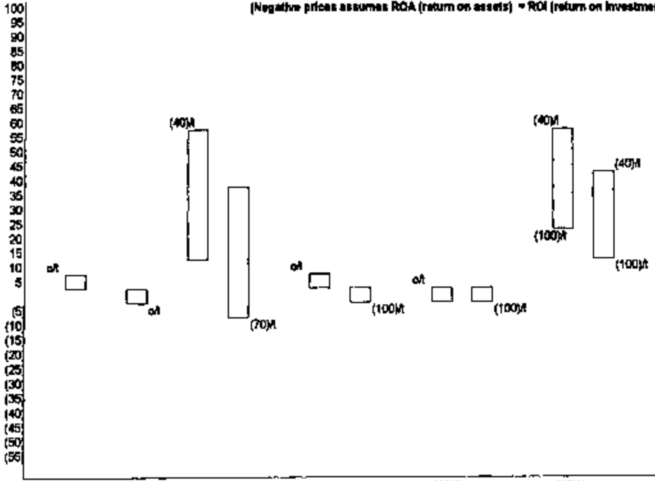
PRICE - HEAT GJ($)

BIOMASS STUDY

FIGURE 5.2.9 ELECTRIC POWER AND HEAT(ANAEROBIC DIGESTION • GASIFICATION) - ROI DERIVED PRICE

WITHIN RANGES OF RAW MATERIAL PRICES (A)

(Negative raw material prices assume that waste is provided for a fee)
(By product prices have been included where approriate)
(Negative prices assumes ROA (return on assets) = ROI (return on investment)

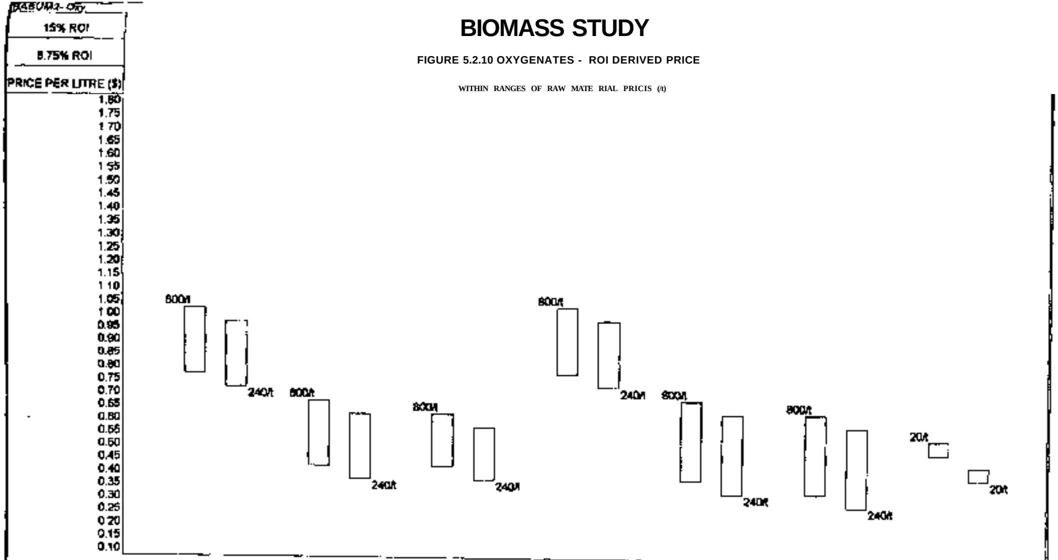


FEEDSTOCK:	INDUSTRY WASTE (liquid food waste)	MSW (unsorted)	MSW	MSW	MSW
TECHNOLOGY:	UASB DIGESTOR	VALORGA DIGESTOR	SCE Gasification	SCE Gasification	Neutralysis
CAPACITY:	32,000 m3/d gas	7.65m m3/y gas	250 MW gas	53 MW gas	45.6 GWh/y
COMMENT:	Biogas	Biogas Assumes fertilizer sale b/w $0 and $200 figure	Gas	Gas	Electricity

BIOMASS STUDY

FIGURE 5.2.10 OXYGENATES - ROI DERIVED PRICE

WITHIN RANGES OF RAW MATE RIAL PRICIS (/t)



FEEDSTOCK:	METHANOL	METHANOL	METHANOL	ETHANOL	ETHANOL	ETHANOL	BAGASSE
TECHNOLOGY:	MTBE In-refinery	MTBE Grass roots	MTBE Grass roots	ETBE In-refinery	ETBE Grass roots	ETBE Grass roots	CSIRO - Furans
CAPACITY:	67.6 m litres/year	270.3 m litres/year	675.7 Litres/year	76 Litres/year	270.3 Litres/year	675.7 Litres/year	196.5 Litres/year
COMMENT:							

5.3 ENVIRONMENTAL REVIEW

5.3.1 Introduction

The environmental criteria for the selection of biomass resources and energy conversion systems are presented, together with an analysis of the environmental issues relating to each system option. The criteria include environmental issues and impacts associated with agricultural and forestry practices, pollution control and environmental regulations relating to industrial waste discharges from processing facilities and global issues, such as greenhouse gas emissions.

5.3.2 Environmental Criteria

The following criteria are desirable in the selection of biomass resources and processing technologies for energy production and used in the assessment of the system options:

- resource use sustainability
- carbon sequestration
- net reduced Greenhouse Gas emissions
- minimisation of impact on biodiversity and wildlife habitat
- minimisation of soil erosion and employ conservation practices
- enable re-afforestation of marginal/degraded agricultural land
- minimisation of the application of fertilisers/herbicides/pesticides
- conserve soil nutrient status and organic matter
- maintenance and re-establishment of natural ecosystems
- low soil compaction harvesting techniques
- avoidance of steep slopes
- maximisation of plantation sites in catchment recharge zones
- suitability for effluent irrigation
- minimisation of genetic pollution of native forests
- minimisation of crop water demand requirements
- minimisation of water requirements for processing
- high standard of effluent wastewater treatment and discharge quality
- minimisation of solid and liquid waste outputs
- encourage options which include solid and liquid waste reuse
- minimisation of air emissions and solid outputs such as noxious gases, particulates and ash
- minimisation of human exposure to toxic chemicals through the growing, handling and storage of biomass feedstocks and produced biofuels.

Land-use practices employed for the production of biomass for energy should be environmentally sustainable.

If conventional agricultural and forestry land use management practices are employed, bioenergy would be unsustainable in the long-term, because present land use practices are not environmentally sustainable due to the degradation of soil and natural ecosystems.

Similarly the proposed biomass conversion technologies must incorporate state of the art technologies to ensure that the nature and volume of the waste output products to soil, water and air are environmentally acceptable.

The issues relating to biomass energy system options are discussed beiow with respect to their characteristic environmental impacts and government policy initiatives.

5.3.3 Lignocellulose Residues to Electricity

This option provides the most significant environmental benefits of all the options primarily because of its potential global impact in the reduction of Greenhouse gas emissions together with its potential to contribute to environmental policy on land revegetation and rehabilitation. This option has the potential to make a significant contribution to the Commonwealth Government's objective of stabilising greenhouse gas emissions based on 1988 levels by the year 2000 and reducing these emissions by 20% by the year 2005.

Electricity produced from lignocellulose residues through combustion and/or gasification technologies would be largely carbon neutral (excluding greenhouse gases emitted during feedstock growth, harvesting and transportation phases) since the carbon dioxide released during conversion would liberate only the carbon dioxide sequestered during the biomass growth phase. However this would only be the case where the biomass is grown as a renewable resource in plantations specifically established for harvesting on a continual rotation basis. Lignocellulose residues obtained from the logging of forest reserves which are not replaced would provide little benefit to the reduction of greenhouse gas emissions since the carbon released during conversion would not be balanced or offset by subsequent sequestration.

For this option to sustain the benefit of carbon neutrality it is necessary for the forestry practices to determine rotations such that carbon sequestration and release from the woody biomass and soil is optimised for the growth and harvest cycle.

A second major potential environmental benefit of this option is that it provides a suitable end use for woody biomass established on cleared and/or degraded lands as an environmental remediation or rehabilitation measure. Similarly significant regional environmental benefits could be achieved if woody biomass which was irrigated with regional sewage effluent wastewater were to be converted to electricity and/or cogeneration end uses.

This scenario contributes to a number of regional, state and national environmental policy objectives relating to sustainable agriculture, improved river and ocean water quality and environmental remediation.

Whilst there is the scope for significant environmental benefits, there is also the potential for substantial environmental impacts if sustainable agricultural and forestry land management practices are not widely used. The primary issues relate to the clearance of native vegetation and habitat, a reduction of biodiversity and habitat diversity, a reduction in water quality through increased chemical use, and an increase in soil erosion and the area of land degradation.

The Greenhouse benefit would be significantly enhanced if the electrical energy produced displaced electricity produced from fossil fuels. This option could have a greater environmental benefit if the feedstock were derived from all lignocellulose resources rather than only residues.

There also remains the potential for air emission impacts related to the stack gases, particulates and solid ash waste emitted as a consequence of lignocellulose combustion similar to those produced by fossil fuel combustion. It is likely that the impact of air emissions produced by combustion technology would be comparable irrespective of feedstock and that substantial pollution control devices would be required on the stacks.

5.3.4 Municipal Solid Waste to Electricity

This option provides for significant environmental benefits which relate mainly to improved urban waste disposal techniques and a reduction in pressure for the availability for land fill sites.

There is the potential for the development of highly efficient recycling processes for non-combustible municipal solid waste (MSW), since the quality of the MSW has an enormous impact on the emissions from the gasification/combustion conversion technology. Without extensive recycling and sorting of MSW the air emissions produced from the conversion to electricity can include lead, sulphur dioxide and highly toxic compounds such as dioxins, furans, heavy metals and hydrochloric acid. Air emissions from waste to energy combustion plants are at a higher rate per kWh generated than for coal fired plants. Consequently combustion of MSW is not a recommended option without comprehensive waste sorting and the development of specialised emission control devices.

However the extraction of landfill gas or biogas from landfill sites and its conversion through gasification has a benefit in the reduction of Greenhouse gas emissions by converting methane to carbon dioxide. Since methane emissions have a proportionally greater impact on the atmosphere than carbon dioxide, this gas conversion is of benefit compared to the present leaking of methane rich biogas from landfill sites. The overall effect on Greenhouse gas emissions would be a small reduction in the present total volume since only a slight offset or displacement of fossil fuel derived electricity would occur.

5.3.5 **Animal and Human Wastes** to **Electricity**

This option provides for environmental benefits through the utilisation of organic waste products which present a significant worldwide disposal problem due to their impact on water quality and nullification, the demand on available land for storage and disposal, and major community health problems.

Consequently, the use of human and animal wastes for conversion to electricity alleviates these problems. However, there remains the potential for localised and regional pollution associated with the storage and handling of these wastes. Generally, the conversion of these wastes is of significant environmental benefit at a local to regional level.

5.3.6 Lignocellulose to Ethanol

This option provides for almost the same level of significant environmental benefits lignocellulose residues to electricity except that the wastewater produced by the fermentation/hydrolysis conversion process could potentially have an extremely negative environmental impact. Since there are no operating conversion plants of this type the exact nature of the environmental outputs are unknown.

However, it is known from the waste outputs from pulp and paper mills that lignin is the most difficult compound to breakdown in the mill effluent wastewater. It is expected that a small quantity of lignin is likely to be discharged in the form of ligno sulphonates in waste process water, which present a serious environmental hazard to biota especially since they have an extremely high biological oxygen demand on the receiving water.

The wastewater would also contain a high nutrient content (nitrogen, phosphorus and potassium) combined with a high Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). To minimise the environmental impact the waste waters should be treated to produce biogas to cogenerate heat and power. It is likely that a lignocellulose to ethanol plant would require a comprehensive environmental impact assessment with approval dependent upon either provision for wastewater discharge to the ocean which is only marginally more desirable than to rivers.

Alternatively, significant environmental benefits as outlined in Section 5.3.3 relating to carbon-neutral energy sources and a reduction or offset of Greenhouse gas emissions, together with the contribution to environmental remediation/rehabilitation policy exist for this option. There are also the added benefits of the ethanol fuel replacing or displacing fossil derived liquid fuels for industrial and transportation use.

This would have a significant impact on the reduction of global Greenhouse gas emissions, particulates, SO_x and CO emissions. Aldehyde emissions from ethanol/gasoline blended fuel powered vehicles are thought to be similar in quantity to those from gasoline powered vehicles, and the aldehyde emissions increase with higher alcohol blends (BTCE, 1994).

A number of health and safety issues occur with the use of ethanol which stem from aldehyde emissions, alcohol vapours and direct contact with alcohol and the potential for fires. Increased production and widespread use of ethanol as a fuel would cause a greatly increased risk of environmental contamination from fuel spillage and toxicological problems from the increased risk of human contact as a result of spillage, inhalation of unburnt fuel and evaporative emissions (BTCE, 1994).

5.3.7 Lignocellulose to Methanol

The significant environmental benefits outlined for the lignocellulose to electricity option generally applies to this option, with the major benefit being a significant reduction in Greenhouse gas emissions. Methanol production from lignocellulose would eliminate the current practice of converting natural gas to methanol and the associated greenhouse gas emissions.

Consequently, this energy option would be carbon-neutral as long as the lignocellulose was derived from continual rotation harvested crops or forest plantations. Detailed assessment of the environmental outputs of this option are not possible since there are no operating conversion plants. However, there are significant environmental issues with methanol production, handling and use which relate to human health and safety and environmental contamination, and increased fire risk.

Methanol is toxic to humans and public exposure through the inhalation of unburnt fuel in exhaust emissions, of fuel evaporating during refuelling or accidental spills, or of hot vehicle evaporative emissions could be fatal or produce serious injury (BTCE, 1994).

5.3.8 Oilseeds to Oilseed Esters

This option provides for environmental benefits by potentially reducing the use of fossil fuels for transportation, thus reducing Greenhouse gas emissions from vehicles. There are no significant waste disposal issues. There is some potential for related environmental impacts as a result of unsustainable agricultural land management practices as outlined in Appendix 5. Biofuels from oil seed esters provides a potential environmental benefit if they are used to power harbour, port and lake waterway vehicles as they are biodegradable if fuel spills occur.

5.3.9 Biomass to Oxygenates

This option provides comparable environmental benefits and costs to those outlined for the options, lignocellulose to ethanol and methanol. The production of oxygenates incurs a Greenhouse penalty where the oxygenate product is produced by the combustion of natural gas and process by-products. The CO2 emission rate is estimated as 0.47 tonnes $C0_2$ per tonne product.

5.4 SELECTION CRITERIA AND METHODOLOGY

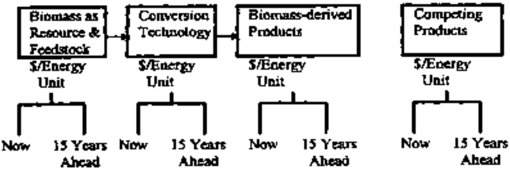
5.4.1 Introduction

The selection process will involve developing and analysing a matrix with a series of options for biomass energy systems on the vertical axis and issues relating to development and commercialisation on the horizontal axis.

The matrix will be analysed and a shortlist of systems selected for further detailed analysis in site specific project case studies.

5.4.2 Development and Commercialisation Issues

These criteria will be handled in a step by step manner as depicted below:



Notes:
1 Resource and feedstock costs will be as at plant gate or equivalent
2 Standard energy units will be used throughout to aid comparison.

Issues to be considered under each of the four sections are as follows:

i) Biomass Resources and Feedstocks

Competitive demands/markets for resources

Present and future costs of delivered biomass, reflecting predicted changes in growing, harvesting and transport costs

Storage

Reliability of supply, including potential mixes and substitutes

Resource volumes on a regional/local basis, present and future

Impact of plant scale

Environmental impacts including sustainability and greenhouse impacts

ii) Conversion Technologies

Capital and operating costs, present and future

Capacity and plant scale

Status of development, commercial, demonstrated; emerging; comparison with world's best

Resource requirements (eg water)

Relevance of by-products

Environmental impacts

iii) Biomass Derived Products

Present cost of energy from biomass (8.75% and 15% return on investment)

Impact of plant scale

Expected issues and trends in future costs.

Attractiveness of biomass projects to investors (eg lead times; return on investment; cash flows; risk)

Environmental impacts

iv) **Competing Product**

Present and future cost of energy supply and delivery

Special issues (oxygenates, bottle-necks, imports, security of supply)

Status of development of technology

Reliability of supply

Impact of plant scale

Environmental impacts

5.4.3 Biomass Systems Possibilities

A wide range of biomass systems options were considered in the study up to this point. The broad range candidate systems, within an Australian context at least, appear to be as set out in Table 5.4.1. These were put through the selection criteria defined above and an initial selection shortlisted for further evaluation.

Included in this evaluation will be an assessment of the export potential of the selected systems in a number of countries, principally in the Asia Pacific region. Any significant opportunities outside of these countries will be highlighted.

Table 5.4.1 : Candidate System Options

		Combustion	to	Heat
		Gasification	to	Power
Lignocellulose	via	Gasification	to	Methanol
MSW		Fermentation	to	Ethanol
		Pyrolysis	to	Diesel fuel
		Gasification	to	Hydrogen
Starches & Sugars	via	Fermentation	to	Ethanol/ETBE
Industry Wastes				
Oilseeds	via	Extraction Esterification	to	Diesel fuel
Animal and Human		Anaerobic		
Wastes	via	Digestion	to	Heat/Power
Industry Wastes		Landfill		
MSW		Combustion Gasification		
Hydrogen	via	Fuel Cells	to	Heat
		Combustion		Power
Ethanol				ETBE
Methanol	or	conversion		MTBE

5.4.4 System Selection

The systems that have been short listed for evaluation are as follows (not in priority order):

1 Lignocellulose Residues to Electricity
2 Municipal Solid Waste to Electricity
3 Animal/Human Wastes to Electricity
4 Lignocellulose to Ethanol
5 Lignocellulose to Methanol
6 Oilseeds to Oilseed Esters
7 Biomass to Oxygenates

A table of summarised data and commentary is included at the end of this chapter for each system option along with footnotes. The tables include commentary on the resources/feedstock position, technology, product pricing and competitive positioning and on the potential alternative uses of the resources. The tables also cover, in a general sense, commentary on all of the proposed selection criteria.

The systems cover a diverse range of resources and markets and each may require a somewhat different approach, for example:

- the production of oxygenates will require a national strategy because a large scale market will be necessary to justify investment in such a plant;

- by contrast, the production of electricity from biomass will be quite consistent with a strategy of regional development. While new policies to reduce cross subsidies by major electricity authorities may be required to underpin this strategy, there are numerous niche market applications.

All prices are in Australian dollars (1994), unless otherwise stated ($A = 71 cents US).

System 1 - Lignocellulose Residues to Electricity

This system has two features highly advantageous for competition in the market place in the next 15 years:

a current cost of production already within range of established electricity technologies;

- significant potential for reduction in the cost of energy from the biomass feedstock.

In the case of the Orbost sawmill residue plant, electricity costs are estimated at 5-8cents a kWh, depending on the feasibility of cogeneration-generation at this site. Other studies indicate that conversion efficiency in plants for biomass combustion could rise from 20% to 30-35%.

The feedstock is a waste product, hence its low cost but also its relatively low resource volume available. Clearly, much larger volumes of lignocellulose could be available, for example from purpose-grown plantations, but these would be more costly. Sawdust and woodchip residues are estimated to have a delivered cost of less than $10 to about $19 a tonne, while purpose grown woody biomass would be at least $35 a tonne.

Lignocellulose gasification technologies also show promise with estimates around 5 cents a kWh from feedstock at $15 a tonne and 15% ROI Investors seem likely to require high returns, especially as combustor fouling problems remain.

Regional niche markets seem most likely for this technology, with plants unlikely to be much above 5.0 MW. Biomass-fuelled plants may be particularly attractive in regions remote from conventional electricity generation; those regions may face substantially increased transmission charges in future.

System 2 - Municipal Solid Wastes (MSW) to Electricity

This system has some characteristics in common with System 1, in that combustion or gasification of a waste product is used to produce electricity. Landfill gasification is already commercial both in Australia and overseas.

Advantages of this system include:

- MSW is an increasing problem, as existing landfill sites become fully utilised and community opposition to new sites gets stronger. The net result of this is an increasingly negative cost of the feedstock, giving the processes involved a "head start".
- the wastes are large in volume, already concentrated and almost by definition, close to major electricity load centres, ie. cities.

Initial financial analysis indicates that gasification of unsorted MSW for cogeneration could be economically attractive, with an ROI greater that 8.75% achievable with electricity sold at 3 cents a kWh. As always with cogeneration, a steam host would need to be found. The very large cost range indicates a need for further study to identify more clearly the most promising applications.

There will be a cost associated with sorting the materials which can be combusted or gasified from those which cannot, such as glass and metal. Fortunately there is a synergy here with recycling, which tends to use some of the non-combustible materials.

Combustion has an environmental problem associated with community perceptions of hazards from emissions of dioxins and other toxins. The challenges here are firstly to find a technological solution at reasonable cost and secondly to convince the community that this is indeed an acceptable solution.

System 3 - Animal/Human Wastes to Electricity

Anaerobic digestion to stabilise sewage sludges has been done for many years. Use of the resultant methane to produce electricity is becoming commercial in Australia and is more established in some other countries.

Like MSW, animal and human wastes are already concentrated in many cases and, generally in those same cases, are a source of environmental concern. This leads to increasing cost of disposal, for example through sewage outfalls into the sea, which are themselves often seen as unsatisfactory. The net result of this is a feedstock which can have an increasingly negative cost. Animal wastes are concentrated in cattle feedlots, piggeries, battery poultry operations and abattoirs. This feedstock in some cases has an alternative use as fertiliser, in which case the feedstock cost would be low but not negative. Some piggeries in Australia are already operating small scale waste gasification to electricity plants.

Animal waste plants recently built in Denmark are highly sophisticated and automated, using both the heat and power produced. Scales range from a few kWe up to about 4MWe.

The volumes of human waste are very large and located, essentially by definition, close to major electrical load centres. Animal wastes would aim more at regional niche markets.

Financial analysis was carried out on the basis of zero feedstock cost, for cogeneration with electricity buyback prices in the range 3-7 cents a kWh. This indicated that ROI greater that 8.75% was achievable with electricity sold at 7 cents a kWh and fertiliser by-product sold at 200 a tonne.

System 4 - Lignocellulose to Ethanol

The three systems so far have all been aimed at the electricity market and have been based on wastes of one sort or another, to minimise feedstock costs.

The remaining four systems aim at the liquid fuels market. This is the more traditional target for biomass-derived fuels, with well-known large-scale ethanol programs in Brazil and the USA.

However, it has to be observed that these programs have been heavily subsidised, driven by a mixture of energy security, environmental and agricultural policies.

Energy security is less prominent as a policy concern than it was in the 1980s. Conversely environmental issues, relating to both greenhouse and other emissions, have increased their profile. As discussed earlier, the costings in this study do not attempt to internalise externalities but rather to indicate how far the costs of biomass energy are from the conventional energy forms, and the potential for cost reduction of the biomass energy The study also attempts to separate out agricultural policy issues.

Against this background, biomass to ethanol processes have a target of unleaded petrol at about 20 cents a litre (Australian) ex-refinery, without tax. Costs of ethanol from present plants in Australia are hard to come by, but a recent IEA study has ethanol from biomass from current processes at around $1 a litre (Australian).

This large gap could be narrowed in two ways:

- an increase in the price of petrol; and
- reducing the cost of ethanol from biomass.

Acknowledging the difficulties of oil price forecasting, there seem to be no resource availability reasons for substantial real increases in petrol prices over the 15 year period of this study. Political upheavals cannot be forecasted but even the 1991 Gulf War did not substantially increase the price of crude oil.

Reducing the cost of ethanol from biomass also has two main possibilities:

- lower feedstock costs; and
- lower conversion costs through technological improvements.

Lignocellulose (including the cellulose component of MSW) has been chosen, on the basis of the information in the Resources section of this study, as the lowest cost feedstock. Feedstocks which have alternative uses as food crops are simply too costly. For example, at the present world wheat price of about $180 a tonne, ethanol by the Vogelbusch process would be about 90cents a litre. It should be remembered that, although alcohol fuels burn somewhat more efficiently than petrol, they have only about half the energy content. Thus the equivalence is about 1.8, meaning that ethanol would have to be about 11 cents a litre to compete with petrol as an unblended fuel.

In addition, lignocellulose conversion technology appears to have better prospects for cost reduction than the technologies for conversion from sugar/starch feedstocks.

However, it is important to note that there are no commercial lignocellulose to ethanol plants in operation and the dangers of estimating commercial costs from laboratory or pilot-scale plants are well-known. These issues are covered in detail in Appendix 3.

The lower cost estimates for ethanol from these new technologies are still around 40cents a litre, around four times more costly on an energy-equivalent basis than petrol.

System S - Lignocellulose ***from Methanol***

This system shares many characteristics with the previous one. However, it has another competitor. Even if methanol *per se* becomes an economic competitor (blended with gasoline or "straight") with petrol, that methanol could be produced from natural gas (or coal) rather than biomass. The natural gas processes are well-established and continually being improved.

Lignocellulose feedstock availability, just as it does for conversion to electricity, will place an upper limit on the scale of plant for conversion to methanol. This indicates regional markets. It also implies that a potential investor would investigate whether electricity or methanol (or ethanol) would give better returns for a given availability of biomass.

Research and development of methanol synthesis from biomass may significantly reduce capital and operating costs, as well as improve process performance. The cost reduction estimates are necessarily tentative, given the commercial immaturity of the biomass-to-methanol route.

Our economic analysis indicates the lowest-cost future estimates for methanol from biomass at about 30 cents a litre, with methanol from natural gas at around half this cost, for the same ROI.

System 6 - Oilseed to Oilseed Esters

Unesterified vegetable oils can be used in some types of diesel engine but generally esterification is required for long-term reliable operation.

The technologies both for extracting vegetable oils, and esterification, are mature. There is in excess of 50 million gallons a year of biodiesel esterification capacity installed in Europe with another 120 million gallons a year planned by 1995. The equivalent capacity is planned in the USA.

The esterification of vegetable oil and animal fat is simple technology which can be done on farm at very small scale. Approximately 10% glycerol is cogeneration-produced with the esterifies biodiesel. This glycerol can be used directly by the saponification market or it can be refined for the pharmaceutical market.

Our financial analysis indicates that small scale production of vegetable oil would cost at least 80 cents a litre, compared to the ex-refinery price of diesel at around 20 cents. There could be some possibilities for on-farm use, provided engines were compatible.

The price of vegetable oil esters covers a huge range. We have used a feedstock price range of $200-800 a tonne - IEA estimates range even higher, due to agricultural subsidies. In addition, prices are very sensitive to the price which can be obtained for the glycerol by-product. Thus, depending on the assumptions, vegetable oil excess could be hopelessly uncompetitive, at $1.25 to $1.45 a litre, or highly competitive, at 10 cents a litre or even less. At the lower end of the range, the vegetable oil esters could be regarded as the by-product and glycerol the product. Large scale processes could well oversupply the glycerol market and so force down its price. With no glycerol credit, vegetable oil esters would be at least 50 cents a litre, with little prospect for reduction through process improvement.

System 7- Biomass to Oxygenates

Oxygenates are a niche market for addition to petrol, eg. in lead phase-down and/or greenhouse gas reduction strategies.
MTBE and ETBE are normally made from methanol and ethanol, respectively, so the relative costs of these feedstocks from either conventional or biomass feedstocks are as discussed for Systems 4 and 5 above. MTBE and ETBE could also face competition as octane enhancers from methanol and ethanol themselves.

The viability of MTBE projects is dependent primarily on the availability of low cost butanes. Large scale MTBE plants are being planned with integrated methanol production which will take additional advantages of associated low cost natural gas sources.

A CSIRO process for making furans from bagasse or other cellulosic feedstock could overcome the limitations imposed by use of methanol or ethanol as oxygenate feedstocks. The process is only at laboratory scale but preliminary financial analysis indicates prices comparable with those of MTBE and ETBE from fossil fuels, at around 50 cents a litre.

Economic studies to date suggest that in order to compete with MTBE, furan production plant capacities will probably need to be greater than about 150,000 tonnes a year, equivalent to around 600,000 tonnes a year bone dry bagasse. Maximum plant capacities are likely to be limited by bagasse supply logistics and studies indicate a likely single plant maximum capacity of around 350,000 tonnes a year furans, equivalent to around 1.4 million tonnes a year of bone dry bagasse.

The development of this process is as yet at an early stage and there are identified areas in the current process concept that, with further research, have potential for reduction in capital cost that may impact on the range of viable plant capacities.

Looking at all systems using lignocellulose, an investor would wish to consider the relative economics of conversion to electricity, alcohols or furans.

5.4.5 Summary

Seven systems were evaluated on their economic viability, the status of their technical development, biomass resource supply and costs, and environmental issues.

Of the seven systems examined, five had combined characteristics of cost, resource, technology and environmental advantages that could turn biomass into a potentially cost effective energy product, at least in some markets.

The five short listed systems offer significant promise for application both in Australia and in a range of countries. These opportunities are analysed in more detail in the following section through site specific case studies.

They also appear to offer the best nest of opportunities around which an Australian research and development and technology strategy for energy from biomass can be formulated and implemented.

Two systems were rejected for further consideration:

- Lignocellulose to methanol; and
- Biomass to oxygenates.

Cost, competition from non-renewables for their manufacture and environmental considerations played a significant role in the decision not to analyse these systems further.

However, it was noted that the CSIRO process for the production of furans as oxygenerates showed promise and could be considered a special case. It differs from the other oxygenate processes in that it does not first involve the conversion of biomass to ethanol or methanol.

5.5 MARKET OPPORTUNITIES OF SELECTED SYSTEMS

5.5.1 Domestic Market Opportunities

These opportunities emerge fairly clearly from the Systems Selection described above, falling into two categories.

- electricity
- liquid fuels, with oxygenate additives as a sub-category.

Electricity

The three electricity feedstocks selected, all of which are wastes of one sort out another, show promise of producing electricity within the range of present Australian electricity prices. They also all show promise of reduced production costs through technological process improvement. The costs of MSW and human and animal feedstocks may also decrease, or the prices to be paid for their removal increase substantially.

All these technologies have scale limitations imposed by feedstock availability, meaning plants are unlikely to be much larger than 10MW. For comparison, the largest coal-fired stations in Australia have a capability of 2640MW. Thus these technologies aim at niche markets. This may not represent a commercial advantage, given the present overcapacity in the system.

Even gas turbine investors are essentially looking for niches, say in the 50-200MW range. These are the main new entrant competitors for biomass-based electricity. This means that replacing a large percentage of Australia's 35,000MW installed electricity capacity with biomass-fuelled electricity is not a realistic prospect in the time frame of this study.

Electricity from biomass may find niches in areas remote from generation, if proposals for cost-reflective transmission pricing came to fruition in conjunction with the introduction of the National Electricity Grid.

Liquid Fuels

Taking the same approach to the market opportunities for liquid fuels from biomass, our financial analysis indicates that costs are still several times those of petrol or diesel in most cases. There are prospects for cost reduction in most processes but even with significant such reductions, the costs of all feedstocks except wastes are too high.

Oil prices are particularly soft at present, but the policy question is what would induce a bank to lend money to a biomass fuels plant on the basis that world oil prices will rise to exceed biomass fuel prices over the next fifteen years. Government measures, for example designed to promote an ethanol industry, would need to be taken into account, but will only be one part of this equation.

Moreover, there is competition between converting (say) lignocellulose residues to electricity or to liquid fuels and an investor, on present evidence, seems likely to choose electricity.

Oilseed esters could be an exception to these comments. They could be viable on-farm when compared to diesel, noting the existence of the diesel fuel rebate. They could also be economically viable on a larger scale, crucially dependent on the market price for glycerol by-product.

Oxygenates *per se* may have a market niche. However, MTBE and ETBE from fossil fuels seem likely to be substantially less costly than from biomass and have been omitted for both cost and environmental reasons.

A CSIRO process for furans from biomass shows promise but is still at laboratory scale.

Environment

The possibility of government measures relating to global climate change, and/or other environmental issues, could change the economics of both electricity and liquid fuels from biomass compared with fossil fuels.

As agreed at the outset of the present study, the analysis does not speculate on what these measures might by, or their economic impact However, the impact of such measures on markets could be potentially large, as shown by various studies on carbon taxes and other measures.

5.5.2 International Market Opportunities

An assessment has been made of the potential of the seven selected systems in a number of countries in the Asia Pacific region. The rationale for this is that the Australian capability that would be developed through the development and application of these systems in Australia could subsequently provide a basis for exports to these other countries.

The Asian countries that have been included are those that were judged as having the greatest potential. They are China, India, Indonesia, South Korea and Malaysia.

A detailed profile for each of these countries has been developed and is presented in the Appendix dealing with international markets. A summary of this follows here.

For the five Asian countries, each profile begins with a statement covering the biomass resource potential, current biomass utilisation, and costs and prices for both biomass derived energy and the competing energy options.

In each case more detailed supporting information is provided covering the biomass resource and the characteristics of the energy market.

The USA is also included in this assessment but in this case a different approach has been taken.

The reason for this is the relatively advanced stage of biomass developments in the US. The starting points are the current status of each system in the US market and the current federally funded biofuels development program. No attempt is made to duplicate the economic assessment on which the US program is founded as this is considered unnecessary. Instead areas of commonality between the seven systems and current US biomass developments have been identified.

A summary guide to future export opportunities is presented in Table 5.5.1 to provide an overview for strategy development work.

TABLE 5.5.1 Summary of Biomass System Export Opportunities

SYSTEM		COUNTRY					
		CHINA	INDIA	INDONESIA	KOREA	MALAYSIA	USA
1.	Lignocellulose Residues to Electricity	Expanding using sugar, rice.	expanding sugar, rice, forestry.	Expanding sugar, rice, forestry.	forest, rice high: study required	Expanding	existing stable
2.	MSW to Electricity	MSW different SEZs	Possible market. Needs adaption for this market.	further study	high: further study	further study	world leader
3.	Animal and Human Wastes to Electricity	currently used urban sewage	possible, requires policy changes	low potential	study required	possible opportunites study required	possible niche needs investigation
4.	Lignocellulose to Ethanol	future?	future?	future?	high future?	future?	leader future?
5.	Lignocellulose to Methanol	future?	future?	future?	high future?	future?	leader future?
6.	Oilseed to Vegetable Oil	no	no	no?	no?	no?	no?
7.	Biomass to Oxygenates	no, future?	no, future?	no, future?	high, future	no, future?	leader, future?

CHINA

Electricity

COMPETING PRODUCT

Almost all electricity in China is from coal and hydro. Much of the hydro capacity is at mini-hydro scale and has been installed at relatively low cost. The balance of capacity is based on domestic coal. China is the largest coal producer in the world. Coal-fired power generation is characterised by low-grade, low cost fuel and low conversion efficiencies. Power is produced at around 5 cents a kWh.

Coal based generation is likely to become even more competitive as power station efficiencies improve.

SYSTEM 1: LIGNOCELLULOSE

Likely niche opportunities at sugar mills, rice mills etc. However, in China this system would have to compete for the residue resource against the current economic applications. On the positive side, the opportunities will be enhanced by China's emphasis on domestic energy resources and by the rapidly expanding energy supply/demand gap.

Notes:
- No cost data for crop and forest residues available. Fuelwood sells for approx. $40 a tonne.
- Capital cost for conversion should be similar to Australia.
- Low labour component for operating costs.
- No kWh costs for this technology in China reported.
- Current utilisation of crop and forest residues is 7000PJ a year including 1000PJ a year for bagasse.
- No potential to expand resource; all residues already utilised for some economic purpose.
- No reported use or development of this system in China.

SYSTEM 2: MSW

At most locations Australian technology is unlikely to be applicable in China due to the very different composition of MSW. However niche opportunities could possibly arise in the newly affluent areas forming in the special economic zones in the south and east.

Notes:
- No reported current or planned use of MSW for electricity generation.
- Urban waste management practices in China are completely different to in Australia and the availability of an MSW component suitable for energy production is unlikely

SYSTEM 3: BIOGAS (ANIMAL AND HUMAN WASTES)

In most locations, this system would have to compete against current use of biogas as a heating fuel for domestic and agricultural processing applications. However there could possibly be niche opportunities for larger scale applications at urban sewage treatment facilities.

Notes:
- Feedstock cost is zero (not negative).
- Small scale biogas units cost $4-10 a m3 of capacity. (The gas is used for heat, not to generate electricity.)
- The resource is already used extensively as an energy resource. 50 PJ a year of biogas is produced.
- No reported developments in electricity generation from biogas in China.

Liquid Transport Fuels

COMPETING PRODUCT

Petrol retails at 50-70 UScents a litre in China, but generally liquid transport fuel options must compete against ex-refinery costs which do not vary more than 30% between countries and international average costs are a better measure.

SYSTEM 4: ETHANOL FROM LIGNOCELLULOSE

Any development or application of this technology in China will follow worldwide technology developments becoming cost-effective (USA, Europe).

Notes:
- No biomass liquid transport fuel developments reported in China.
- For notes on the lignocellulose residue resource potential and costs, see notes for System 1.

SYSTEMS: METHANOL FROM LIGNOCELLULOSE

As for System 4.

SYSTEM 6: BIO-DIESEL FROM OILSEEDS

There is no potential in China for application of any system which would utilise land, crops, or products suitable for food production

SYSTEM 7: OCTANE ENHANCERS/OXYGENATES

There is no significant market in China for high-octane unleaded fuel or the oxygenates/octane enhancers required to produce them Otherwise the situation is as for System 4.

INDIA

Electricity

COMPETING PRODUCT

- Sources: thermal 64%; hydro 33%; nuclear 3%
- Fuel Costs: coal $0.53 a GJ ($0.26 a GJ ex. tax); oil $5.80 a GJ ($5.10 a GJ ex. tax)
- Plant Capital Costs: coal $1650 a kW; oil $1360 a kW
- Ave. Generation Costs: coal (minemouth) 2.6 cents a kWh; coal 4.4 cents a kWh; oil 6.7 cents a kWh.
- Ave. Transmission Increments: industrial customers 0.3 cents a kWh; rural customers 0.9 cents a kWh (coal minemouth) to 1.6 cents a kWh (oil).
- Ave Tariffs: 6 to 13 cents a kWh

SYSTEM 1: UGNOCELLULOSE

Firm opportunities for bagasse cogeneration into grid at sugar mills of 750-1500MW and possible opportunities for electricity generation from rice hulls at rice mills and from forestry residue resources. All these opportunities could be a suitable match to Australian capabilities and experience. Possible participation in World Bank funded projects and priority Indian Government initiatives.

Notes:

- Residue Fuel Costs: Agricultural residues are already traded and used extensively for domestic and industrial thermal applications at prices ranging from $12 a tonne ($0.7 a GJ) for rice hulls to $37 a tonne ($2.4 a GJ) for other crop residues. Bagasse (wet) for cogeneration 19-27 $ a tonne; Wood residues for gasification $29 a tonne.
- Conversion Costs: Cogeneration with bagasse 700-850 $ a kW (to upgrade existing boilers); capital 1.2-2.3 cents a kWh; O&M 0.6 cents a kWh; fuel 1.6 cents a kWh.
- Product Cost: Bagasse cogeneration into grid 3.1-4.9 cents a kWh; Gasification of wood 3.6-4.3 cents a kWh (5kW-l MW).
- Resources: Estimated potential of 10,000 PJ a year; wood 33%, animal wastes 18%; bagasse 16%; rice hulls 4%; other agricultural residues 3%; Estimates of current residue use (mainly thermal) vary up to 8500 PJ a year. Bagasse cogeneration into grid has firm potential of 750-1500MW; Rice hull resource at 300,000 rice mills.

SYSTEM 2: MSW

Possible opportunity if any technology developed in Australia could be adapted to composition of MSW in Indian cities.

Notes:

- No reported current use but feasibility studies have been completed.
- 13,800 tonnes a day at nine cities with total potential capacity of 170 MW.
- Composition of MSW different to Australia.
- Indian Government landfill gas program established in 1984; also program on incineration of MSW.

SYSTEM 3: BIOGAS (ANIMAL AND HUMAN WASTES)

Possible opportunity if Indian Government is successful in reducing use of the animal waste resource directly as a domestic fuel. Otherwise the resource cost of this economic application will remain too high for electricity generation via biogas from animal wastes to be a cost-competitive option.

Notes:

- Substantial quantity of animal waste resource currently burned as a domestic heating and cooking fuel. Price of dungcake is $29 a tonne ($2.40 a GJ).
- Animal waste resource potential estimated to be 1800 PJ a year; Current biogas production from animal wastes of 14PJ a year (for thermal use).
- Indian Government policy is to discourage use of animal wastes as a heating fuel; (Established program to produce biogas at 140 distilleries in India but this is not within the system definition).

Liquid Transport Fuels

COMPETING PRODUCT

The retail price of leaded regular is 65 UScents a litre (ex. tax 20 UScents a litre) and for diesel it is 22 UScents a litre (ex. tax 17 UScents a litre). However, generally liquid transport fuel options must compete against ex-refinery costs which do not vary more than 30% between countries and international average costs are a better measure.

SYSTEM 4: ETHANOL FROM LIGNOCELLULOSE

Any development or application of this technology in India will only follow worldwide technology developments becoming cost-effective (USA, Europe).

Notes:

- No biomass liquid transport fuel developments reported in India.
- For notes on the lignocellulose resource potential and costs see notes for System 1.

SYSTEMS: METHANOL FROM LIGNOCELLULOSE

As for System 4.

SYSTEM 6: BIO-DIESEL FROM OILSEEDS

There is no potential in India for any system which would utilise land, crops, or products suitable for food production.

SYSTEM 7: OCTANE ENHANCERS/OXYGENATES

There is no significant market in India for high octane unleaded fuel or the oxygenates/octane enhancers required to produce them. Otherwise the situation is as for System 4.

INDONESIA

Electricity

COMPETING PRODUCT

- Generation Capacity: oil 1700MW; hydro 1100 MW; gas 950 MW; coal 800MW; geothermal 30 MW.
- Production Costs: oil 6.7-12.9 cents a kWH; hydro 1.6-9.4 cents a kWh; gas 6.1-8.9 cents a kWh; coal 3.3 cents a kWh (low reliability data)
- Ave. Tariff: 8.7 cents a kWh

SYSTEM 1: LIGNOCELLULOSE

Possible opportunities at agricultural processing plants, especially sugar and rice mills, and from forestry residues.

Notes:

- Residue Resource Costs: No cost data for crop and forest residues available. Fuelwood is priced at 18-21 $ a tonne.
- Product Cost: 7-60 cents a kWh via gasification.
- Resources: Biomass resource potential of 2300 PJ a year against reported current utilisation of 2700 PJ a year. Residues are available from forestry operations and at sugar mills, rice mills, palm oil plants, and coconut processing plants.
- Small scale gasification being commercialised; No other developments reported.

SYSTEM 2: MSW

No identifiable potential. Possibility that potential could be identified if feasibility studies are undertaken

Notes:

- No reported current or planned use of MSW for electricity generation.
- Urban waste management practices and the composition of MSW at Indonesian cities have not been studied from an energy perspective but will certainly be different to those in Australia and may be unsuitable for energy production.

SYSTEM 3: BIOGAS (ANIMAL AND HUMAN WASTES)

Insufficient data available. Prospects would be long term if any.

Notes:

- No reported current or planned biogas developments in Indonesia.
- No data on extent of resource in Indonesia.

Liquid Transport Fuels

COMPETING PRODUCT

International average ex-refinery costs.

SYSTEM4: ETHANOL FROM LIGNOCELLULOSE

Any development or application of this technology in Indonesia will follow worldwide technology developments becoming cost-effective (USA, Europe).

Notes:

- No biomass liquid transport fuel developments reported in Indonesia.
- For notes on the lignocellulose residue resource potential and costs, see notes for System 1.

SYSTEM 5: METHANOL FROM UGNOCELLULOSE

As for System 4.

SYSTEM 6: BIO-DIESEL FROM OILSEEDS

The application of any energy production system which competes against a current or potential food production option is very doubtful in Indonesia. Any possibility in the longer term will follow worldwide technology developments becoming cost-competitive.

SYSTEM 7: OCTANE ENHANCERS/OXYGENATES

There is no significant market in Indonesia for high-octane unleaded fuel or the oxygenates/octane enhancers required to produce them. Otherwise the situation is as for System 4.

SOUTH KOREA

Electricity

COMPETING PRODUCT

- Sources: nuclear 43%; LNG 19%; coal 18%; oil 13%; hydro 4%.
- Production Costs: Relatively high as all fuels are imported except for a small proportion of domestic anthracite.
- Ave. Tariffs: 10.7 cents a kWh; industrial 8.9 cents a kWh; domestic 14.9 cents a kWh.

SYSTEM 1: LIGNOCELLULOSE

Likely significant medium term potential from forestry and rice milling operations. Feasibility studies are required to evaluate economic viability but the high costs of electricity production in Korea are favourable.

Notes:
- No forest or agricultural residue cost data reported.
- No current use or costs for this system reported.
- Resources: The sustainable potential of the resource is ten times the current utilisation level. The total agricultural and forest residue potential is 3700 PJ a year; Current utilisation is: firewood 72 PJ; rice residues 30 PJ; other agricultural residues 15 PJ; all for thermal use in the rural domestic sector.

SYSTEM 2: MSW

Likely to be a substantial opportunity. Feasibility study required.

Notes:
- No reported current use or costs for this system or its resource (However it is reported that there are 361 industrial waste incineration units producing energy for some purpose.)

SYSTEM 3: BIOGAS (ANIMAL AND HUMAN WASTES)

Potential unknown. Feasibility study required.

Notes:
- There are 45 installations producing biogas from animal wastes, (plus 20 using industrial wastes), but no generation of electricity from this source is reported and no costs.
- Nothing reported on extent of resource.

Liquid Transport Fuels

COMPETING PRODUCT

Prices are: premium $1.46 a 1; leaded and unleaded $1.11 a 1; diesel 39 cents a 1; LPG 56-84 cents a 1. However, generally liquid transport fuel options must compete against ex-refinery costs which do not vary more than 30% between countries and international average costs are a better measure.

SYSTEM 4: ETHANOL FROM LIGNOCELLULOSE

Korea would be a significant potential export market should this system become cost-effective as a result of the substantial R&D programs in North America and Europe.

Notes:

- No biomass liquid transport fuel developments reported in Korea.
- For notes on the lignocellulose residue resource potential and costs, see notes for System 1.

SYSTEMS: METHANOL FROM LIGNOCELLULOSE

As for System 4.

SYSTEM 6: BIO-DIESEL FROM OILSEEDS

Although no quantitative data is available, Korea is not thought to have any potential for developing the oilseed resource.

SYSTEM 7: OCTANE ENHANCERS/OXYGENATES

As for System 4.

MALAYSIA

Electricity

COMPETING PRODUCT

- Sources: Substantial indigenous black coal, brown coal, oil, gas and hydro resources. Generation is currently 80% from oil but this will reduce to 40% by 2000.
- Production Costs: Current production costs are high but should reduce substantially as a result of dramatic increases in generation capacity based on lower cost resources. For independent diesel systems 20 cents a kWh (35kW).
- Ave. Tariffs: TNB 9.4 cents a kWh (the main utility); SESCO 14.9 cents a kWh; SEB 15.1 cents a kWh.

SYSTEM 1: LIGNOCELLULOSE

Major opportunities with forestry residues and at sawmills and plywood plants; especially to upgrade existing low pressure boilers to cogeneration facilities. Also opportunities to expand the already substantial cogeneration capacity at palm oil mills, and significant opportunities at rice mills; Substantial rubberwood resource suitable for gasification.

Notes:
- Resource cost: bagasse $14 a t; cane residue $11 a t
- Conversion Cost: wood-fired; 100MVV $170m; 30MW $165m; 3MW $9m.
- Product Cost: bagasse 4.6 cents a kWh; cane residue 4.6-7.4 cents a kWh; rice husk 5.4 cents a kWh (at mill); fuelwood (plantation) 100MW 4.9-7.6 cents a kWh, 30MW 6.3-11 cents a kWh, 3MW 9.3-15 cents a kWh; gasification of rubberwood 13.4 cents a kWh
- Energy Potential of Residue Production: forestry 290 PJ; oil palm 140 PJ; rubber tree 100 PJ; rice hulls 25 PJ; coconut palm 4 PJ; bagasse 1 PJ.
- Many low pressure boilers producing heat from forestry residues A few cogenerating in 1 MW range.
- Cogeneration is the norm in the palm oil industry which is energy self-sufficient (640 Gwh a year).
- Small number of cogeneration systems at rice mills.

SYSTEM 2: MSW

No identifiable potential. Possibility that potential could be identified if feasibility studies undertaken.

Notes:
- No reported current or planned use of MSW for electricity generation.
- Urban waste management practices and the composition of MSW at Indonesian cities have not been studied from an energy perspective but are likely to be significantly different to those in Australia and may be unsuitable for energy production.

SYSTEM 3: BIOGAS (ANIMAL AND HUMAN WASTES)

Possible minor opportunity

Notes:

- Resource Potential: animal wastes 5 PJ a year.
- No current use or costs reported.

Liquid Transport Fuels

COMPETING PRODUCT

International average ex-refinery costs.

SYSTEM 4: ETHANOL FROM LIGNOCELLULOSE

Any development or application of this technology in Malaysia will follow worldwide technology developments becoming cost-effective (USA, Europe).

Notes:

- No biomass liquid transport fuel developments reported in Malaysia.
- For notes on the lignocellulose residue resource potential and costs, see notes for System 1.

SYSTEM 5: METHANOL FROM LIGNOCELLULOSE

As for System 4.

SYSTEM 6: BIO-DIESEL FROM OILSEEDS

Any possibility in the longer term will follow worldwide technology developments becoming cost-competitive.

SYSTEM 7: OCTANE ENHANCERS/OXYGENATES

There is no significant market in Malaysia for high-octane unleaded fuel or the oxygenates/octane enhancers required to produce them. Otherwise the situation is as for System 4.

UNITED STATES of AMERICA

(Note: all costs in Australian dollars unless otherwise stated.)

Electricity

SYSTEM 1: LIGNOCELLULOSE

The significant existing use of this system in the US is unlikely to increase significantly in the future. Australian manufacturers of wood-fired boilers could supply to any new projects if they could compete on price. Any technology developed in Australia which improved efficiency or reduced costs would find a ready market in the US, as would Australian developments which solved emission or waste management problems.

Resource Status:

- Current Costs: logging residues >$4 a GJ; urban wood wastes and land clearing $3 a GJ; forest manufacturing residues $1.50 a GJ, environmentally collectible agricultural residues 1.5-3 $ a GJ; commercial forest wood <$3 a GJ.
- R&D Target Costs: logging residues <$3 a GJ; urban wood wastes and land clearing $3 a GJ; forest manufacturing residues <$1.50 a GJ; environmentally collectible agricultural residues $1.50 a GJ; commercial forest wood <$3 a GJ.
- Resource Potential: 15600 PJ a year; logging residues 800 PJ a year, urban woodwastes and land clearing 1200 PJ a year; forest manufacturing residues 2100 PJ a year; environmentally collectible agricultural residues 2000 PJ a year; commercial forest wood 4500 PJ a year; improved forest management 4500 PJ a year; shift 25% of wood industry to energy 500 PJ a year.
- Current Utilisation: 25 PJ a year utility electricity generation from wood; 1650 PJ a year industrial heat and power from wood (mainly paper and allied products); 20-40 PJ a year commercial heat and power from wood.

Conversion Technology Status:
Direct Combustion:

- Cost: Cost-competitive at suitable locations.
- Existing Capability: 8000 MW of biomass electricity generation capacity installed in the US is mostly this system;

- Mostly forest industry mill wastes where the collection cost is borne by the sellable timber. 50 US companies manufacture suitable wood-fired boilers.
- Constraints. Very site specific, most of the easily accessible resource is already utilised; Seasonal resource; Grid interconnection constraints; Emissions (NOx, SOx, CO), public opposition.

Gasification:

- Cost: Only cost-competitive at specific sites and under special government programs.
- Existing Capability: 3 projects, Florida 270 GJ a hour, Missouri 190 GJ a an hour, Georgia. 15 US manufacturers of gasification

equipment but no US suppliers of complete packaged systems as there are in Canada and Europe.

- Constraints: Problem of damage to combustion equipment caused by tars in gas.

SYSTEM 2 :MSW

As Australia is generally following behind US developments in applying this system, it is unlikely that opportunities for Australia will arise in the US market.

Resource Status.
. Current Cost: 3-4 $ a GJ.
. R&D Target Cost: <$2 a GJ.
. Resource Potential: 2400 PJ a year (includes industrial food waste).
. Current Utilisation: 820 PJ a year.

Conversion Technology Status:
Landfill Gas:

- Cost: Cost-competitive at suitable locations
- Existing Capability: Over 100 installations, up to 50 MWe; Several commercial developers and suppliers.

Direct Combustion:

- Cost: Viability of specific projects is dependant on public support, tipping fees, avoided costs, and air pollution emission requirements.
- Existing capability: For Mass-Burn Type, there are over 80 installations either operating or under construction; typically 5-10 MW, and there are numerous US suppliers of the technology. For Refuse Derived Fuel (RDF) Spreader-Stoker type, there are 14 installations with capacities up to 3000 tonnes a day, and there are several US equipment suppliers. For RDF co-firing with coal or oil, 14 utility boilers have been retrofitted, and there are existing US equipment suppliers. For RDF fluidised bed boilers (FBC), there are no currently operating facilities, one commercial installation has closed, and 2 installations are under construction. There are existing US FBC suppliers but they have no experience with RDF.

Pyrolysis/ Thermal Gasification:

- Cost: Not a cost-competitive option
- Existing Capability: Technology is at the R,D&D stage and there are no commercial suppliers.

SYSTEM 3: BIOGAS (ANIMAL AND HUMAN WASTES)

Possible opportunity to supply packaged systems for small to medium scale applications.

Resource Status:
. Current Cost: <$6 a GJ
. R&D Target Cost: $5 a GJ
. Resource Potential: 500 PJ a year

Conversion Technology Status:

- Cost: Site-specific but generally comparable to the retail cost of electricity.
- Existing Capability: Several operating installations at intensive animal production facilities but small scale off-the-shelf systems are not yet commercially available from US suppliers. A mature technology for municipal wastewater treatment. Markets for waste by-products have not yet developed.

Liquid Transport Fuels

The US Government is supporting a US$60m R&D program with the primary objective of developing cost-competitive liquid transport fuels from biomass sources. Substantial R&D programs are underway on both feedstocks and conversion technologies. Feedstock R&D is directed primarily at poplar and switchgrass. There is also an R&D program on feedstock/ conversion whole system optimisation.

SYSTEM 4; ETHANOL FROM LIGNOCELLULOSE

Too early to know whether R&D cost target will be achieved.

Resource Status

Current Costs:	wood energy crops $4 a GJ; herbaceous energy crops (lignocellulosics) $6 a GJ.
R&D Target Costs:	wood energy crops $3 a GJ; herbaceous energy crops (lignocellulosics) $3 a GJ.
Resource Potential.	8700 PJ a year; wood energy crops 3200 PJ a year; herbaceous energy crops (lignocellulosics) 5500 PJ a year.

Conversion Technology Status:

- R&D Target Cost: 18 UScents a litre by 2000 (in 1990 dollars ie: competitive with the projected unsubsidised wholesale gasoline price).
- Existing Capability: R&D is underway on acid pre-treatment optimisation, xylose conversion systems, cellulase production, and economically viable co-products.

The New Energy Company of Indiana are operating a US$1 m pilot plant using corn fibre feedstock. Amoco are involved in construction of a pilot-scale cellulose feedstock facility (enzymatic breakdown of cellulose to sugars).

SYSTEM 5: METHANOL FROM UGNOCELLULOSE

Too early to know whether R&D cost targets will be achieved

Resource Status:

- As for System 4.

Conversion Technology Status:

- R&D Target Cost: 14 UScents a litre by 2000.

- Existing Capability: R&D is underway on engineering development of gasifier auxiliaries and new catalytic synthesis systems. A 100 tonne a day synthesis test bed facility is under construction. In addition R&D is planned and funding allocated for commercial development of catalysts and for hot gas conditioning for both catalysis and the BCL gasifier.

SYSTEM 6: BIO-DIESEL FROM OILSEEDS

In the US, this system is assessed as not having any potential to become cost-competitive.

Resource Status:

- Cost: This resource has not been given sufficient priority by USDOE to receive any funding under the current program. (Instead the program has allocated substantial funds to the development of bio-diesel from aquatic species.)
- Resource Potential: 700 PJ a year; agricultural oilseed 300 PJ a year; new energy oilseed 400 PJ a year.

Conversion Technology Status:

- The technology is proven but not cost-competitive.

SYSTEM 7: OXYGENATES/OCTANE ENHANCERS

This system is unlikely to become cost-effective or to be commercialised in the short or medium term.

Conversion Technology Status:

- Existing Capability: The USDOE R&D program is concentrating entirely on RDF feedstock. Laboratory scale whole system development is underway. Funding is allocated for a 50 tonne a day pilot plant to demonstrate fast pyrolysis and catalytic cracking processes at an existing refinery. The is also funding for a catalyst development program to improve selectivity to olefines and to increase catalyst life.

SYSTEM 1 - LIGNOCELLULOSE RESIDUES TO ELECTRICITY

	BIOMASS FEEDSTOCK	CONVERSION TECHNOLOGY	BIOMASS DERIVED PRODUCT	COMPETING PRODUCT	ALTERNATIVE USES
DESCRIPTION	**Lignocellulose Residues**	**Gasification and/or Combustion**	**Electricity**	**Electricity from Fossil Fuels or Hydro**	**Other Product Options**
Cost Now	\$2.7/tonne to \$44/tonne[3] \$11-55/tonne[7]	\$12m capital[3] \$2.8m annual operating[3]	5-8 cents/kWh[6]	3-6 c/kWh product[1] \$500-2000/kW capital 1-4 c/kWh operating	
Cost Future	Would increase with demand	Conversion efficiency could increase from 20% to 30-35%[6]	2-5 cents/kWh[9]	Approx stable except for remote loads[2]	
Reliability	Regional but not seasonal	Medium		Very high	
Total Resource Volumes Now	N/A			Extremely large	Other biomass energy systems[8]
Total Resource Volumes Future	N/A			Extremely large	
Environmental Impacts	Need for sustainable forestry		CO_2 emissions reduced	Greenhouse emission and mine sites. Other emissions not significant in Australia	
Scale		0.5 to 5.0 MW for combustion. Up to 100MW for gasification		Full range kW to GW	
Technology Status - Australia			5 Australian combustion plants - many overseas	Australia leading edge in aspects of coal technology	
Special Issues		Combustor/fouling			

SYSTEM 1 NOTES:

1 Existing prices are from a publicly-owned monopolistic system, with transmission costs averaged at about 1 c/kWh, so no geographic price signals.

2 Prices may fall due to greater competition but private owners may also require higher returns. Transmission charges could fall for locations close to power stations and rise significantly for remote locations; the NGMC has an example 8c/kWh transmission charge to a remote load.

3 "Break-even" price for Orbost plant calculated from various electricity buy-back price assumptions, which may or may not reflect the market price of sawdust and woodchips. If a co-generation load cannot be attracted, break-even price would fall to $8.7/tonne, even for peak electricity prices.

4 Southern California Edison report that nearly all solid waste combustion projects have had large "deposit" facility problems caused by alkali levels in the biomass. There are major activities underway to analyse and reduce these problems, which cause excessive down time (R Mendelsohn, Overseas Visit Report, November 1993).

5 As set out in note 3, CSIRO calculations are not based on market price for feedstock. SIRF biomass pricing model assumed $8.7/tonne of feedstock, giving electricity output costs of 6 c/kWh at 6% discount rate and 8 c/kWh at *8%* discount. The resources evaluation chapter of the present study notes that the Orbost Cooperative estimates it will be able to obtain sawmill wastes delivered to the plant from some mills for less than $10/tonne and that the most it will have to pay will be about $18/tonne. ($8.7/tonne is the CSIRO paper break-even economic price for a *6%* DCF ROI without co-generation). Thus, the upper figure of 8 c/kWh could be optimistic.

6 CEC Section, R Mendelsohn Overseas Visit Report, November 1993.

7 From Resources Evaluation Chapter; includes softwood thinnings. Sawmill wastes A$l 1-26/tonne (dry) delivered,

8 Main current user is wood for domestic heating, at about 6Mt/year. Ethanol and Methanol can also be produced from lignocellulose.

9. Financial analysis for this study. For gasification, BEST, lower end of range assumes zero cost feedstock and 8.75% ROI.

SYSTEM 2 - MSW TO ELECTRICITY

	BIOMASS FEEDSTOCK	**CONVERSION TECHNOLOGY**	**BIOMASS DERIVED PRODUCT**	**COMPETING PRODUCT**	**ALTERNATIVE USES**
DESCRIPTION	**MSW**	**Gasification and/or Combustion**	**Electricity**	**Electricity from Fossil Fuels or Hydro**	**Other Product Options**
Cost Now	Negative[1,3]	$2000/kWh[4] capital for landfill gasification	Buy back tariffs crucial for landfill gas process	3-6 c/kWh product $500-2000/kW capital 1-4c/kWh operating	
Cost Future	Increasing negative	Should reduce significantly	Should reduce significantly	Approx stable except for remote loads	
Reliability	Already concentrated Not seasonal	High for gasification Medium for combustion		Very High	
Total Resource Volumes Now	About 14 million tonnes total wastes for Australia[3]			Extremely large	Recycling, building materials, compost, other biomass energy systems
Total Resource Volumes Future	Reducing due to recycling but still very large[3]			Extremely large	
Environmental Impacts	Reduced demand on diminishing landfill sites	Incineration not favoured Gasification viewed positively		Greenhouse emissions and mine sites. Other emissions not significant in Australia	
Scale	Individual plants quite small	Few MW - good flexibility		Full range kW to MW	
Technology Status - Australia		Landfill gas established here. This and other technologies overseas		Australia leading edge in aspects of coal technology	
Special Issues					

SYSTEM 2 NOTES:

1 United States analyses assume energy companies may be paid about US$65-85 to take refuse derived fuel (RDF) from waste transfer and sorting stations (R Mendelsohn, overseas visit report, November 1993).

2 Australian waste collection costs are around $37/tonne (Industry Commission, Waste Management and Recycling: Survey of Local Government Practices, Information Paper, March 1991). Landfill gas about $l-2/GJ. (S Bateman, Outlook 93 Conference, ABARE).

3 From National Waste Minimisation & Recycling Strategy, CEDA, 1992. Energy content (HHV) usually taken to be about 9 GJ/tonne (Van der Brock, 1991).

4 Bateman, S, Landfill Gas Control and Utilisation, Outlook 93 Conference, ABARE 1993.

5 Much of the recyclable materials cannot be combusted or gasified.

6 Financial analysis this study. This very large range depends particularly on feedstock costs and whether or not a steam host can be found to enable co-gemation. One plant type could achieve an ROI better than 8.75%, even with a buyback electricity price as low as 3 cents/kWh.

SYSTEM 3 - ANIMAL/HUMAN WASTES TO ELECTRICITY

	BIOMASS FEEDSTOCK	**CONVERSION TECHNOLOGY**	**BIOMASS DERIVED PRODUCT**	**COMPETING PRODUCT**	**ALTERNATIVE** USES 1
DESCRIPTION	**Animal/Human Wastes[1]**	**Gasification/Gas Turbine**	**Electricity & Heat**	**Electricity from Fossil Fuels or Hydro**	**Other Product Options I**
Cost Now	Low to negative[2]	Up to $27 million[5]	3-7 cents/kWh[6] Negative to $85/GJ heat	3-6 c/kWh product, $500-2000kW capital 1-4c/kWh operating	
Cost Future	Increasingly[2] negative?		Will depend* on feedstock and by-products	Approx stable except for remote loads	
Reliability	Already concentrated	High		Very High	
Total Resource Volumes Now	High			Extremely large	Fertiliser/carbon source for other conversion processes
Total Resource Volumes	Increasing			Extremely large	On site composting will reduce volume
Environmental Impacts	Major disposal problem at present which could be alleviated			Greenhouse emissions and mine sites. Other emissions not significant in Australia	
Scale		kW to few MW		Full range kW to MW	
Technology Status - Australia		Becoming commercial here. Commercial overseas.		Australia leading edge in aspects of coal technology	
Special Issues					

SYSTEM 3 NOTES:

1 **Includes sewage, excludes MSW. Food processing wastes could also be used.**

2 **Animal wastes may have a market value as fertilizer. This could either compete with energy as a use for the feedstock, or be a by-product from the energy process.**

3 **Denmark, for example, has 10 centralised biogas plants providing power and district heating. Electricity is subsidised at 6 cents/kWh. Total manure input 346,000 tonnes/year.**

4 **Anaerobic digestion is well-established technology, so substantial reductions in capital and operating costs are not expected.**

5 **\$27 million is the capital cost estimate for a plant supplied by 100,000 cattle producing over \$15 million m^3 biogas annually. Some plants are operating with as few as 26 cattle.**

6 **Financial analysis for this study. This is based on co-generation with buyback electricity prices assumed to be in the range 3-7 cents/kWh. The upper end of best price range is for 15% ROI, 3 cents/kWh and zero value by-product. Negative price for heat (with 8.75% ROI, 7 cents/kWh and 200/t by-product) implies ROI greater than 8.75% achievable. Financial analysis also covers a range of processes.**

SYSTEM 4 - CELLULOSE TO ETHANOL

	BIOMASS FEEDSTOCK	**CONVERSION TECHNOLOGY**	**BIOMASS DERIVED PRODUCT**	**COMPETING PRODUCT**	**ALTERNATIVE** USES
DESCRIPTION	**Cellulose[12]**	**Fermentation[1] or Hydrolysis**	**Ethanol**	**Petroleum products[3]** **Other oxygenates**	**Other Product Options**
Cost Now	$ll-55/tonne[7]	$280m capital[8] for 119 million litres/year	$1/litre[4]	20 US cents/litre[5.6]	
Cost Future	Would increase with demand	Research could significantly reduce capital & operating costs	36-88 cents/litre[4] 40-70 cents/litre[8]	Depends on world oil price	
Reliability	Regional but not seasonal	Plant technology not well	Established as blends in engines	Very High	
Total Resource volumes Now	N/A			Very large	Traditional wood uses including combustion. Beverage alcohol.
Total Resource Volumes Future	N/A			Very large	
Environmental Impacts	Need for sustainable forestry	Disposal of effluent a possible problem	Greenhouse emission reductions	Greenhouse and other emissions	
Scale		No commercial plants		Very large, plus extensive distribution network	
Technology Status - Australia	Substantial research on crops in Australia	Research in Australia and overseas		Mature	
Special Issues					

SYSTEM 4 NOTES:

1 **Any lignocellulose source, as per 2.5 of the Resources Evaluation Chapter, plus the cellulose component of MSW.**

2 **Food industry by-products/waste streams could also be competitive, as site-specific niche feedstocks.**

3 **Gasoline, diesel, LNG, CNG, LPG, MTBE, ETBE, Furans Methanol.**

4 **J D Wright and P A Feinberg 'Comparison of the Production of Methanol and Ethanol from Biomass', Tenth International Symposium on Alcohol Fuels. Future costs are estimated based on processes now at laboratory to pilot scale.**

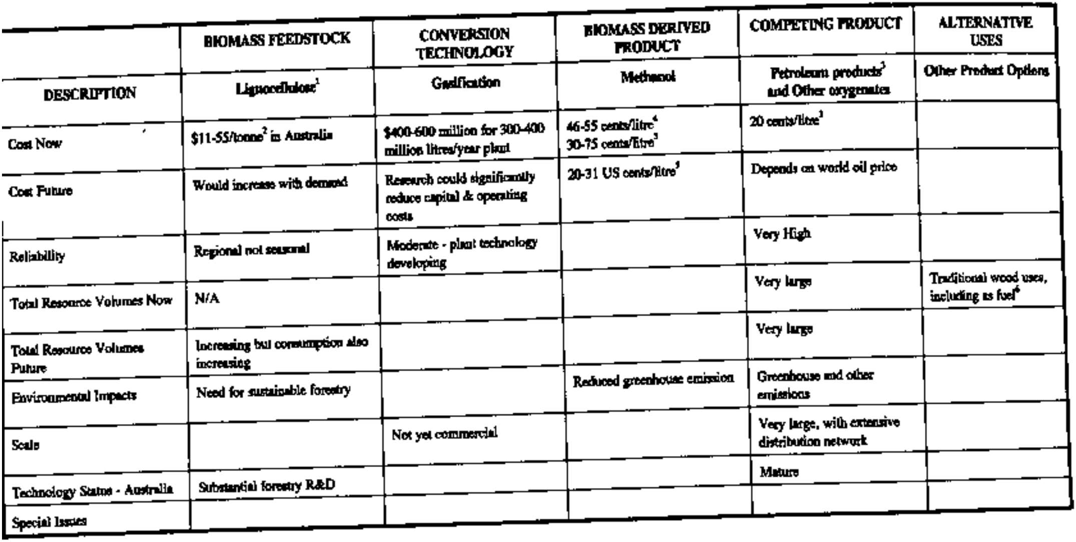
5 **Australian refinery gate price, exclusive of marketing costs and government taxes and charges.**

6 **One litre of petrol is equivalent to approximately 1.8 litres of achohol fuel in "driving distance", allowing for energy content and combustion characteristics.**

7 **From Resources Evaluation Chapter: Includes softwood thinnings. Cellulose from MSW could be less costly, depending on tipping charges and sorting costs.**

8 **Financial analysis for this study, NREL process. Low end of price range has $ 10/L feedstock and 8.75 % ROI.**

SYSTEM 5 - LIGNOCELLULOSE TO METHANOL



	BIOMASS FEEDSTOCK	CONVERSION TECHNOLOGY	BIOMASS DERIVED PRODUCT	COMPETING PRODUCT	ALTERNATIVE USES
DESCRIPTION	Lignocellulose[1]	Gasification	Methanol	Petroleum products[3] and Other oxygenates	Other Product Options
Cost Now	$11-55/tonne[2] in Australia	$400-600 million for 300-400 million litres/year plant	46-55 cents/litre[4] 30-75 cents/litre[3]	20 cents/litre[3]	
Cost Future	Would increase with demand	Research could significantly reduce capital & operating costs	20-31 US cents/litre[5]	Depends on world oil price	
Reliability	Regional not seasonal	Moderate - plant technology developing		Very High	
Total Resource Volumes Now	N/A			Very large	Traditional wood uses, including as fuel[6]
Total Resource Volumes Future	Increasing but consumption also increasing			Very large	
Environmental Impacts	Need for sustainable forestry		Reduced greenhouse emission	Greenhouse and other emissions	
Scale		Not yet commercial		Very large, with extensive distribution network	
Technology Status - Australia	Substantial forestry R&D			Mature	
Special Issues					

SYSTEM 5 NOTES:

1 Any lignocellulose source, as per 2.5 of the Resources Evaluation Chapter, plus the cellulose component of MSW.

2 From Resources Evaluation Chapter; includes softwood thinnings. Sawmill wastes A$l 1-26/tonne (dry) delivered.

3 Gasoline, Diesel, CNG, LNG, LPG, MTBE, ETBE, Ethanol, Methanol from natural gas or coal. 20 cents/litre applies to gasoline, diesel and methanol from natural gas.

4 IEA 'Biofuels' 1993, unpublished.

5 J D Wright and P A Feinberg 'Comparison of the Production of Medianol and Ethanol from Biomass', Tenth International Symposium on Alcohol Fuels. Future costs are estimated based on processes now at laboratory to pilot scale.

6 Also conversion to electricity or ethanol.

7. Financial analysis for this study. Lower end of range assumes $5/tonne feedstock and 8.75 % ROI, also process still under development.

8. Estimate for this study.

SYSTEM 6 - OILSEEDS TO OILSEED ESTERS

	BIOMASS FEEDSTOCK	CONVERSION TECHNOLOGY	BIOMASS DERIVED PRODUCT	COMPETING PRODUCT	ALTERNATIVE USES
DESCRIPTION	**Oilseeds, eg Canola**	**Crushing & Esterification**	**Oilseed Esters, eg Canola methyl ester**	**Diesel**	**Other Product Options**
Cost Now	A$210-410/tonne[1] US$720-1030/tonne[2]	A$40m[3])capital US$7m[2]) A$4m)operating	10-180 cents/litre[1] $1.34-1.89 $/litre[2]	20 cents/litre	
Cost Future	Set by commodity markets (post GATT agreement)	Mature technologies little room for cost reduction	Dependent on feedstock cost	Depends on world oil price	
Reliability	Seasonal (Dec-May Aust) Regional	High	Dependent on feedstock availability	Very High	
Total Resource Volumes Now	260,000 tonne/year[1]			Very large	Food/Edible Oils
Total Resource Volumes Future	Could increase - land is available			Very large	
Environmental Impacts	Need for sustainable agriculture		Reduced greenhouse emission reductions	Greenhouse and other emissions	
Scale		33 million litres/year[3] 60 tonnes/day[2]		Very large, plus extensive distribution	
Technology Status - Australia	Well established crop Local R&D?	Many large plants overseas		Mature	
Special Issues			Glycerol by-product needs a market		

SYSTEM 6 NOTES:

1 Data from Chapter 2, Resources Evaluation.

2 Financial analysis for this study. Small scale (0.03-0.46m litres/year non-esterified oil 85-180 centrs/litre. Low end of range assumes raw material is reject seed on-farm, and 8.75% ROI.

3 Esterified oils range from 10-145 cents/litre, critically dependent on feedstock cost and value of glycerol by-product. With no by-product, price of esterified oil is at least 60 cents/litre.

SYSTEM 7 - BIOMASS TO OXYGENATES

	BIOMASS FEEDSTOCK	**CONVERSION TECHNOLOGY**	**BIOMASS DERIVED PRODUCT**	**COMPETING PRODUCT**	**ALTERNATIVE USES**
DESCRIPTION	**Any which will produce Methanol or Ethanol[2]**	**Feedstock - dependent**	**MTBE, ETBE or Furans**	**MTBE or ETBE from fossil sources** **Other oxygenates**	**Other Product Options**
Cost Now	See Systems 4 and 5	See Systems 4 and 5 plus etherification	See Systems 4 and 5 plus conversion costs	MTBE and ETBE 40-100 cents/litre[1]	
Cost Future	See Systems 4 and 5	Research could significantly reduce capital and operating costs	40-60 cents/litre for furans[3]	Reducing as technology matures	
Reliability	See Systems 4 and 5	Moderate to high	As for same product from fossil sources	High	
Total Resource Volumes Now	See Systems 4 and 5			Very large	
Total Resource Volumes Future	See Systems 4 and 5			Very large	
Environmental Impacts	See Systems 4 and 5		Greenhouse benefits reduced due to non-renewable components	Greenhouse emissions greater than if sourced from biomass	
Scale		No commercial plants		MTBE - 20,000 bbl day[1] ETBE - not in major production	
Technology Status - Australia	See Systems 4 and 5	Substantial research overseas on MTBE & ETBE.		MTBE - fairly mature ETBE - emerging Australia	
Special Issues					

SYSTEM 7 NOTES:

1 Financial analysis this study.

2 For example lignocellulose. Furans research being done on bagasse.

3. Estimated from laboratory scale plant.

6.0 SITE SPECIFIC CASE STUDIES

6.0 SITE SPECIFIC CASE STUDIES

6.1 INTRODUCTION

This section of the study is intended to provide a more detailed and realistic assessment of the commercial prospects of the most promising systems defined in Section 5, together with their environmental impact.

This detailed assessment will help define the key strategic issues and provide a basis for the development of the action plan that will lead towards their commercialisation.

Location specific data has been collected from sites and capital and operating costs on technology have been obtained from industry to improve data reliability. Identification of the nature and size of barriers to commercialisation and the steps needed to overcome these barriers is a key feature.

The site-specific studies identified are at different stages of technological development.

Economics will remain the driving force, continuing with the agreed policy that this study will identify how each site-specific technology compares to their established technologies non-renewable competitors.

The use of examples from feasibility and other economic studies presently being undertaken for some of the case studies has inevitably led into issues of commercial confidentiality. Accordingly, some of the case studies have had details of their project economics limited and/or the actual sites and/or identity of their proponents suppressed.

Contacts were made with the sugar industry regarding possible case studies on bagasse. Although these contacts were sympathetic to the aims of this study, they were at a delicate stage of negotiations with prospective purchasers of the electricity to be produced from bagasse and all details were regarded as commercially confidential. However, it can be observed that the scale involved is large by biomass standards, with units in the 30-40MW range being considered. In addition, the questions of buy back rates and standby charges pervade bagasse projects just as much as other biomass electricity projects.

The study would like to thank all those with whom discussions were held and particularly those (named in brackets below) who were kind enough to provide the information used in this study.

The following systems were evaluated in detail as case studies:

1. Electricity from Direct Combustion and Gasification
    - (1) Cogeneration from wood waste (Energetics/NSW Office of Energy)
    - (2) Cogeneration from rice hulls (Energetics/NSW Office of Energy)
    - (3) Cogeneration from cotton wastes (BEST/TREElectric)
    - (4) Cogeneration from MSW (Heidelberg Electricity)
2. Electricity from Anaerobic Digestion
    - (1) Cogeneration from regional biowastes (Ecosound Solutions/ BioResources Australia)
    - (2) Cogeneration at a centralised MSW Biogas plant (Shire of Pakenham/BioResources Australia)
    - (3) Biogas from wine industry wastes (S Smith & Son/Environmental Solutions International)
3. Ethanol from Lignocellulose and Cellulose Waste
    - (1) Ethanol from agroforestry and crop residues (Dept of Conservation and Land Management, WA/Dept of Agriculture, WA)
    - (2) Ethanol from waste paper (Australian Paper/Visy Recycling)
4. Ethanol from Food Processing Wastes
    - (1) Ethanol from potato industry wastes (Edgell-Birdseye/ Fermtech)
    - (2) Ethanol from starch processing wastes (Goodman-Fielder/Bunge)
5. Vegetable Oil/Esters from Oilseeds
    - (1) Esters from canola and cotton seed oil (Cargill/Unilever)

6.2 ELECTRICITY FROM DIRECT COMBUSTION AND GASIFICATION

Case studies to illustrate the application of heat and/or power generation from biomass were selected using a range of feedstocks and capacities. Technologies, where possible, were included to represent those under development in Australia.

6.2.1 Cogeneration from Wood Waste

6.2.1.1 Site Energy Demand

This case study, not identified by name or location, is for a factory that manufactures wood products and requires substantial inputs in the form of electricity and heat.

Raw materials for the manufacturing process consist mainly of logs, woodchips and shavings. The majority of the woodchips are purchased from the nearby factories, with more external sourcing required as the output is increased.

Woodchips for the process are dried using hot air from dryers fired by woodwaste generated internally or bought from external mills with the exception of one dryer which is diesel-oil fired.

Heat for the board-forming machines is provided in the form of hot oil and high-temperature hot water heated by woodwaste-fired heaters.

The energy inputs for the site are electricity, woodwaste, LPG and diesel oil. A typical annual total energy cost is $2.4 million which forms a significant part of the total production cost. The demand for heat and electricity is continuous which is a requirement for cogeneration to be viable.

The study is based on installing a new woodwaste fired boiler to cogenerate 2,209 kW of electricity and heat.

The monthly average electricity load and the maximum demands for the year indicate a baseload of approximately 2MW but drops to 1.2MW when the factory is undergoing its scheduled weekly maintenance. The baseload of 2MW will influence the sizing of the cogeneration system provided that the heat load is sufficient to support it.

Three major forms of heat are required for the process:

(a) Hot air at 900°C for drying the woodchips.

(b) Hot water at 185°C for board-forming presses.

(c) Hot oil for board-forming presses and other machines

The heat for the two hot-oil and one hot-water system could be replaced by cogeneration heat and together with the electrical baseload mentioned above, form the basis for the cogeneration equipment selection and sizing.

6.2.1.2 Biomass Resources Available

Woodwaste used as fuel at the site fuel comprises bark suitably chipped, sanderdust and externally-sourced woodwaste which may also include woodchips. Some of the typical properties of woodwaste are shown in Table 6.1.

Table 6.1 : Typical Properties of Woodwaste of Various Types

	Moisture %	Ash %	Gross CV MJ/kg
Air-dried wood	10-20	0-0.5	15.5
Chips	24	1	14
Sawdust	27	1	14

Source: Energetics

Woodwaste is available from an adjacent softwood plant, at a price of $28.17 a tonne on average, i.e. $2.01 a GJ which is more than the average price for coal. Availability of woodwaste is not a problem at present.

Sanderdust, which forms part of the internally-generated woodwaste, has approximately the same moisture content as the hot air-dried woodwaste (2.5-3 per cent). Other possible sources of woodwaste are both approximately 60km away, which would incur significant transport costs.

Another possible source of woodwaste is the abundant pulpwood presently discarded on the forest floor after logging. These are the top third of trees that are too small for milling but could be chipped into 'forest chips' on-site and transported to the cogeneration plant. It is possible that there could be a shortage of conventionally-available woodwaste in this area and depending on the cost of chipping and transportation, a new industry could be chipping the pulpwood.

The factory is already buying some forest chips, with a bark content of approximately 8 per cent, from the softwood plant at a cost of approximately $45 a wet tonne. This is expensive because the softwood plant has to pay a royalty to the state of NSW for the pulpwood.

Based on forest chips supplied to a wood panel plant in South Australia, it is estimated that the cost of forest chips could be reduced to approximately $25 a wet tonne if the forest were to belong to the factory owner and no royalties were payable.

6.2.1.3 Conversion Technologies

Some of the possible cogeneration configurations and their characteristics are discussed below.

(i) The woodwaste could be fed into the gasifier to produce combustible gases for fuelling a gas engine driving an alternator. The exhaust gases are usually at approximately 550°C and can be used for heating the hot oil, the hot water and also be supplementary-fired (with some additional air supply) to produce higher temperature exhaust gases for other dryers. However, woodwaste gasifiers for gas engines are still in the developing stages (see other case study).

(ii) Alternatively, very high temperature steam could be produced by a woodwaste-fired boiler and expanded through a turbine driving an alternator to produce electricity. The steam leaves at approximately 300°C and is suitable for heating the hot oil at 250-260°C through a heat exchanger, in a topping cycle for the hot oil. However, at the high pressures involved, the boiler and steam turbine are non-standard and costly

The turbine is a back-pressure turbine and because of its conventional pressure ratings, it is readily available and competitively priced. However, this system supplies only one-third of the heat load derived from woodwaste and produces only 176kW of electricity which is negligible compared to the total site baseload of approximately 2MW. The turn-key capital cost of the project is estimated to be $1.8 million. Due to the small electricity output, this alternative is not favoured and will not be considered any further.

(iii) In this system, superheated steam at 4.5MPa abs and 450°C is produced in a boiler and expanded through a steam turbine driving an alternator to produce electricity. Steam is extracted from the turbine at 2MPa abs and is used in a heat exchanger to produce hot water at 185°C. The remainder of the steam continues its expansion through the turbine to give substantial increase in electricity generation before being condensed in the condenser.

The appropriate turbine would be a 'condensing turbine with one controlled extraction' and because of its conventional pressure rating, it is readily available and competitively priced. The cogeneration plant will be configured to act as the lead boiler with the existing hot-water generator relegated to standby duties. This is the system recommended; the economics are discussed below.

6.2.1.4 Economics

The economics for the cogeneration plant were calculated using present electricity tariffs and woodwaste prices, and the estimated turnkey capital cost for the cogeneration plant rated at 2,290kW of electricity after allowing for the electrical burden required by the cogeneration plant's ancillary equipment.

For outputs less than 30MW, buyback guidelines have indicated that the generator requires no standby charge, however, after consulting the local distributor a standby charge or $3.8 a kVA a month is allowed for in the economics.

The cogeneration plant will use 31,900 tonnes a year of woodwaste, replacing 10,500 tonnes a year that would have been consumed by the existing hot-water generator. Therefore, an overall increase of 21,400 tonnes a year of woodwaste is required. But for that extra woodwaste, the cogeneration plant also produces 16,165MWh a year of electricity, which saves on import of electricity from the grid.

The resulting balance, based on the site's present tariff, is an annual electricity cost saving of over $1.2 million including maximum demand charges.

Off-set against these electricity savings is the cost of maintenance which is estimated at $162,000 a year, resulting in net savings of over $909,000 a year. This assumes the extra 21,400 tonnes a year of woodwaste required cogeneration is *free-of-charge.*

The annual savings give a simple payback period of 5.3 years for the turnkey cost of the investment estimated at $4.8 million. The net present value (NPV) over the same period is $0.36 million (i.e. positive), indicating that the project is economically viable. The after-tax, nominal (before inflation) rate of return (ERR) over 15 years is 15%.

If woodwaste is at $28.17 a tonne, then the IRR is almost 0.

On other sensitivities:

- at a peak price for imported electricity of 10cents a kWh, the ERR is 14.5%, rising to 16.2% for 14cents a kWh;
- at a capital cost of $4million, the ERR is 18%, falling to 10% for capital cost of $6.5million; and
- varying the standby charge from $0 to 7$ kVA a month changes the ERR from 16% to 15%.

6.2.1.5 Environment

By using woodwaste for electricity generation, non-renewable fossil fuels will be conserved since they are the dominant fuels being used for power generation in NSW. On average, the electrical efficiency for coal-fired power stations in NSW is approximately 35 per cent before transmission and distribution losses. Their overall CO_2 coefficient is 393 kg of CO_2 per GJ of useful electricity after transmission and distribution losses. Thus, the CO_2 emission saved by the 16,000 MWh a year of electricity generated by the on-site cogeneration plant would be 22,600 tonnes a year assuming that CO_2 produced in combustion is absorbed by regrowth timber.

This saving is reduced slightly by the fossil fuels required to chip the pulpwood and waste and to transport the woodchips to the factory, in addition to the fossil fuels used in the establishment and harvesting of the forest resources utilised.

The three major environmental issues relating to the implementation of the cogeneration system here are the loss of biodiversity, forestry sustainability and implications for greenhouse gas balances.

The first two issues depend entirely on the geographic extent of softwood plantation establishment. In the context of the case study region there is a significant existing area of softwood plantation resource. The wood waste available for cogeneration is derived from regional softwood plantations, as chipped pulpwood or sanderdust. The major environmental impacts are those related to plantation management on the local/regional catchment, including minimising slope and soil erosion, protecting water quality through the provision of buffers and minimising the application of chemical fertilisers, insecticides and pesticides.

Environmental costs include the impact on biodiversity through the loss of native flora and fauna habitat since softwood plantations comprise of an exotic monoculture crop. A direct environmental benefit is the use of the woodwaste to generate heat and electricity rather than its disposal through either landfill or open incineration creating a local air pollution problem. Consequently the environmental issues largely relate to appropriate management.

This also applies to the amelioration of air emissions by adhering to the relevant EPA requirements on air emissions. There is considerable potential for air emission impacts related to the stack gases, particulates and solid ash waste produced through the combustion of woodwastes. These air emission impacts are similar to those produced by conventional fossil fuel combustion. Appropriate air pollution control devices would be required to be installed on the stacks.

The region is well serviced with electricity distribution, which is derived from hydroelectric generation. Consequently these CO2 savings are representative only and would be more applicable to rural areas where there is not a renewable electricity supply.

6.2.1.6 Summary and Conclusions

The factory manufactures wood products and requires substantial energy inputs in the form of electricity and heat. For a recent year, the factory had annual energy bills of $1.6 million for electricity, $0.38 million for LPG and $0.44 million for externally-sourced woodwaste.

This study is based on installing a new woodwaste-fired boiler to drive a steam turbine alternator producing a net 2,209 kW of electricity. Partially expanded steam is extracted from the turbine and is used to produce high-temperature hot water.

Extra woodwaste is purchased at $28.17 a tonne which is comparable to the price of coal. At this price, the cogeneration plant is not viable However, if free woodwaste was available, such as from the abundant pulpwood left on the forest floor, then the cogeneration plant would be more cost-effective. The effect of wood price is crucial to viability.

Only the hot-water load can be economically replaced by cogeneration heat. The hot oil and hot air cannot be economically replaced due to the higher temperatures required (over 285°C). A gasification technology, when available, could supply the required heat.

6.2.2 Cogeneration from Rice Hulls

6.2.2.1. Site Energy Demand

The unidentified rice mill used in this case study accepts raw paddy from the surrounding areas for processing into finished white rice for the local and export markets. Rice husks are produced as waste.

The paddy arrives at the site already dried to varying degrees of moisture contents. Should the moisture content be above the required 14% by weight, then additional drying on-site is required before milling can commence.

The energy inputs for the site are electricity and LPG. Annual total energy costs for the year ending July 1993 are of $1.2 million of electricity and $271,000 of LPG.

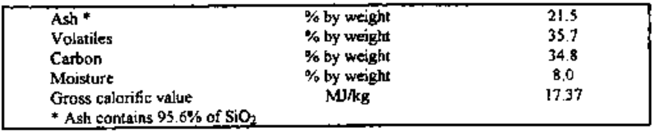
The demand for heat and electricity is continuous during the harvesting season (April-July) and continuous for electricity only for the remainder of the year (August-March). The baseload throughout the year is 1,100 kW. The maximum load is 4,300 kW occurring in winter while the minimum is 2,100 kW occurring in summer.

At the site, heat in the form of hot air is supplied from LPG-fired hot-air generators to dry any wet paddy before milling and to prevent the growth of mould and infestation by insects. The requirement for drying is greatest during the harvesting season.

6.2.2.2 Biomass Resources Available

Generally, the composition of rice husks, at a moisture content of 8% by weight, is as shown in Table 6.2:

Table 6.2 : Typical Composition of Rice Husks at 8% Moisture Content



Ash *	% by weight	21.5
Volatiles	% by weight	35.7
Carbon	% by weight	34.8
Moisture	% by weight	8.0
Gross calorific value	MJ/kg	17.37

* Ash contains 95.6% of SiO_2

However, at 14% moisture content, the gross calorific value is much lower and is approximately 9.9 MJ a kg This is the figure used for the economics of the cogeneration plant.

Approximately 60,000 tonnes a year of rice husks are currently disposed of by burning or in landfills. The availability is spread reasonably uniformly throughout the year. This quantity will be available as fuel for the cogeneration plant.

6.2.2.3. Conversion Technologies

The economics are normally dictated by the amount of heat that can be replaced by the cogeneration plant thermal output. In this case however, the fuel is free, in abundance and available all-year round so that it is possible to size a bigger plant to suit the fuel supply and export any surplus electricity to the grid. The cogeneration equipment selection and sizing takes into account the following:

- The harvesting season, on average, starts in April and lasts till on July-August, ie approximately 15 weeks duration.
  Tariff for imported electricity.
- Thermal efficiency of LPG-fired hot-air generators in use is typically 70%.
  On average the site requires 24,500 GJ a year of LPG.

A direct combustion boiler produces superheated steam at 4.5 MPa absolute and 450°C and expanded through a steam turbine driving an alternator to produce electricity. Steam extracted from the turbine will be used for producing hot air (30°C and 60°C) in heat exchangers. The balance of the steam produces electricity and goes to a condenser for eventual return to the boiler as feedwater. This is a 'condensing with one controlled extraction system. This is the most economical configuration and is the scheme recommended.

When there is no requirement for steam to dry the paddy, there will be no steam extraction and all the steam entering the turbine from the boiler will be expanded to produce maximum electrical output. This is the 'all-condensing' mode of operation for the turbine. The steam returns to the boiler as feedwater.

Based on the 60,000 tonnes a year of husks expected to be available in 1994, the cogeneration plant is sized to produce all the heat to replace that presently supplied from LPG.

Accordingly, the matching cogeneration plant is rated at either:

- 4.2 MW net of electricity and 3.3 MW of hot air in extraction-condensing mode, or

  5 MW net of electricity only in all-condensing mode.

During summer, the cogeneration plant is expected to be exporting electricity to the grid at all times.

The cogeneration plant for the rice mill requires a special boiler designed for rice husk-firing. For this study, suspension-firing is recommended.

Unfortunately, the suspension-firing process introduces the potential problem of fly-ash which is entrained in substantial concentrations by the flue gases leaving the stack. It is therefore necessary to filter out the fly-ash before the stack.

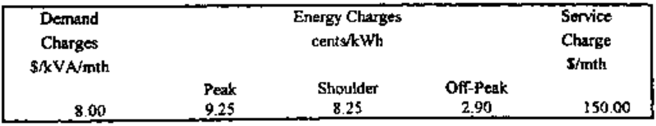
The quantity of ash is large and is one of the major problems of the rice-husk burning process, especially for the required continuous operation of the furnace. Therefore, a system which permits continuous removal of the ash to provide the best possible combustion conditions is necessary. For this study, the boiler is thus equipped with a mechanical cyclone dust extractor and a fabric-bag filter. The abrasiveness of the ash will influence the design of the convection passes in the boiler because abrasive fly-ash could grit-blast the inside surfaces.

As rice husks have relatively low calorific values per unit volume, the storage system is characterised by its large physical volume compared to equivalent fossil fuel systems. For example, approximately 15-18 times by volume of rice husks must be burnt compared to coal to generate the same amount of steam.

6.2.2.4 Economics

The site is on the tariff as shown in Table 6.3 below:

Table 6.3 : Site Electricity Tariff



Demand Charges $/kVA/mth	Energy Charges cents/kWh			Service Charge $/mth
	Peak	Shoulder	Off-Peak	
8.00	9.25	8.25	2.90	150.00

For outputs less than 30 MW, buyback guidelines have indicated that the generator requires no standby charge. However, a standby charge from the local distributor would apply. A charge of $4 a kVA a month is allowed for in the economics.

The rice husks are free-of-charge and by utilising them in the cogeneration plant, some of the disposal cost is saved. However, the present disposal cost is still unquantified. Therefore, for the purpose of this study, this saving was not credited to the cogeneration plant project.

The cogeneration plant will use 60,000 tonnes a year of rice husks, replacing 24,442 GJ a year of LPG that would have been consumed by the existing LPG-fired hot-air systems. The cogeneration plant also produces 29,063 MWh a year of electricity, which saves the entire present import of 13,929 MWh a year of electricity from the grid. The balance of 15,134 MWh a year is exported to the grid and credited to the project economics. The resulting balance, based on the site present electricity tariff, is an annual electricity cost saving of over $2.16 million including maximum demand charges and export receipts.

To off-set against these electricity savings is the cost of cogeneration plant maintenance, estimated at approximately $436,000 a year, resulting in overall net savings of approximately $1.5 million a year.

The annual savings give a simple payback of 4 years for the turn-key cost of the investment estimated at $6.7 million and based on budget prices provided by equipment suppliers.

The after-tax nominal internal rate of return (IRR) over 15 years is 18%. The net present value (NPV) over the same period is approximately $1.9 million.

Other sensitivities included:

- if feedstock cost $8 a tonne, IRR would be 11%; and
- increasing capital cost from $6m to $8.5m reduces IRR from 18% to 14%.

6.2.2.5 Environment

By using rice husks for electricity generation, non-renewable fossil fuels will be conserved since they are the dominant fuels being used for power generation in NSW. On average, the electrical efficiency for coal-fired power stations in NSW is approximately 35% before transmission and distribution losses. Their overall CO_2 coefficient is 392 kg of CO_2 per GJ of useful electricity after transmission and distribution losses. Thus, the CO_2 emission saved by the 29,000 MWh a year of electricity generated by the on-site cogeneration plant at the rice mill is 40,900 tonnes a year. This is on the assumption that the regrowth of rice absorbs as much CO_2 as is released from combustion, giving a net CO_2 emission of zero.

Assuming complete combustion, the CO_2 coefficient for LPG is 60 kg of CO_2 emitted per GJ of useful energy. The CO_2 emission saved by the 16,205 GJ a year of cogeneration heat (in the form of hot air) is 970 tonnes a year.

Thus, the total annual CO_2 emission saved by the cogeneration plant amounts to 41,870 tonnes a year.

Also, by using the rice husks in a cogeneration plant, the need to allocate land for landfills is saved. Pollution is also reduced by the lesser transportation required for the ash compared to the bulky husks.

The local and regional impacts of rice production on the water demand for irrigation, stream water quality and shallow groundwater aquifer levels are potential barriers to the sustainability of the rice industry. Crop irrigation is causing significant groundwater recharge in the Murrumbidgee Irrigation Area in part contributing to rising watertables and land salinisation. There are also widespread impacts caused by frequent discharges of variable quantity and quality irrigation drainage water into natural water courses.

The use of agricultural chemicals, in particular pesticides, is intensive and runoff containing residue chemicals especially pesticides and nutrients is degrading stream water quality and causing significant impact on aquatic and riparian ecosystems and stream hydraulic capacity. These issues are far more relevant than the origin and supply of energy for electricity and heat at the mill, if we examine the life cycle of the waste rice hulls.

The Rice Growers' Association of Australia instigated an environmental policy study of the rice industry "Rice 2000" which outlines the present unsustainability of the rice industry and the actions required to achieve environmental sustainability by addressing the above issues.

In the greenhouse gas analysis, it has been assumed here that the carbon released in the form of $C0_2$ is equivalent to that amount sequestered during the plant growth phase. Significant quantities of methane are produced by anaerobic decomposition of organic ruminants, flooded rice fields and wetlands as a result of rice growing. As a result of present practices, $C0_2$ is produced by the burning of cleared vegetation, rice stubble and rice husks.

Air emissions from the combustion of rice hulls will be similiar to those from woodwaste. The high silica composition (95%) and the high volume of the ash produced by the combustion would need to be disposed of to landfill or may be suitable for reuse as a soil fertilizer additive.

6.2.2.6 Summary and Conclusions

Rice husks, presently being disposed of in landfills and in open fires which can cause pollution problems, are available to the rice mill as free fuel.

The installation of a cogeneration plant, rated at 4.2 MW electrical in the extraction-condensing mode and 5 MW electrical in the straight-condensing mode, is economically viable, saving the rice mill about $1.5 million a year in energy costs and producing a ROI of 18% Cogeneration electricity surplus to site requirements will be exported to the grid.

6.2.3 Cogeneration from Cotton Wastes

6.2.3.1. Site Energy Demand and the Wider Market

This study, unlike the previous two, utilizes technology at the R&D stage.

A cotton farmer located near Bourke wishes to expand his farming operations but is restricted by the cost in up-grading the power line to supply the additional electricity required for irrigation pumping.

The Namoi Valley Electricity Authority has agreed to assist TREElectric in project evaluation of a grid-connected cogeneration system. TREElectric believe that there are sufficient quantities of cotton waste available to ensure continual and profitable operation of biomass fuelled generator sets. In addition, the National Grid Management Council is to report to the Council of Australian Governments (COAG) on network service pricing (NSP). If such pricing is agreed on a fully cost-reflective basis, NSPs to users remote from generation would rise, providing further opportunities for viable projects.

Namoi Valley Electricity Authority may also be able to use the stand-alone generator sets as a back-up power supply to the Nyngan feeder line which, on occasions, experiences damage from the natural elements causing an intermittent supply of power to the Nyngan region.

6.2.3.2. Biomass Resources Available

Results of a survey carried out by the Department of Agriculture show that there are 500,000 tonnes of cotton stalks and gin trash produced each year in the Gwydir Valley, Western and Namoi Valley districts. Of this, it is estimated that 200,000 to 250,000 tonnes could be utilised for energy production. Assuming an overall conversion efficiency of 25%, the total electricity that could be generated is 230,000MWh.

The average plant would be 2 x lMWe modules and assuming that electricity was generated for 16 hours a day for 320 days a year, then the installed electrical capacity would be approximately 50MW

6.2.3.3 Conversion Technologies

The unit consists of a gasifier, a system of removing particles and tar from the gas stream and an engine generator and heat exchanges to use the waste heat to dry the fuel. The system is unique in that part of the exhaust gas from the engine is re-injected into the gasifier.

6.2.3.4. Economics

Initial costing of systems with electrical outputs of lOOkW, 1MW, 2MW and 4MW has now been carried out. For a 1 OOkW system using off the shelf automotive engines, the installed cost is approximately $ 100,000; for a 4MW system $4,700,000. Using cotton waste as a fuel it is estimated that the cost of generating electricity is between 3 and 6 cents a kW at a biomass cost of $10 a tonne.

6.2.3.5. Environment

The Australian Cotton Foundation believes that the majority of the cotton stalks are required to be retained and mulched into the soil to provide an organic nutrient source and is seeking ways to achieve this.

Soils upon which cotton is grown are critically depleted in nutrients In addition, the large monoculture cotton industry causes significant environmental impacts on native habitat clearance, soil compaction and land degradation, water supply and diversion in a semi-arid environment resulting in reduced environmental flows in the supply river network,

together with a high level of agricultural fertiliser, pesticide, insecticide and defoliant use.

High nutrient and chemical loads, particularly pesticides, in runoff and irrigation tailwater from the cotton producing areas have been identified as a major source of inland waterway nutnfication problems, leading to algal blooms and loss of aquatic biota including fish kills.

There is also the significant threat to the environment caused by the resistance of cotton crops to insecticide application, which results in increased pesticide loads in runoff and in local air which leads to a massive impact on the environment. If the life-cycle of the cotton wastes is examined it is clear that the industry is not environmentally sustainable under current practices and by implication, neither is the supply of the wastes.

The production of electricity via gasification produces ash that does not contain hazardous compounds and can be disposed of either to landfill or as fertiliser. There are no significant environmental impacts associated with biomass gasification.

From a national perspective the provision of electricity from small 1MW plants has savings on diesel fuel use and hence a comparable $C0_2$ saving. However, there would need to be a huge number of these plants to have any significant effect on national greenhouse gas balances. Cotton is produced by industries which involve substantial fossil fuel use and energy in crop establishment, harvesting and transport. The OECD International Energy Agency believes that potential cogeneration of electricity from crop wastes could significantly reduce life-cycle energy use and net greenhouse gas emissions to about 10-20% of those from conventional fuel.

6.2.3.6. Summary and Conclusions

TREElectric and BEST are determining the technical and economic viability of generating electricity from cotton wastes using an entrained flow gasifier. They are developing a design for a turn-key 1MW commercial gasifier system for use in remote areas to be fuelled primarily with agricultural residues. The companies plan to to install a demonstration plant at a cotton gin near Wee Waa, NSW and carry out an economic evaluation before drafting full production plans.

The consortium has recognised that there is a market for plant with outputs from iOOkW to SMW The potential for both build-own-operate ami equipment sales in Europe and Asia is much greater than in Australia TREElectric may apply for a license to generate electricity in the UK under the NFFO scheme. This scheme offers 20cents a kWh to power generators using non-fossil fuels such as fuelwood grown by farmers.

There is possibly a market for 10,000MW of installed capacity over the next 10 years in Europe and 1,000 MSW installed electrical capaicty in the UK. Key markets in the Asia region include China, Indonesia, Thailand and the Philippines.

6.2.4 Cogeneration from MSW

6.2.4.1. Site Energy Demand

The City of Heidelberg, currently an electricity distribution authority, shortly to become part of Electricity Services Victoria, is planning a project to cogenerate power from wastes at it MSW transfer station. The transfer station is across Waterdale Road from the Heidelberg Repatriation Hospital in Melbourne.

Steam and electricity are required at the Repatriation Hospital twenty four hours a day and seven days a week; 8 tonnes an hour of steam are needed on average throughout the year. The minimum power demand for the hospital is less than 980 KVA and the monthly peak demand is about 2800 KVA.

It is expected that this system will be able to absorb any power or energy produced at the waste-to-energy plant.

6.2.4.2. **Biomass** Resources Available

The composition of some of the domestic waste collected at the Heidelberg transfer station has been analysed by the City of Heidelberg. An analysis was performed in March 1992 showing the composition in Table 6.4.

This composition is representative of about one third of the present waste handled at the transfer station. No compositional analysis is available of the other two thirds of the waste stream.

The successful operation of a waste-to-energy plant relies; on some selectivity in the feed material. If there were a large proportion combustible material in the feed waste stream, it reduce calorific value increase ash quantity and possibly reduce ash quality.

together with a high level of agricultural fertiliser, pesticide, insecticide and defoliant use.

High nutrient and chemical loads particularly pesticides, in runoff and irrigation tailwater from the cotton producing areas have been identified as a major source of inland waterway nullification problems, leading to algal blooms and loss of aquatic biota including fish kills.

There is also the significant threat to the environment caused by the resistance of cotton crops to insecticide application, which results in increased pesticide loads in runoff and in local air which leads to a massive impact on the environment. If the life-cycle of the cotton wastes is examined it is clear that the industry is not environmentally sustainable under current practices and by implication, neither is the supply of the wastes.

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The consortium has recognised that there is a market tor plant with outputs from lOOkW to 5MW. The potential for both build-own-operate and equipment Sales in Europe and Asia is much greater than in Australia. TREElectric may apply for a license to generate electricity in the UK under the NFFO scheme. This scheme offers 20cents a kWh to power generators using non-fossil fuels such as fuelwood grown by farmers. There is possibly a market for 10,000MW of installed capacity over the next 10 years in Europe and 1,000 MSW installed electrical capacity in th UK. Key markets in Asia region include China, Indonesia, Thailand and the Philippines.

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This composition is representative of about one third of the present waste handled at the transfer station. No compositional analysis is available of the other two thirds of the waste stream.

The successful operation of a waste-to-energy plant relies on some selectivity in the feed material. If there were a large proportion of non-combustible material in the feed waste stream, it would reduce calorific value, increase ash quanitity and possibly reduce ash quality.

together with a high level of agricultural fertiliser, pesticide, insecticide and defoliant use.

High nutrient and chemical loads, particularly pesticides, in runoff and irrigation tailwater from the cotton producing areas have been identified as a major source of inland waterway nullification problems, leading to algal blooms and loss of aquatic biota including fish kills.

There is also the significant threat to the environment caused by the resistance of cotton crops to insecticide application, which results in increased pesticide loads in runoff and in local air which leads to a massive impact on the environment. If the life-cycle of the cotton wastes is examined it is clear that the industry is not environmentally sustainable under current practices and by implication, neither is the supply of the wastes.

The production of electricity via gasification produces ash that does not contain hazardous compounds and can be disposed of either to landfill or as fertiliser. There are no significant environmental impacts associated with biomass gasification.

From a national perspective the provision of electricity from small 1MW plants has savings on diesel fuel use and hence a comparable CO2 saving. However, there would need to be a huge number of these plants to have any significant effect on national greenhouse gas balances. Cotton is produced by industries which involve substantial fossil fuel use and energy in crop establishment, harvesting and transport. The OECD International Energy Agency believes that potential cogeneration of electricity from crop wastes could significantly reduce life-cycle energy use and net greenhouse gas emissions to about 10-20% of those from conventional fuel.

6.2.3.6. Summary and Conclusions

TREElectric and BEST are determining the technical and economic viability of generating electricity from cotton wastes using an entrained flow gasifier. They are developing a design for a turn-key 1MW commercial gasifier system for use in remote areas to be fuelled primarily with agricultural residues. The companies plan to to install a demonstration plant at a cotton gin near Wee Waa, NSW and carry out an economic evaluation before drafting full production plans.

The consortium has recognised that there is a market for plant with outputs from lOOkW to 5MW. The potential for both build-own-operate and equipment sales in Europe and Asia is much greater than in Australia TREElectric may apply for a license to generate electricity in the UK under the NFFO scheme. This scheme offers 20cents a kWh to power generators using non-fossil fuels such as fuelwood grown by farmers.

There is possibly a market for 10,000MW of installed capacity over the next 10 years in Europe and 1,000 MSW installed electrical capaicty in the UK. Key markets in the Asia region include China, Indonesia, Thailand and the Philippines.

6.2.4 Cogeneration from MSW

6.2.4.1. Site Energy Demand

The City of Heidelberg, currently an electricity distribution authority, shortly to become part of Electricity Services Victoria, is planning a project to cogenerate power from wastes at it MSW transfer station. The transfer station is across Waterdale Road from the Heidelberg Repatriation Hospital in Melbourne.

Steam and electricity are required at the Repatriation Hospital twenty four hours a day and seven days a week; 8 tonnes an hour of steam are needed on average throughout the year. The minimum power demand for the hospital is less than 980 KVA and the monthly peak demand is about 2800 KVA.

It is expected that this system will be able to absorb any power or energy produced at the waste-to-energy plant.

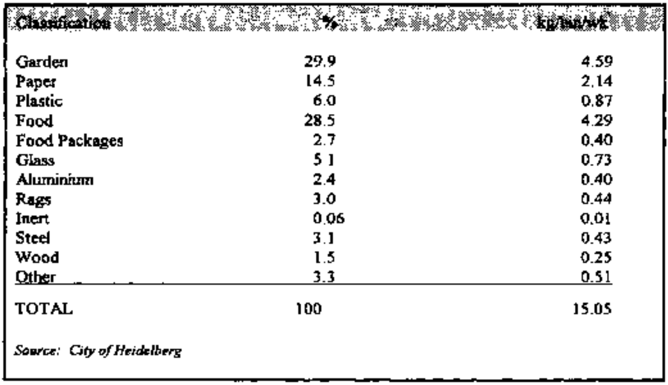
6.2.4.2. Biomass Resources Available

The composition of some of the domestic waste collected at the Heidelberg transfer station has been analysed by the City of Heidelberg. An analysis was performed in March 1992 showing the composition in Table 6.4.

This composition is representative of about one third of the present waste handled at the transfer station. No compositional analysis is available of the other two thirds of the waste stream.

The successful operation of a waste-to-energy plant relies on some selectivity in the feed material. If there were a large proportion of non-combustible material in the feed waste stream, it would reduce calorific value, increase ash quantity and possibly reduce ash quality.

Table 6.4 : Typical Municipal Domestic Waste Composition for Heidelberg



Classification	%	kg/hh/wk
Garden	29.9	4.59
Paper	14.5	2,14
Plastic	6.0	0.87
Food	28.5	4.29
Food Packages	2.7	0.40
Glass	5.1	0.73
Aluminium	2.4	0.40
Rags	3.0	0.44
Inert	0.06	0.01
Steel	3.1	0.43
Wood	1.5	0.25
Other	3.3	0.51
TOTAL	100	15.05

Source: City of Heidelberg

The domestic waste feed to operate the waste-to-energy plant is supplied throughout the year on a five day a week basis, though self-hauled domestic waste can arrive seven days a week. The total waste received is estimated to be 40,000 tonnes a year.

For preliminary design purposes the full 40,000 tonnes of municipal waste was assumed to have a calorific value of about 8.5GJ a year. This assumption would need to be investigated in detail before making any decision to proceed with the design of a plant. The process will require selective feeding of wastes and possibly some preprocessing of the waste prior to combustion. More than 40,000 tonnes of waste may therefore be required.

6.2.4.3 Conversion Technologies

Three main types of waste-to-energy technology are used for this application. They are:

- moving grate;
- fluidised bed; and
- gasification plants.

Moving grate incinerators have found their major application in the incineration of domestic refuse. In this process, the refuse is predried before combustion. The waste is mixed by tumbling down the moving grate in both the drying zone and the combustion zone.

The fluidised bed incinerator consists of a refractory lined vessel with a bed of granular material which is fluidised by pumping preheated air through diffusers in the base of the vessel. A major advantage of this incinerator type is the efficiency of the system. The large quantities of heat stored in the bed enable shock loads of waste to be tolerated without significant alteration to the incineration temperature. In addition, acid gas emissions can be controlled by careful selection of a basic bed material (such as dolomite). The system has been applied to the incineration of municipal refuse sewage sludge, industrial waste and has been applied in thermal power stations.

The gasification process is still under development.

6.2.4.4. Economics

The budget capital costs received from the various candidate plant manufacturers of the mechanical and electrical plant and equipment and civil and building works varied from about $12 million to over $60 million depending on the manufacturer, the emission standards achieved and the equipment used. The lower end of this range did provide a plant capable of meeting the German emission standards which are the only ones in place for MSW systems. The plant would include an electricity generating plant and a steam generating plant. However it would only involve a single incineration line, thereby increasing the risk of interruption to waste services. A dual line to reduce that risk could increase capital costs substantially; the estimates discussed below are on the basis of a single line.

The annual operating and maintenance costs of a plant capable of meeting the German emission standard would be about A$2.1 million.

The budget estimates of saleable steam from the candidate plants varied from 8 tonnes an hour to 15 tonnes an hour. The latter figure was without electricity generation capability and the former with some electricity generating capability.

An alternative technology to the waste-to-energy plant, would be 3 x 3 MW natural gas fired boilers. These boilers would produce about 8 tonnes an hour of steam on average (about 5MW demand). The total cost of steam might be about $20 a tonne.

The optimal waste-to-energy plant sizing for Heidelberg is a complex issue. The Repatriation Hospital currently purchases substantial amounts of energy with a base demand around 980 kVA. Given the disparity between the cost of purchasing electricity (14cents a kWh was used in the Maunsell study) and the buyback rates offered by Heidelberg Electricity (about 5cents a KWh), it appears that the optimal size for the waste-to-energy plant is for steam to the hospital, plus electricity generation to supply the hospital and waste station (about lOkVA), with no export of electricity to the distribution grid.

A number of financial outcomes were tested, depending upon alternative pricing policies adopted. The results of the economic evaluation indicate that the viability of this project is very sensitive to real increases in charges for waste disposal, the value of steam sold and the return on investment required by the plant operator.

Heidelberg Council has indicated that an 8% return on equiry and an analysis based on 2% above CPI inflation for burning fees is their preferred base case.

Sensitivity tests were run on that base case assuming steam is sold at $20 a tonne. This base case indicates a burning fee in 1994 dollars of about $46 a tonne of waste. The current operating costs of the Recycling and Waste station are $47 a tonne of waste without capital redemption or depreciation.

If capital redemption was excluded from the waste-to-energy plant, the burning fee would drop from $46 to about $23 a tonne.

A waste disposal charge can be set as low as $23 a tonne if Council sells the steam for $30, expects an 8% return on the capital invested and escalates the waste disposal price at 4% above CPI.

This compares favourably with existing prices of $47 for waste disposal and $31 for steam.

It is expected that the price for waste disposal will rise rapidly over future years because environmental standards will become more stringent and the locations more distant. Landfill charges for Heidelberg City were $26.0 a tonne in 1993, increasing in about 6% pa.

Federal, State and Local Government waste minimisation targets have been set and ratified in principle. Some of these targets indicate a 50% reduction in landfilled waste by the year 2000 relative to 1990 performance. Landfill costs have a substantial fixed cost component, so the unit charge for landfilling will tend to increase as throughput diminishes.

An examination of transportation costs indicates these costs have been remarkably steady in real terms for the period 1982 to 1993. The future forecast for transportation costs is therefore for no real increase above CPI. However, due allowance should be made for increased distances associated with the new Wollert site. It is expected that transport will increase by about $2.40 a tonne when the move to the new site occurs.

6.2.4.5. Environment

Germany is the only country that has implemented standards for emissions from waste to energy plants. The only plants offered that would apparently achieve the German emission standard were the Von Roll plant and the single line proposal received from ANI-Ebara. The other plants could probably achieve that standard with the addition of further equipment at extra cost.

The air pollution control devices treat the gases from the combustion chamber prior to their release to the atmosphere via the stack. Their primary purpose is to remove certain products of the combustion process, particularly acid gases, fine ash and non-combustible contaminants. The air pollution equipment required will vary depending upon the quality of combustion in the furnace.

Until recently, waste-to-energy plants were generally not provided with acid gas scrubbers. (For instance, the Waterloo Process Plant in Sydney). New and existing facilities in the north-east of the USA and California are now being provided with scrubbers, and acid rain problems in Western Europe could lead to their general application there also. Some waste-to-energy plant manufacturers are offering NO_x removal by way of catalytic converters.

Municipal solid waste (MSW) from domestic sources is available year-round from the Heidelberg Transfer Station. Comprehensive waste sorting is required to remove components not suitable for combustion.

The environmental impact of the combustion plants will depend upon the level of waste stream sorting prior to combustion. The waste by-products of the combustion technology include, highly toxic organic compounds such as dioxins and furans, together with heavy metals in fine ash, and hydrochloric and sulphuric acids.

Strict environmental legislation for air emissions will require extensive air pollution control devices. The ash waste is normally disposed of in landfill sites. The combustion plant will need to be located in a zone which has a buffer of 500 m to any residential areas. The town planning requirements for the establishment of a MSW combustion plant will necessitate their location in existing industrial areas or on the periphery of urban areas, and this could limit their ability to economically provide cogeneration to proximal facilities such as the Heidelberg Hospital in this case study.

There are significant environmental problems in planning for landfill sites in close proximity to many urban areas in Australia. The recycling of MSW will reduce the area required for landfill sites. In addition since the major portion of MSW comprises of organic wastes including garden wastes, food wastes and paper wastes it is a major source of the biogas produced in landfills and leaked to the atmosphere. Consequently the combustion of the MSW will significant reduce the production of biogas in landfills. The reduction in leaking biogas and in particular CH4 is significant in reducing greenhouse gas emissions since a volume of CH4 emissions has a much greater impact than the same volume of CO2.

There are also significant environmental benefits outlined in the case study with respect to the replacement of coal fired steam with steam produced from the cogeneration combustion of MSW at the Heidelberg Hospital. These benefits include a reduction of vehicle movements to supply coal briquettes and to dispose of the waste and ash together with the obvious reduction in CO2 emissions with displacement of the coal briquette fuel by the cogeneration steam. The case study estimates a net reduction in CO2 emissions of 55, 000 tonnes a year or 45% of the present emissions from the present steam generation at the hospital. The net greenhouse gas savings are further enhanced if the quantity of CH4 emissions from the potential disposal of the waste to landfills is accounted for.

The exact benefit of cogeneration from the combustion of MSW across Australia is difficult to estimate, with the cogeneration potential restricted by location controls to urban fringes or large industrial areas. The benefits obtained from a reduction in vehicle movements transporting the MSW will be reduced as distances will be similar to the present distances to landfill sites.

6.2.4.6 Summary and Conclusions

Several proprietary plants are available that can technically achieve the combustion of mixed municipal waste and convert it to suitable forms of energy and with demonstrated environmental capability.

Generation and sale of steam is likely to be more economic than generation of electricity.

More detailed investigations to confirm the assumption used in this study on the quantity and characteristics of the waste feedstock, and in particular the calorific value of the waste are needed.

The capital cost would be of the order of A$12m for a single line plant. The operating and maintenance costs would be about A$2.1m and a revenue of between A$1.2m and A$1.8m should be achievable from energy products depending on the price of steam. A burning fee would also be chargeable and at present that fee should be set to compete or to be equal with landfill charges. At present waste transfer and landfill charges the burning fee would generate about $1.4m a year. Thus together the energy revenue and burning fee revenue would cover the operating and maintenance costs for the waste-to-energy plant but not the capital cost.

However, based on past experience, landfill charges may rise in real terms, if:

- landfill locations become more distant;
- transport charges increase at greater than CPI; and
- environmental requirements for landfills become more stringent.

This apparent differential between expected costs for waste transfer and landfilling, and waste-to-energy based burning fees or gate fees for acceptance of waste is the key to successfully servicing the capital costs of the plant.

Gate fees of $50 a tonne are viable and increasing these at *2%* a year is considered sustainable by Heidelberg. This, with revenue from steam at $20-$25 a tonne will provide a ROI of about 9%. Reducing gate fees to $40.25 a tonne will allow the project to break even.

There could be negative cashflows in the early years of operation, with potentially positive cashflows in the latter years of operations. This situation also occurs with conventional power stations and is an issue for "bankability", covering contracts and financing available and returns required.

Environmental approval will depend largely on the requirements of the Victorian Environment Protection Authority, which are still under development, as this is a new type of project in their jurisdiction. Their requirements might be centred on:

- adoption of suitable air quality levels equivalent to the 1990 German Standards, which are the yardstick for international best practice;

- modelling of stack discharge plumes taking into account the local topography and meteorology; and

- adoption of suitable buffer distances from residential areas, conjointly based upon the air quality standards and discharge plumes described above. This is a substantial hurdle to overcome, as residential areas are situated well within the normal buffer distance. However, these distance were not specifically established for a waste-to-energy facility and would be subject to review. The low emission levels achievable at such a plant, stack heights, exhaust plume characteristics and a suitable outcome to a risk analysis could result in reduction of the buffer distances.

6.3 ELECTRICITY FROM ANAEROBIC DIGESTION

The anaerobic digestion process is proving a viable and environmentally acceptable way of disposing of a range of organic wastes produced across a variety of sectors, including agriculture, industry and domestic and commercial municipal wastes.

The anaerobic co-digestion of animal manures, the organic portion of household waste, sewerage sludges, abattoir and other wastes such as dilute wastes from the food processing industry has proven to be not only feasible, but enhanced by a carefully managed synergy which improves the biological activity and the reliability of the operation.

The correct processing of wastes will result in the production of biogas, generally a rich mixture of methane (60-70%) and carbon dioxide. The gas can be used to provide heat directly by combustion or heat and power through cogeneration plant. A by product of the process is a stable, nutrient rich humus organic fertiliser.

Three case studies will be examined in this section, two involving the construction and operation of a regional biogas facility producing heat and power from a mix of wastes, including animal, food industry, and municipal sold wastes. The third example will be a case study using waste water from the wine industry, originally examined for its potential for ethanol production and rejected because of the dilute sugar content.

6.3.1 Cogeneration at a Centralised MSW Biogas Plant

A large number of small and medium size industries dealing with food processing have located in Pakenham, near Melbourne, over the last few years in response to increased foodstuff production in the nearby Gippsland area. In addition, a large number of poultry farms have been developed in the region.

According to the local authority predictions, the number of houses in the Pakenham area alone is expected to grow from 3,000 presently to 25,000 by the year 2001 and by then the population living in the area is expected to be in excess of 250,000. This rate of growth is likely to cause an impact on the local environment and requires a carefully studied plan for the disposal of the waste generated in the area.

The growth will also require a large amount of energy in the form of power and heat, particularly for expanding industries.

Agricultural enterprises located in surrounding rural areas, in particular the rapidly expanding intensive horticultural and floricultural enterprises, will require an increasing amount of fertiliser, particularly of the organic type, to maintain and even improve the fertility of the local light sandy soils.

If established conventional waste management procedures are followed, sewage will be diverted to a treatment plant, where the wastewater will be stripped from the waste component and then discharged, while the waste solids will be neutralised with little attempt to recover nutrients and organic compounds which are valuable to the soil.

In most of the cases, treated wastes from sewerage treatment plants finish in landfills along with Municipal Solid Wastes (MSW), wastes from food processing plants, manures and vegetable wastes.

The organic component of these wastes or biowastes contains metabolizable energy and nutrients which originally came from the soil and should return to the land in a suitable form to restore fertility.

Environmental concerns require more complex systems for the treatment and disposal of wastes, and these systems generally require more energy to operate and higher construction costs. For example new standards for sewerage treatment now require that nutrients are stripped from effluent waters before these waters are discharged into public water bodies; new landfills must be prepared in a manner which eliminates the risk of groundwater contamination from the leached fluids. This regulation, when enforced, will particularly affect the establishment and running costs of landfill sites in the region which is the subject of this case study, because of the sandy nature of the area.

The cost of disposal of a tonne of waste may increase from the present $16.80 (Shire of Cranbourne data), to the $40 experienced in other parts of Melbourne.

To meet environmental requirements a management system which involves the treatment of biowastes and the recycling of energy and fertilisers could be implemented.

This involves the development of a biogas generator plant using anaerobic digestion technology, placed in a strategic position to reduce the biomass transport costs into the plant and to efficiently utilise the by-products generated. The implementation and use of this type of waste management system is becoming increasingly popular in Europe and Asia.

The anaerobic co-digestion of animal manures, the organic portion of household waste, sewerage sludges, abattoir and other wastes such as from the food processing industry has proven to be not only feasible, but enhanced by a carefully managed synergy which improves the biological activity and the reliability of operation.

In established areas, it is difficult to set up a source-separation of organic and non-putrescible household waste. When this operation has to be carried out in a purpose built transfer station it can become very expensive.

The primary treatment of sewage wastewaters in existing plants is carried out mainly by using physical processes and the solid and nutrients removal efficiency from the wastewaters flow is very low.

This case study will evaluate processing the organic fraction of municipal solid wastes, sewage sludge, manures, food processing wastes produced in the Cranbourne-Pakenham region, on the outskirts of Melbourne.

6.3.1.1 Estimation of Biowaste Resource

The development of the biogas waste treatment facility is proposed in two phases.

In the initial phase the plant will be able to digest biowaste produced in the area until the year 1998 and the second for the years 2000-2005.

The population until 1998 is predicted to be around 150,000 and in excess of 250,000 after the year 2000.

It is assumed that the biowaste produced by the human inhabitants in the area will total 75 tonnes of dry solids a day for the first phase and 125 tonnes for the second phase.

It is estimated that other biowastes available in the area include effluent and refuse from four abattoirs; several food processing plants including butter and cheese dairies; a semi-cooked ready meals factory; and vegetable packaging facility. The daily waste volume will amount to 10 tonnes of dry matter a day in the first phase and 25 tonnes in the second stage of the development.

It is estimated also that the poultry population (layers and broilers) in the area is close to 300,000 and may grow to in excess of 500,000 head by the end of the century. It is estimated that the average daily production of manure available would be around 15 tonnes in 1988 and 25 tonnes in 2000.

6.3.1.2 The Biogas Process

The biowaste is collected, pulped, and mixed into a sludge containing about 5% of solids. It needs to be anaerobically digested in a contact type process in which the regulation of the biological process is planned to achieve the maximum gas yield and sludge fertiliser value and stabilisation.

The hydraulic retention time would be of 10 days and the solid retention time could be flexible, extending up to 40 days, by using a selective settling system which allows the recirculation only of the partially digested and undigested biomass, and "active" biological material.

The plant would be designed to contain construction and running costs, and to require a minimum process supervision.

6.3.1.3 Capital and Operating Costs

The capital cost of the regional biogas generator plant, including the cogeneration system is estimated to be around $9 million for the first phase, with an additional $2 million dollars for the expansion of the second phase.

6.3.1.4 Energy and Other By-products

i) Heat and power

In the first stage about 32,000 N m^3 a day of biogas are expected to be generated, rising to 56,000 m^3 a day on the second stage

The cogeneration plant will have a capacity in the first stage of:

- 44.69 MW of electric energy and
- 76.80 MW of thermal energy.

In the second stage the capacity of the cogeneration plant would be:

- 78.29 MW of electric energy and
- 134.50 MW of thermal power.

ii) Fertiliser

The plant will produce up to 1250 tonnes a day of digested, humus like sludge (10% solid) which could be used "as is", and applied at the rate of 40-50 tonnes a hectare for intensive cropping, parks or green fields.

It could also be dewatered to a consistency of 35-40 % of solids and either mixed with other hygroscopic by-products from industry, for example fibre shorts from the paper manufacturing industry or brown coal powder, and bagged to be sold as garden fertiliser-soil conditioner or spread directly on the fields.

Considering the nature of the raw biowaste and its nutrient content, it is expected that the digested sludge, on a dry basis, will contains in N, P, K, about 3-4%, 2-3%, 0.8-1.0% and about 30-40% of organic matter, mainly lignin.

6.3.1.5 Economics

The Pakenham project was analysed in two phases, as described above.

In the first economic scenario, power buy-back rates of Scents (equivalent to a grid buy back rate) and lOcents a kwh (equivalent to the price if used internally or sold to a commercial project partner) were assumed, with the only other income to the project provided by the sale of steam.

In the first phase, the cogeneration system is designed to provide an electric power output of about 44.5MW a day into the grid during peak hours.

For a return of 15% ROI to be achieved, the steam must be sold at about $24.9 and $16.8 a GJ, which compares unfavourably to the industry norm price of $8 - $12 a GJ assumed throughout this study.

If the project receives an average by-product credit for waste disposal of $17 a tonne (incorporating a $20 tipping fee for MSW and industry waste, and $2 a tonne for animal waste) and the same two power prices are assumed as above, the steam must be sold for between $8 and $16 to achieve a ROI of 15%. The latter price for steam compares favourably to the industry norm price of $8 - $12 a GJ, and the project appears to be viable.

Additional project income to this scenario from the sale of fertiliser at $20 a tonne as produced (30 - 35% solids) allows the price of steam to drop to $zero a GJ to achieve a greater than 15% ROI, making a viable project for both sets of electricity price assumptions.

In the second phase, the cogeneration system is designed to provide an electric power output of about 78.2MW a day into the grid during peak hours.

For a return of 15% ROI to be achieved, the steam must be sold at about $14.5 and $6.4 a GJ at electricity prices of 5cents and 10 cents a kwh respectively, which indicates project viability in the 10 cents a kwh scenario only

Again, if the project receives a by-product credit for waste disposal of $20 a tonne, equivalent to the tipping fee, and the same two power prices assumed, both projects are viable, with steam available at $8 a GJ for the 5cent scenario and a very low cost of $0.4 a GJ for the 10 cent a kwh scenario.

Additional project income to this scenario from the sale of fertiliser at $20 a tonne (30 - 35% solids) allows the price of steam to drop to $zero a GJ, again making a viable project at a ROI much greater than 15% for both sets of electricity price assumptions in this scenario.

6.3.1.6 Environmental

The feedstocks include a mixture of the organic fraction of MSW, sewage sludge, animal manure and food processing wastes. The wastes are derived from a rapidly growing area with potential waste disposal problems and the need for large amounts of energy. Clearly the collection of these wastes to be recycled to energy and fertilisers will provide a significant local and regional environmental benefit by reducing the requirements for new landfill areas and large additional wastewater treatment plants, and minimising the discharge of nutrients to surface water and groundwater.

The mixed biowastes will be converted to energy and fertilisers using a biogas generator plant based on anaerobic digestion The environmental impacts are similar to those for Lietchville (see next case study).

The environmental implications are mainly benefits to the local and regional communities in the provision of a centralised waste treatment facility and the potential for the minimisation of water quality problems, landfill sites and organically contaminated groundwaters. However, whilst the generation of electricity for export has potential savings in greenhouse gas emissions, these small savings would not be significant at the national level. In addition, in areas such as the case study site grid electricity is readily available and would be difficult to displace.

6.3.1.7 Summary and Conclusions

The economic analysis has been undertaken for the construction and operation of a regional biogas waste treatment facility to process the putrescible portion of sorted municipal waste, industry wastes from the food processing industry and from intensive animal rearing facilities.

No plants operating on this type of feedstock mix exist in Australia, and those built elsewhere, particularly in Denmark and Germany have not operated viably because they have been based on existing plants, with the technologies adapted to accept the new mix of waste resources being processed.

The analysis assumed that it would be possible to be paid to process the mixed waste feedstock streams, receiving a tipping fee of $20 a tonne for taking the municipal and industry wastes and $2 a tonne for the animal wastes.

The analysis also assumed that the project would be able utilise 25% of the energy produced to operate the facility and to sell all the excess electricity produced either to the grid or to a nearby end user. Further it was assumed that the steam and fertiliser produced could be disposed of locally to industry and broad acre agriculture.

Issues raised in investigating the case study have indicated certain opportunities for establishing a new project of this type in a development in its early stages, such as exists in the Pakenham region.

The centralised plant should be built at a site to maximise the return from process by-products: in particular where there is a ready market for the hot water produced in a cogeneration system and for the digested sludge to be used as a fertiliser.

From an initial investigation it appears that the industrial area of Pakenham satisfies these criteria.

In this area there is a large food processing plant and an abattoir, both of which require large amounts of hot water for processing and cleaning purposes. Other industries which may require hot water include bakeries, tanneries, poultry processing plants and wool scouring plants, - some of which already exist in the area or are planned for the future.

In established areas it is difficult to set up a source-separation between organic and non-putrescible household waste. When this operation has to be carried out in purpose built transfer station it can become very expensive, unless the economics of the transfer station are based on the recovery and sale of reuse and recyclable components in the waste.

The primary treatment of sewage wastewaters in existing plants is carried out mainly by using physical processes and the solid and nutrient removal efficiency from the total wastewater stream is very low. By using, however, more appropriate physico-chemical processes, the removal efficiency can be significantly improved, providing larger volumes and a thicker sludge and effluent water containing less polluting components. This not only produces more recyclable biowaste, but considerably reduces the size and cost of the equipment required for "polishing" separated waters.

The Cranbourne-Pakenham area, provides an opportunity to develop an integrated infrastructure to support the development of new housing estates, services and industrial processing plants.

The new houses could, for example, be fitted with triturators installed in the kitchen sinks , so that organic wastes are pulverised and discharged into the sewer. The sewers would be designed to receive the mixture of pulped household wastes with other effluent. Incentives could be considered to encourage the disposal of organics via the triturator. The cost of MSW collection could be reduced proportionally and the sewage rates increased also proportionally.

The sewerage treatment complex could be built with a state of the art separation technology to ensure the solid and nutrient portion of the waste water are recovered in an efficient way and allowing the sanitized sludge to be treated in the regional biogas facility.

The first phase of the project was found to be viable only if power could be sold for lOcents a kwh and by-product credits are received for waste disposal at $17 a tonne and a minimum price is paid for steam of $6 a GJ. If disposal fees for waste treatment and the sale of steam and fertiliser (at $20 a tonne) are included, the project becomes viable at both 5cents and lOcent a kwh buyback rate.

The expanded Phase 2 project was viable in all scenarios except the one in which there is a power buy-back price of 5 cents a kwh and there are no waste disposal fees paid and no fertiliser sales. In this scenario, the economics is marginal, requiring a steam selling price of $14 a GJ.

6.3.2 Cogeneration from Regional Biowastes

6.3.2.1 Introduction

Intensive animal husbandry systems, despite their high level of efficiency, still utilize only a fraction of the potential metabolic energy and nutrients contained in the animal feed.

The unutilized portion passes into the manure, which, if not properly treated becomes a pollutant as well as being a wasted resource. They can be treated in anaerobic digestion facilities to produce energy.

Food processing plants also produce organic and biodegradable effluents which have a general tendency to ferment rapidly and release obnoxious odours. These effluents may also be treated by anaerobic biological methods with recovery of biogas. However the process often becomes deficient in nutrients, thus requiring the expensive dosing of additional nutrient materials, many of which are often found in large amounts in manures.

This case study examines a regional biogas waste treatment facility at Leitchville in Victoria.

Leitchville is situated on the Murray Valley Highway, in northern Victoria, between Gunbower and Cohuna.

A large cheese dairy factory producing cheddar is situated on the outskirts of the town. The factory also produces, as a by-product of the process, whey ad a waste water stream. The whey is, in part, utilised by a large number of piggeries for pig feed. The waste water is used to ? pasture, together with excess whey.

The piggeries have difficulties in considering expansion plans unless satisfactory waste management solutions are implemented. Conventional disposal techniques of spreading effluent containing high particulate matter on land requires substantial land areas and the pollution of water resources is aggravated by the high water table found in the area.

Leitchville and Gunbower do not have an established sewerage and wastewater treatment system. Houses in the area have septic tanks and the clarified waters are discharged into stormwater waterways.

A large number of dairy farms in the area produce milk for the cheese factory. The dairy farmers are under increasing pressure from various organisation to improve the management of the effluents produced in their dairy milking complexes, where cows are housed for an average of two hours a day.

6.3.2.2 Biomass Resources

It is estimated that a pig population of around 27,000 is present in a radius of 5 km from Leitchville, producing about 121.5 tonnes of manure a day.

The cost to the farmer for the disposal of the piggery's wastes is estimated to be around $4 a head a year. The nutrient recovery rate is negligible and it is estimated that up to 90% of the compounds are lost by leaching.

The same area also has 21 dairy farms, milking around 4,000 cows a day and the manure collected on the dairy sheds is estimated to be 18 tonnes a day. The same considerations and costs of disposal for piggery effluent may apply here too.

The cheese factory produces an average of about 11 kilolitres of a sludge concentrated at 5% of Suspended Solids.

The disposal of this sludge in landfills would cost around $15 a kilolitre

6.3.2.3 Anaerobic Digestion Plant

The scope of the case study here is the plant will be designed to recover and recycle the biowaste produced in the Leitchville area by using an anaerobic digestion for the production of biogas and a humus-like compound which may be used as organic fertilizer. The plant considered may be similar to the one developed for the Berrybank piggery farm in Victoria.

The plant will be able to process an existing biomass resource of around 18 tonnes of total solids, using the biogas produced to drive a cogeneration plant for the production of both electric and thermal energy.

6.3.2.4 Energy Products

i) Gas

The anaerobic process is expected to produce daily about 6,500 normal cubic metres of biogas daily in the first phase, containing around 70% of methane.

The biogas output would double at the second stage of the development.

About 25% of the biogas produced will be required to supply the energy - power and heat - to run the plant, and the balance will be available for export.

The biogas produced in the first phase may be utilised to run a cogeneration plant producing 9,720 kW of electric energy and about 18,000 kW of thermal energy daily.

ii) Biofertiliser

About 65 kilolitres of stabilised digested sludge will be extracted from the digester. This humus-like sludge may be dewatered to 30-35% solid consistency to produce a daily amount of around 22 tonnes of cake.

The sludge may be used in substitution or as a complement to conventional fertilizers.

From the Berrybank experience, an average amount of 20 kilolitres of digested sludge is able to produce a 4 tonne a hectare of wheat or oat grains and sustain a good pasture grass production.

This rate may be doubled in intensive farming conditions.

6.3.2.5 Capital and Operating Costs

The regional plant development is estimated to cost about $3 million for the first phase and an additional $1 million for the second phase.

The annual running costs are estimated conservatively at $0.2 million.

6.3.2.6 Economics

The first phase of a project to construct a regional project was analysed to assess the parameters under which it appeared viable.

The cogeneration system is designed to provide an electric power output of 9.7 MWh of electricity a day into the grid during peak hours.

Electric power buy-back rates of Scents (equivalent to a grid buy back rate) and lOcents a kwh (equivalent to the price if used internally or sold to a commercial project partner) were assumed.

It was assumed initially that only other income to the project was provided by the sale of steam. For a return of 15% ROI to be achieved in this scenario, the steam must be sold at about $49 and $41 a GJ, which compares unfavourably to the industry norm price of $8 - $12 a GJ assumed throughout this study.

The project was then evaluated receiving an average by-product credit for waste disposal of $3 a tonne, calculated by taking into account the cost to farmers of disposing of animal wastes and industry their effluent stream, and the same two power prices assumed above. In this case the steam must be sold at about $37 and $30 a GJ, which is still uneconomic.

Additional project income from the sale of fertiliser at $20 a tonne as produced (30 - 35% solids) allows the price of steam to drop to between $27 and $20 a GJ, which is still unacceptable.

For a return of 15% ROI to be achieved under a requirement that the steam to be sold at $8 a GJ, the fertiliser must be sold at between $40 and $65 a tonne. The fertiliser is claimed to contain nutrients valued at $90 a tonne, making the required returns on investment possible if this is correct.

6.3.2.7 Environment

The Leitchville region is located within the Murray Irrigation Area and is underlain by very shallow watertables and extensive land salinisation, together with severe nutrification and salinity of the major streams and drainage channels. The salinity problem is exacerbated by the irrigation practices and the major source of the waterway nutrification problem is the inappropriate effluent disposal techniques, runoff of nutrient rich water and leaching of nutrients into the shallow groundwater table from the pig and dairy farms.

The proposed collection and use/recycling of these biowastes would provide significant benefits for the improvement of the nutrient status of the waterways and shallow groundwater table.

The generation of biogas and its conversion to electricity/steam will substantially reduce CO2 and CH4 emissions from the decay of the biowaste. Wastewaters produced may require further treatment before being disposed of to either irrigation drains or to land as irrigation water. Careful siting of wastewater disposal and pondages will be required to avoid leaching to groundwater.

The major environmental implications of the conversion of biowastes to electricity are the benefits at the local and regional level, which include; amelioration of stream/drain nutrification, and loss of aquatic biota and nutrient leaching to shallow groundwater. It also provides a mechanism for the regional control of effluent waste from both industry and intensive dairying/piggery operations which are presently difficult to environmentally control. To maximise environmental benefits piping the waste to the conversion facility would be preferable to road transport.

At a national level there are large potential benefits to improve water quality and excessive leaching of nutrients to the groundwater table. Other environmental benefits include the reduction in CO2 and CH4 gas emissions from the decay of the solid fraction of the biowastes effluent, and the production of electricity for export to the regional grid. Whilst the scope for export may be small in areas close to large urban centres, it could be significant in inland regions. Life-cycle energy and greenhouse gas balances would need to include the environmental sustainability of the agricultural enterprises producing the wastes. However, a qualitative analysis would suggest that there is the potential for significant savings in energy and greenhouse gas production.

6.3.2.8 **Summary and Conclusions**

This case study has examined a project to construct the first phase of a regional biogas facility at Leitchville in Victoria. In the near term, feed material will consist of animal wastes and wastes from a local cheese factory.

Products from the facility include 9,720 kwh a day of electric power and 18,000 kwh of thermal energy from a cogeneration system burning 6500 normal cubic meters of biogas a day . Exported energy will amount to 75% of the total energy produced, 25% will be used by the biogas facility itself.

Assuming electric power buy-back rates of Scents (equivalent to a grid buy back rate) and lOcents a kwh (equivalent to the price if used internally or sold to a commercial project partner) and a required ROI of 15% on the project, the steam must be sold at between $8 and $12 a GJ and the fertiliser must be sold at between $70 and $85 a tonne to achieve a viable project. Fertiliser sales in this range are critical to project viability.

The nutrient value contained in a tonne of the fertiliser is calculated as worth $90. In addition, anecdotal evidence on the use and performance of the fertiliser in Australia to date and its unique humus characteristics would indicate that a price of $80 to $100 a tonne is achievable. This issue, however, remains unresolved in any formal manner, and considering the importance of this issue in the economics, and hence the development of a market for these systems, effort should be made to scientifically price the product.

6.3.3 Biogas from Wine Industry Wastes

6.3.3.1 Introduction

The wine industry in Australia processes about 500,000 tonnes a year of grapes. About 80% of the fresh grapes used are processed by the three largest wineries, two in SA and one in NSW.

Wastes account for about 10% of total input. Consisting mainly of marc (skins, seeds and excess pulp from fermentation) about 40 to 50% of this semi-solid sludge is discarded and the rest is collected and processed to recover any remaining ethanol and other useful chemical by-products The solid wastes remaining after this are used as fertiliser after 12 months of composting.

The industry also produces a wastewater stream from cleaning operations that carries with it roughly 0.5-1% of the grape input. As a result, Australian wineries produce a total of l,500million litres of waste water annually, with 4000-6000ppm BOD.

About 95% of the organics contained in the waste water has been shown to be degradable in anaerobic digestion systems.

The strong economic and environmental pressures to recycle water for re-use in the larger wineries, has resulted in some work in Australia to assess the technology required to make energy recovery and water recycling economic.

The total annual energy potential from the wine industry's waste water stream is 70,200GJ

This case study examines the potential for applying anaerobic digestion to winery effluent produced at the Smith and Son Yalumba winery at Angaston, South Australia.

6.3.3.2 Resources

The winery produces some 90 million litres of effluent a year. The weekly maximum can be as high as 4 million litres during the peak season. The waste water has a typical COD of 4,500mg a litre.

6.3.3.3 Technology

The winery has examined the costs of various technologies for the digestion of their wastes, including low rate systems such as IMCAL (Intermittently Mixed Cyclic Anaerobic Lagoon) and high rate systems such as UASB and the new HYBRACTOR technology developed by Environmental Solutions International (ESI) in Perth. ESI have recently commissioned a full scale HYBRACTOR plant at a brewery in Perth and is building one five times larger to treat meat industry wastewaters.

ESI and Smith & Son are presently carrying out trials to recover biogas from the waste stream using a pilot scale HYBRACTOR plant, with a view to economically treating the wastewater and eventually recycling 20-25% of the effluent water stream back to the plant.

6.3.3.4 Capital and Operating Cost

The winery has examined the costs of various technology options, ranging from $1.3 to $4.4 million capital investment and operating costs ranging from $0,085 to $0.182 million annually.

At an estimated $1.43 million the IMCAL process offers the slightly least cost option and the highest risk with associated with it, as it is as yet unproven in this application. The most expensive capital and operating cost is for a UASB plant.

ESI estimate a turn-key HYBRACTOR plant at Yalumba Winery will cost $1.5 - $1.8 million with operating costs of around $80,000 a year.

6.3.3.5 Energy yields

Anaerobic systems work best in the mesophilic temperature range (ie. 25-35°C) range.

Winery wastewater is generally cool as minimal hot water is used for cleaning and washing operations, consequently some of the biogas energy will be used for wastewater pre-heating prior to the anaerobic plant. To increase the winery wastewater to the low mesophilic range will require burning of approximately 40% of the produced biogas in a hot water generator.

The annual biogas production is estimated at 150,000m^3 annually, with an energy value of 26-30 MJ a m^3, or approximately 4,200 GJ a year in total. Of this 2,500 GJ a year will be available for "export" to the winery.

6.3.3.6 Energy use at the winery

The winery presently consumes about 15,500 GJ of electricity and about 8,000 GJ of natural gas. The biogas could therefore substitute for 30% of the natural gas consumed.

6.3.3.7 Economics

An analysis of the cost of biogas produced from the winery wastewater were carried out. In a scenario in which no by-product credits were included in the analysis, the biogas can be produced for under $178 a GJ, to provide a ROI in the project of 15%. This value of the energy produced is well above the price of energy supplied by natural gas, which is about $5.30 a GJ.

The energy price is extremely sensitive to the cost that could be incurred for waste disposal. If savings amount to $400,000, the cost of energy matches that of natural gas.

6.3.3.8 Environment

Winery effluents include a semi solid sludge of skins, seeds and excess pulp from fermentation, and an organic rich wastewater stream, which is the feedstock for the biogas plant. The recycling of the effluent stream will ameliorate the high BOD nutrient input to local streams and minimise the odour problems associated with their disposal. Wineries require irrigation, considerable soil tillage and annual fertilisation with nitrogen, phosphorous and potassium together with foliar sprays.

Chemicals are also applied for pre-planting pest and weed control, with 10 herbicide chemicals applied, together with several fungicides. Chemicals in runoff from vineyards degrade water quality and aquatic ecosystems.

The winery waste is converted to biogas using an IMCAL anaerobic digester. The biogas would provide environmental benefits by displacing up to 25% of the current usage of natural gas in the winery. Application of cogeneration of electricity and/or steam has the potential to significantly expand these benefits in displacing fossil fuel use.

6.3.3.9 Summary

An initial evaluation of the project to produce biogas from winery wastes at a major winemaker appears to be very attractive economically, provided the costs of the newly developed ICAL system are proven to be realistic in the upscaling of the pilot plant presently being tested on site at Yalumba in South Australia, and savings can be made in waste disposal or water purchasing totalling about $400,000 a year.

Most of the 15 to 20 larger wineries in Australia would appear to have waste streams that might be economical for treatment in anaerobic digestors. The Yalumba winery is about the 12th largest, crushing about 13,000 tonnes of grape. The largest, Southcorp wines, crushes about 162,000 tonnes annually.

Successful commercial application of the technology could enable the development of the market in Australia and overseas for the technology in the winemaking and other food industry applications, allowing reduced manufacturing costs through water recycling and cleaner production through effective waste treatment.

6.4 ETHANOL FROM LIGNOCELLULOSE

6.4.1 Ethanol from Agroforestry and Crop Residues

Large areas of Australia are experiencing environmental degradation as a result of intensive dryland and irrigated annual crop production.

Particularly affected are the dryland regions in Western and South Eastern Australia growing cereal crops, where the onset of salinity and erosion are affecting the viability of productive land use.

The majority of land under irrigation and adjacent dryland regions across Australia are also affected by land degradation and salinisation due to annual cropping cycles. Irrigation practices and large scale vegetation removal have resulted in shallow water tables close to the surface, often between 1 and 2 m deep in the root zone of vegetation. With increasing soil and sub-surface water salinities, vegetation cover has decreased due to salt stress and agricultural productivity of the irrigation areas has also significantly decreased.

Proposals have been put forward to use agroforestry, the commercial use of trees as an integral part of agriculture, to provide the perennial crop component required to rehabilitate degraded land. Other solutions include the replanting of native vegetation, including trees, grasses and shrubs on salt damaged soils to address the salinity problem. The retention of organic matter on the soil to address erosion problems is also becoming imperative practice.

Trees are also being examined as a potential sink for greenhouse gases.

For soils that are still productive, it is suggested that between 10 and 15% of land area be allocated to a mix of highly productive low and tall tree planting to act as water pumps, as well as to provide wind breaks and shelter belts.

Work has been undertaken in some states to assess the viability of various tree crop species suitable for agroforestry and to identify opportunities for the biomass produced in the wood, pulp and paper and essential oil and energy industries. Short and long rotation systems are being studied, depending on potential end-use markets.

The acceptance of agroforestry as a means to effect land rehabilitation, improve agricultural efficiency and diversify farm returns has been slow. Whilst education remains a major factor in addressing this, the agricultural community needs to be convinced that the practice of agroforestry is viable and cost effective and that there is a viable and sustainable market for agroforestry derived lignocellulosic products.

The case study developed here will examine the potential use of lignocellulose from dryland agroforestry, cereal production and saline land rehabilitation for ethanol production.

The area selected as the case study example uses the wheat growing region of Esperance in Western Australia. The results of the case study, can in general, be translated to other dryland and irrigated areas of Australia.

The total biomass available from cereal farming, agroforestry and land rehabilitation at Esperance is equivalent to the production of over 275 million litres a year at this site alone. About 30% or some 82.5 million litres could result from biomass grown for environmental and land rehabilitation purposes in the future.

It is estimated that there are between 12 and 20 equivalent dryland sites in Western Australia alone at which the system can be replicated, and many more than this around Australia itself.

The town of Esperance lies on the south coast of Western Australia, about 600 km from Perth. Whilst only a relatively small town (population approximately 8,500) it is the main port of supply of goods and liquid transport fuels to the Esperance agricultural district and to the hinterland mining towns of Kalgoorlie and Coolgardie.

Some 143,000 tonnes of diesel fuel are transported through Esperance to these mining towns annually. Diesel fuel retails at about 74.5 cents in Esperance and 77.9 cents in Kalgoorlie. Perth prices for diesel are 68 cents a litre.

A 20% blend of diesel fuel with ethanol would create a demand for close to 30 million litres a year of the alcohol in the region.

The Esperance region covers a total area of 2.8 million ha in an almost rectangular form approximately 80 km north/south and 320 km east/west. Of this total area, 360,000 ha of land is cultivated under dryland crops and pasture, of which 304,000 ha is used to grow cereals, totalling some 477,200 tonnes in 1992/93. Production intensity is highest in the regions surrounding the town of Esperance, well within a 60-80 km radius of the town itself.

Present practices either burn the cereal residues produced or leave it in the field for sheep to graze or to reduce soil erosion.

The practice of clearing the land of native vegetation and trees and the practice of intensive agriculture over the last 25 years have resulted in significant land degradation.

Land presently affected by salinity in the region totals some 21,200 ha, over 5% of the total area under crops and pasture. The rate at which land is becoming saline is so rapid that it is expected to reach between 20% and 30% of all farmland in the region over the next 15 to 20 years, providing a strong incentive to undertake landcare programs with treecrops.

6.4.1.1 Resource Production Scenario

Biomass costs were calculated to provide prices on a return to farmers of 0% and 5% on costs, and the prices reported below are fully costed at these returns. The assumptions made regarding potential biomass mix for the Esperance region are that:

- Farmers will continue to grow cereal crops on prime land and make available 580,000 (10% moisture) tonnes a year of residues (stalks) for energy production, leaving sufficient straw for 50% ground cover on the land to provide organic matter and protection from erosion. Delivered cost of this residue is $40-55 a tonne (dry wt).

- There will be active participation by farmers in future programs to retard or reduce salinity. These include the planting on an area equivalent to 10% of prime land of:

  low growing Mallee eucalypt species in linear belts as hedges across the land in "alley farming" mode to cover say, 7.5% of prime farmed land. This will make available 135,000 dry tonnes a year of woody biomass, at a cost of between $44 and $59 a tonne (green);

  high growth, taller tree species to provide windbreaks and shelter on 2.5% of prime farm land, making available 720,000 tonnes (green) of biomass residue 10 years after planting at a cost of $18 a tonne (green). The Prime market for wood from these trees is assumed to provide pulp or hardwood and the residue price is based on return of harvestry and delivery costs only.

- Active rehabilitation of the land already designated saline in the area will occur in the future by planting perennial saltbush and salt tolerant grasses to combat salinity and provide biomass for energy production. Total biomass production is estimated as between 16,000 and 24,000 tonnes a year (green) at a cost of between $23 and $30 a green tonne.

6.4.1.2 The Ethanol Production Facility

The technology choses to implement in the case study is the state of the art enzyme, simultaneous saccharification and fermentation (SSF) process being developed by National Renewable Energy Laboratory (NREL) in the US. The first fully integrated demonstration plant under construction in the US.

The plant capacity chosen was 50 million litres a year of fuel grade ethanol, requiring 146,520 dry tonnes a year of biomass feedstock. The ethanol yield on the present state of development of technology is 341 litres a tonne of dry biomass. By-product lignin is used as boiler fuel, and together with biogas from an integrated waste treatment facility, used to produce steam and electricity for internal use in the plant. Excess power is exported to the grid..

The capital cost of 50 million litre a year plant is $109 million, including utilities, tankage and waste treatment facilities. The operating costs were estimated at about $9 million.

6.4.1.3 Anticipated Improvements Over the Next 5 Years Affecting Cost

If low-growing eucalypts are harvested for oil production in the expected development of a eucalyptus oil industry at Esperance the spent wood/residue from this industry could be available for as little as $10 a tonne (green), reflecting only transport costs.

With regard to other improvements in biomass production, harvesting and transport, little is known in Australia about these for the forms of biomass considered here, so they has not been taken into account in this analysis. However, work in the US is aiming for dedicated biomass resource costs of US$34-55 by the end of the decade, and this cost range was included in the scenarios considerations undertaken here.

NREL anticipate significant process improvements to their process by the end of this decade. These include improving SSF yields, improving xylose to ethanol yield and decrease fermentation times It is expected that the total capital investment is reduced to at least $95.6 million with these improvements.

The effect of plant capacity was also considered in the analysis undertaken.

Adequate resources are available in the scenarios developed to construct and operate a 120 million litres a year facility at Esperance. The plant capital cost for a this capacity is estimated as $171 million, including the projected process improvements. The operating costs for a plant of this capacity are $16.9 million a year.

The lignin produced in the plant totals some 76,000 tonnes a year, and will again be used as a fuel to provide energy.

6.4.1.4. Economics

The results of the economic analysis of a 50 million litres a year plant required to produce 15% ROI are summarised below

The early years in the project are assessed using the present state of development of the conversion technology developed by the National Renewable Energy Laboratory (NREL) in the US. The biomass mix in the early years is heavily reliant on cereal residues and agroforestry products, excluding low cost residues from shade trees

Assuming full costs, the delivered cost of biomass is $60 a tonne (dry) and ethanol can be produced for about 91c a litre.

If future improvements were to reduce capital costs by 20%, the ethanol price would be 81 cents a litre. If operating costs under went the same reduction, it would be 86 cents a litre.

Assuming that the delivered cost of woody biomass from agroforestry is based only on the harvesting and delivery costs, with the establishment and maintenance costs of biomass production recovered by the agricultural and environmental benefits, ethanol can be produced at around 85 cents a litre with a feedstock mix at an average delivered cost of about $41 a dry tonne.

If biomass from low trees is delivered as a residue from eucalyptus oil production in this scenario, the price of ethanol remains unaffected.

In the later years of the project it is assumed that the anticipated improvements in NREL technology and yields have taken place. The ethanol price reduces to about 85 cents a litre assuming the biomass is fully costed at $60 a tonne (dry) and that cereal residues still play a significant role in the biomass mix.

If capital costs were 20% less than assumed here, the ethanol price would be lowered to 66 cents a litre and if operating costs were reduced the same amount, the price would be 69 cents a litre

If the feedstock mix is optimized to include the lowest cost biomass mix at $42 a dry tonne fully costed (wood from low trees and residues from harvesting of shelter trees for pulpwood or sawlogs), the ethanol price is 72c a litre. If it is possible to include the biomass from low trees as residue from a eucalyptus oil processing facility at $20 a dry tonne, the average biomass cost is reduced to $26 a dry tonne and the ethanol price drops to 67 cents.

Scenarios were also run to determine the conditions that would produce ethanol at 20c a litre assuming no by-product. This could be achieved on a 50 million litre a year plant, using the improved process, by either:

(i) Providing a subsidy of about $29.4 million a year, equivalent to 58c a litre on a 15% ROI and $21.8 million a year (40c a litre) for a plant requiring an 8% ROI with fully costed biomass at $60 a dry tonne; or

(ii) Providing a subsidy of $24.05 million a year, or 48 cents a litre for a 15% ROI and $15.77 million a year (32 cents a litre) for a 8% ROI, utilizing biomass residues at $26 a dry tonne; or

(iii) Achieving a by-product lignin recovery price of $912 a dry tonne, with fully costed biomass feed at $60 a tonne.

If the ethanol is exempt from Federal excise and produced on a 50 million litre a year plant, as would be the case under existing legislation, the price with which to compare ethanol becomes 50c a litre, as excise is about 30c a litre of petrol.

The subsidy in this scenario assuming fully costed biomass amounts to $15.8 million annually, equivalent to 32c a litre of ethanol produced in a plant returning 15% ROI, and $7.2 million for the 8% ROI case, resulting in a necessary subsidy of only 14 cents a litre.

If biomass residues are utilized at $26 a dry tonne in this scenario, the subsidies required are $10.51 million (21 cents a litre) at 15% ROI and $1.9 million (3.8 cents a litre) at 8%ROI.

The plant was upscaled to about 120 million litres a year using the improved NREL process to test ethanol price sensitivities relative to plant capacity. At this capacity, using a fully costed feedstock mix ($75 dry tonne), the price of ethanol drops to about 60 cents a litre. If future improvements were to reduce capital costs by 20%, the ethanol price would be 66 cents a litre. If operating costs under went the same reduction, it would be 69 cents a litre.

With residue available from eucalyptus processing, the biomass cost drops to \$33 a dry tonne, and the ethanol price to 60 cents a litre. If the biomass feed is further reduced to \$26 a tonne the price of ethanol become 58 cents a litre.

Economic analyses were carried out to assess the effect of marketing by products, for example lignin, on the production price of ethanol. A by product credit of \$570 a tonne is required to reduce the ethanol price to 20cents a litre.

The ethanol price was also tested in a scenario of fully costed biomass supply at the larger ethanol capacity. At an average resource cost of \$81 a tonne and a by-product credit for lignin of just under \$800, ethanol can be produced for 20cents a litre.

There are at present no known by-products that can achieve these income streams.

6.4.1.5 Environmental

Lignocellulose will be derived from a mixture of residual wheat straws, wood waste from coppiced low growing eucalypts, wood wastes from groundwood harvesting of shelter belts, salt bush and perennial grass harvesting.

It is assumed that environmentally sustainable agricultural and silvicultural practices are employed to minimise chemical applications, water use and soil tillage and erosion. Approximately 1-1.5 tonnes a ha of wheat straws or an amount equivalent to provide a 50% surface cover are required to protect the soils from erosion and to be mulched for soil nutrients. If these practices are employed then the collection of residual wheat straws for bioenergy use is considered environmentally sustainable.

Saltbush and perennial pastures are planted in the region to rehabilitate salinised catchments by either forming a vegetative cover and by acting as groundwater pumps or to minimise groundwater recharge. The perennial pastures would provide a sustainable biomass resource since they are vigorous growing plants and can be repeatedly harvested without damaging their extensive rootstock. Regular harvesting of perennial pastures ensures their capability to pump groundwater to the surface for loss by transpiration.

In contrast a significant portion of the saltbush ground cover must be maintained to continue the land rehabilitation and groundwater control measures for which the saltbush has been established. Coppiced harvesting of saltbush would enable the retention of rootstock without disturbing the surface soil structure. Such harvesting would need to be planned to avoid exposing the soil surface to high risk of water and wind erosion.

The proposed conversion technology is the NREL fermentation process plant. The most significant output from the fermentation of ethanol from lignocellulose is the lignin in the waste stream.

However the pilot plant described in the case study uses the lignin and other organic waste as boiler fuel to provide cogeneration of steam and electricity which alleviates the environmental impact of lignin disposal. However the waste water stream from the distillation process is estimated at 8,000 m3 a day with an extremely high BOD of 20,000 mg/1 and includes high strength organics such as phenols. The process wastewater is treated by anaerobic digestion followed by aerobic treatment before discharge to a receiving water body. Other solid outputs such as gypsum and boiler ash is disposed to landfill. Air emission control devices will recover ethanol and other volatile organic compounds.

The International Energy Agency (1993) have estimated that for fuel ethanol from wheat using straw in a facility using straw cogeneration for power would use approximately 21% of gasoline primary energy use and produce 18% of gasoline life cycle CO2 emissions and 26% of gasoline life cycle total greenhouse gas emissions. This case study would provide those benefits.

It is important to note that the greenhouse gas emissions from the ethanol combustion process in vehicles are similar to those for gasoline combustion but is carbon neutral if the equivalent type and quantity of biomass is regrown to sequester the carbon which is eventually released through fermentation and combustion.

Whilst a significant net reduction in national life cycle greenhouse gas emissions could be achieved by the large scale production and use of ethanol local environmental problems associated with the siting of ethanol plants and the treatment and disposal of wastewater need to be assessed in detail once the composition and characteristics of the wastewater and the required wastewater treatment processes are known.

However, during the next decade industrial wastewater discharge to water bodies is being progressively eliminated by EPA regulations in favour of land disposal for irrigation. It is unclear whether NREL wastewater would be suitable for land disposal without further treatment.

The use of ethanol as a transport fuel would generally result in lower particulates, CO and SOx vehicle emissions whilst emissions of NOx and volatile organic compounds (VOCs) which play a major role in the production of ozone and the formation of photochemical smog are likely to be similar or increased in the case of evaporative VOC emissions to those from gasoline/diesel vehicles. High level ethanol fuel blends are likely to have a greater effect on trophospheric ozone levels than gasoline.

Similarly aldehyde emissions from ethanol/gasoline blended fuel powered vehicles are thought to be similar in quantity to those from gasoline powered vehicles, and the aldehyde emissions increase with higher alcohol blends. A number of health and safety issues occur with the use of ethanol which stem from aldehyde emissions, alcohol vapours and direct contact with alcohol and the potential for fires. Increased production and widespread use of ethanol as a fuel could provide a greatly increased risk of environmental contamination from fuel spillage and toxicological problems from the increased risk of human contact as a result of spillage, inhalation of unburnt fuel and evaporative emissions.

6.4.1.6 Summary and Conclusions

The technology chosen for the case study developed by the National Renewable Energy Laboratory (NREL) in the US is considered state-of-the-art, and is still in a state of development. According to Davy John Brown who provided the cost estimates, contingencies were included that reflect the stage of development of the process and the capital cost estimates are therefore likely to be conservative. The capital and operating costs need to be verified on the first pilot scale facility presently being constructed in the US.

A plant with a capacity of 50 million litres produces ethanol at between 67c and 85c a litre, based on the expected improvements to the NREL technology, and without by-product credits.

At 120 million litres, costs are between 58c and 72c litre without any by-product credits. These are summarised in Table 6.5.

The sensitivity of the price of ethanol to 20%, reductions in capital and operating costs resulted in a decrease in the price of 11% and 3% respectively for the smaller plant and 5% and 3% for the larger plant, indicating the high dependence of the price on feedstock costs.

Improved technology, the scale of operation and the capital and operating costs are all key factors in reducing the cost of ethanol. The effects of these are shown on Table 6.5 below.

TABLE 6.5 : Summary of Ethanol Price Sensitivity (no by-products)

	Ethanol Price in cents/litre		
Plant Capacity	**50 million l/y**	**50 million l/y**	**120 million l/y**
Biomass Cost $/dry tonne	**Present Technology**	**Future Technology**	
75			72
60	91	85	
39-42	85	72	
33			60
26		67	58

Comparing prices to the price of petrol at 20c and 50c a litre indicates that to compete on **a** commercial basis, ethanol production must be subsidised.

The subsidies required for a 50 million litre a year production facility at Esperance using improved technology and fully costed and residue biomass are shown in Table 6.6 below.

TABLE 6.6 : Subsidies **Required to** Achieve **Ethanol** Prices Competitive With Petrol

	Subsidy Required in cents/litre and ($million/year)			
	Target Fuel Price			
	20 cents a litre		**50 cents a litre**	
50 million l/year plant	**ROI 8%**	**ROI 15%**	**ROI 8%**	**ROI 15%**
Fully costed biomass ($60/dry tonne)	40 (21.8)	58 (29.4)	14 (7.2)	32 (15.8)
Biomass residues ($26/dry tonne)	32 (15.8)	48 (24.1)	3.8 (1.9)	21 (10.5)

The subsidy required to bring the ethanol to a tax exempt price equivalent to 50 cents a litre is relatively small and in the range of 4-20 cents a litre, depending on the return required. Much higher subsidies of 30 to 60 cents a litre are needed to match the ex-refinery price of petrol at 20 cents.

The total annual subsidies, shown in brackets in Table 6.6, vary from $2 million to $30 million a year across all the scenarios considered above.

It is of interest to compare the required subsidies with what might happen to land values and agricultural production in the region as a result of the expected effects of expanding salinity and land degradation.

If salinity is not arrested or reversed, about 30% (amounting to about 90,000ha) of all productive land will become unproductive over the next 10 to 15 years. The average land price is quoted as $700 a hectare. Assuming this land becomes "worthless" the lost value would be about $63 million to farmers in the area. The total lost production will be some 135,000 tonnes a year of wheat, worth about $20 million annually. Externalities could therefore significantly affect project viability.

Two other issues could affect the level of subsidies. In low blends, ethanol provides octane, the market value of which is uncertain. In addition, the price differential of petrol and diesel in Esperance, compared to Perth, is about 6 cents a litre higher at the pump - probably reflecting the cost of transporting the fuel by road tanker or ship. It would therefore be economic to make ethanol from residues at Esperance in a project requiring an 8% ROI.

The biomass supply potential in the Esperance region, both in the short and long term is more than adequate for ethanol plant capacities of 50-120 million litres a year.

The price of fully costed biomass, at between $60 and $120 a dry tonne delivered, is high.

The US is targeting the average cost of delivered feedstock from intensive biomass production at US$34 a dry tonne for later this decade.

Little work has been done in Australia to reduce the cost of biomass production, harvesting and transport for energy.

The biomass costs at Esperance that closest approach this US target are those of cereal and agroforestry residues.

Given the importance of low biomass costs in providing competitive ethanol prices, the following could provide opportunities to develop lower cost biomass resource systems for energy.

* maximising biomass production, including optimising biomass resource mixes and residue retrieval

* developing new harvesting and transport techniques to lower biomass residue costs (wheat straw, forest, wood residues)

- internalising the external environmental cost benefits of biomass production for environmental and land rehabilitation objectives
- determining what costs to attribute to biomass grown for environmental reasons
- assessing the potential benefits and cost benefits of high yield coppice farming of energy crops for environmental and energy use
- assessing the potential of multiple product tree crops for both energy and other products

Initially it was anticipated that a plant with a capacity of about 120 million litres could be economically viable as there would be a market for lignin. Lignin would need to be sold at about $500 to $800 a tonne for ethanol to be produced at 20c a litre, even with a fully costed biomass feedstocks.

An initial investigation into the world market for lignin has failed to confirm a viable and expanding market, given presently known uses for the product. Using lignin as a high value by-product must therefore be discounted in this study.

In addition, finding markets for the ethanol produced on a large scale 120 million litre a year facility moves from a local issue to a regional one, requiring the involvement the major distributors, marketers and end users. At this scale, ethanol would need to be either backloaded to Perth or used locally for other energy inputs, including the possibility of replacing the diesel fuel presently used at the 15MW power station at Esperance

6.4.2 Ethanol from Waste Paper

The apparent consumption of paper in Australia is approximately 2.8 million tonnes annually.

A total of 1.1 million tonnes a year are collected for recycling, of which about 1 million tonnes are reprocessed and 0.1 million tonnes exported. This paper is collected mainly as clean packaging paper and newsprint in the capital cities.

Of the 1.6 million tonnes not collected, most ends up in land fill sites. About 6% is uncollectable tissues and *2%* goes into the production of wallboard for the building industry. A portion of this 1.6 million tonnes is in the regional and country areas of Australia.

There are segments of the waste paper stream for which there is no demand at present. These include low quality newsprint (such as telephone books), coated "mechanical" type papers, (those associated with liquid packaging), paper contaminated with food wastes and paper from garbage. The "mechanicals" uncollected totals about 250,000 tonnes annually. Their coatings and coloured inks are undesirable in the recycled paper process.

Telecom collects 55-60,000 tonnes of telephone books annually. This paper is available at a cost of between $0 and $35 a tonne. Uses for this product are presently being sought.

The major producers of recycled paper are Australian Paper and Visy. The former is the largest, consuming a total of about 600,000 tonnes (10% moisture) annually. Visy utilise 400,000 tonnes of recycled paper and a quantity of recycled cardboard.

Plants producing recycled paper have effluent streams, totalling between 5 and 10% of the total input as reject. This reject, in the form of a wet pulp, mixed with string, metals (paper clips) and plastics is presently sent to landfill at a cost to the processors. Alternative uses for this effluent stream are being sought, including combustion for cogeneration.

Waste paper and processing wastes from recycling paper can be converted to fuel ethanol.

The total potential of ethanol from paper in domestic garbage, assuming 50% recovered, is 225 million litres annually.

That from paper recycling wastes and telephone books is about 25 million litres annually.

This case study examines the viability of a small 6 million litre a year located at a paper recycling facility, using waste paper and paper recycling wastes as feed stock.

6.4.2.1 Raw Materials

The raw materials for a plant to convert waste paper and paper processing wastes to ethanol was assumed as follows:

(i) Processing waste from recycling plants: 33,000 tonnes a year total waste (wet)

Total dry matter.	18,150 tonnes a year
Organic dry matter:	12,700 tonnes a year

Raw material cost: $0 to (-$20) tonne processing waste (delivered, wet)

Composition of the waste organic dry matter is:

Cellulose	60%
Hemicellulose	18%
Lignin	22%

(ii) Recycled telephone books: 10,000 tonnes a year

Moisture:	10%
Dry matter	9,000 tonnes a year
Raw material cost:	$ 10 a tonne (dry) delivered

Composition of dry matter: as (i) above

6.4.2.2 Capital Cost of Plant

The capital cost of the facility is calculated from the Natural Renewable Energy Laboratory process being developed in the US, making the following assumptions:

1. The plant is located at the site of a recycled paper manufacturer.
2. Steam and utilities are supplied by utility plant already existing on-site.
3. A waste paper to ethanol plant differs as follows from a wood to ethanol facility:

   The milling facilities are removed. Pre-treatment is steam explosion without acid.

- The utility plant is removed, the major proportion of which is a
- boiler/cogeneration plant, and paid for as imported steam and power.

The capital cost of the plant is $16 million, and the operating cost $2.8 million a year.

6.4.2.3 Economics

The economics of ethanol from waste paper indicates an ethanol production cost of about $1 per litre, taking into account credits of $5 a tonne that might be obtained from diverting wastes from landfill.

The dominant costs in the production of the alcohol are the operating costs of the plant, principally consisting of steam and manpower.

Taking the "unrealistic" case of locating the plant at a site at which there is excess steam and power available free, the price of the alcohol produced drops to 78 cents a litre.

6.4.2.4 Environmental

The feedstock resources are processing waste from waste paper recycling plants comprising of wet pulp and recycled telephone books. Both these waste products are presently stockpiled (books) or disposed of to landfill The feedstock is composed of cellulose, hemicellulose and lignin Consequently, there are considerable environmental benefits from the recycling of these waste products, including reduced landfill disposal and a reduction in the need for new forest plantations

The conversion technology is the NREL fermentation process plant Cogeneration of steam is not produced due to the existing utilities on site. The major environmental impact of the NREL process plant are the organic rich distillation wastewater which has a high BOD and the solid organic residue. The wastewater will require comprehensive treatment prior to discharge.

The conversion of waste paper and waste paper processing sludge to ethanol provides a direct environmental benefit through recycling wastes. However timber production and paper manufacturing require high primary energy inputs with widespread environmental impacts. The life cycle discussion of the derivation of these paper wastes must include the source of the timber, whether it is grown in plantations or in native forests to determine the impact on biodiversity, natural ecosystems and carbon sequestration, the forest management practices employed in the growth/harvesting of the timber, including, catchment erosion, stream water quality impact and the use of agricultural fertilisers and pesticides, the energy use in paper production and the discharge of organic rich wastewaters.

These combined impacts together with the disposal of organic rich wastewater from the NREL fermentation plant are significant environmental problems when viewed at the local and regional level. Consequently, it is important to view these impacts as being a major concern to the environmental sustainability of using recycled paper wastes for ethanol production. From a national perspective, the environmental benefits derived from the net reductions in greenhouse gas emissions as a result of the displacement of fossil fuels with ethanol can only be significant if there are widespread waste paper to ethanol conversion plants.

The re-used paper for ethanol production results in a net reduction in biogas emissions from anaerobic breakdown of paper wastes in landfill sites. If the potential of these ethanol plants is small scale then the local/regional environmental impacts will most probably outweigh the small offset in the greenhouse gas emissions.

6.4.2.5 Summary and Conclusions

The cost estimate of the facility analysed here is very uncertain, having been based on downscaling a large ethanol from wood facility.

The production of ethanol from waste paper is marginally economic if a 6 million litre a year plant can be built for $10 million, steam and power are provided at no cost and the cost of the raw material (paper waste) are offset against waste disposal.

6.5 ETHANOL FROM FOOD PROCESSING WASTES

Industry wastes containing starch and sugar can be fermented to ethanol by relatively simple and proven technologies. For wastes containing lignocellulosic materials there has been a strong a move away from the traditional, low efficiency acid hydrolysis technologies towards enzyme routes that are presently in development for a range of lignocellulosic feedstocks such as wood, agricultural residues and waste paper.

The environmental pressure on industry to clean up on waste disposal coupled with increasing costs of disposal, makes value-adding with these resources attractive.

Disposal alternatives include fermentation to ethanol, incineration, anaerobic digestion (see case studies in other sections of this report) and landfill.

Two industries were examined for their potential to produce ethanol from wastes: the starch processing industry and the potato processing industry. Case studies were selected at typical sites producing these waste products, to serve as models for other industries with similar wastes.

The total potential for ethanol production from fresh waste potatoes is 9 million litres annually, and that from processing peel slurry is estimated to be about 7 million litres annually. The total ethanol production capacity from wastes in the starch processing industry is estimated to be about 40 million litres a year.

Other industry wastes that could be used for ethanol production include the milk processing industries, which produce about 1,560 million litres of whey annually, half of which might be available for use as a feedstock for ethanol. The ethanol potential is estimated as about 20 million litres a year from this source.

6.5.1 **Ethanol from Potato Industry** Wastes

6.5.1.1 **Introduction**

Australia produces approximately 1.1 million tonnes of potatoes annually. About half find their way into domestic kitchens as fresh potatoes and the other half ends up in commercial processing facilities for conversion to crisps and french fries.

Harvesting and grading of fresh potatoes results in the rejection of tubers considered unsuitable for sale. The volume of rejected potatoes discarded back onto land is estimate at around 100,000 tonnes year.

Of the total volume of fresh potatoes going to processing facilities, about 385,000 tonnes a year or 70% are converted to french fries and 165,000 tonnes a year, or 30%, are used to produce chips.

Wastes are generated by the potato processing industry are typically of three types: peel sludge, solids and starch.

Peel slurry wastes result from the steam peeling process, totalling between 5 and 15% of fresh potato input (depending on the time of year and type of potato). It contains about 90% bound water and 10% starch and solids, and is used as a fertiliser, animal feed or discarded to landfill. It is estimated that Australian industry produces between 27,500 and 82,500 tonnes of this waste annually.

Solid wastes produced are chips/french fries in both raw and cooked form. These are disposed of as stockfeed, and generally form the smaller waste stream from these plants. Solid wastes tend to be recycled for the production of products such as hash browns, potato gems and other dried or granulated products.

Liquid wastes containing starch are disposed of as irrigation water.

This case study will examine the potential of ethanol production from peel slurry.

6.5.1.2 Resources

The site chosen for this case study is a large potato processing facility Tasmania.

It is assumed that the plant processes about 180,000 tonnes a year of fresh potatoes.

Peel waste slurry is produced totalling 15-20,000 tonnes a year, consisting of about 12-15% solids, made up of starch and peel. These sludge wastes are presently disposed of to landfill.

The other solid wastes produced, which include green potatoes, wastes from french fry production containing oil and other cooked wastes, are disposed of as animal feed.

6.5.1.3 Ethanol Facility

A prefeasibility study for an ethanol facility utilising potato waste sludge is presently being undertaken by the Melbourne based company Fermtech for Tasmanian Mountain Distilleries under a grant from the Horticultural Research and Development Corporation (HRDC).

An interim report provides details of expected project economics for various plant capacities. The capacity chosen for this case study is 120 tonne per day of potato processing waste slurry, with a starch content of 14%. The overall ethanol yield was 79 litres per tonne, producing 3 million litres a year of fuel ethanol.

The total capital investment, including site works, process plant and equipment, storage (food and alcohol product), start up and by-product recovery for animal feed is given as $1.9 million.

The process facility produces by-product (yeast and spent solids) at a rate of 660 tonnes a year. The HRDC proposal assumes that this byproduct could fetch as much as $3,300 a tonne as feed supplement high in amino acids.

For the purposes of this analysis, a price of $400 a tonne as animal feed has been assumed. This price is in the standard price range paid for animal feed from industry wastes of this quality.

The operating costs, including utilities, manpower and overheads are estimated at $960,000 a year excluding depreciation and ethanol transport costs to the distributor. The original proposal includes the use of ethanol as boiler fuel for steam production, but this study has adjusted the operating costs to assume wood residue is used instead.

Waste treatment facilities have been excluded. It has been assumed the plant delivers high BOD waste water into either hydroponic or field irrigation systems, the cost of which are not part of the project.

6.5.1.4 Economics

The economics of ethanol production from potato processing wastes, using the data supplied by Fermtech, indicates a price for ethanol of 520 a litre, without consideration of a fee for waste disposal from the potato processor and by-product credits for solid wastes that might be sold as animal feed.

If the potato processor were to pay a fee of $5 a tonne for the disposal of the waste that costs them more to dispose of to landfill, the ethanol price would drop to 45 cents a litre.
If, in addition, the solid wastes produced in the ethanol plant are sold as animal feed for $400 a tonne, the price of ethanol further reduces to 42 cents a litre.

Analysis of the capital and operating costs shown by Fermtech has been compared to the costs of a simple molasses plant reported elsewhere in this study. Scaling the molasses facility to an equivalent capacity, the capital cost comes out at about $5 million. The reasons for this discrepancy are not immediately transparent from the information available to this study. It was therefore of interest to perform a sensitivity analysis on capital cost, and a scenario was run in which this was doubled to assess the impact on ethanol price.

Doubling the investment cost reported by Fermtech increases the ethanol price from 42 cents to 57 cents a litre.

Fermtech also explore in their report, the costs associated with doubling the plant's capacity from 120 to 240 tonnes a day potato waste input, raising the capacity to about 6 million litres a year. Additional feed material would come from an expanded potato processing facility and whey from a nearby cheese factory.

Using their capital investment figure for this capacity of $3 million and an adjusted operating cost of $ 1.1 million, the price of alcohol production will be 24 cents a litre, including credits obtained from the sale of animal feed. Doubling the capital cost raises the ethanol price to 36 cents a litre.

6.5.1.5 **Environmental**

The feedstock is potato peel slurry wastes from the steam peeling process which are presently disposed of to landfill sites and disused mine shafts, is used as fertiliser and animal feed. The peel slurry waste is composed of 12-15% solids made up of starch and peel with bound water.

There is a direct environmental benefit in recycling these wastes by reducing demand for landfill sites and reducing the potential biogas production. Significant environmental impacts such as soil and water contamination can occur from the use of fertilisers, fungicides, pesticides and insecticides in potato agriculture. Soil contamination with Dieldrin residues employed in some potato growing areas has had significant impact on the long-term sustainability of the industry, particularly in Victoria. In addition soil conservation must be employed to ensure sustainability of the potato industry.

The outputs from the conversion plant are estimated to be high BOD liquid waste streams, but the composition is unknown.

The centrifuge liquid waste stream will contain 1000-3600 kg a day dissolved solids whilst the distillation liquid waste stream is assumed to have a discharge of approximately 115 m3 a day Both waste streams will probably require aerobic treatment prior to their application as irrigation water.

The conversion of potato slurry wastes to ethanol provides for environmental benefits in the form of a net reduction of greenhouse gas emissions from both decay of wastes in landfill sites and from the displacement of fossil fuels used for transport. Its environmental sustainability is dependent upon sustainable agricultural land management in the growing and harvesting of potatoes. Suitable treatment of the high BOD liquid waste stream will need to be implemented together with an identification of suitable land for irrigation. Electricity for the potato processing plant is generated by hydro-electricity and hence is not a contributor to greenhouse gas emissions. However, steam is produced by coal. Overall the conversion of potato slurry wastes to ethanol provides environmental benefits at both the local and national levels.

6.5.1.6 Summary and Conclusions

The case study adopted here is from an industry project being developed by a private sector joint venture. The proponents have past experience in the brewing industry, and their proposal was used as the base case scenario for economic evaluation.

Comparison of their equipment and operating costs with information developed by Davy John Brown in this study for roughly similar types of plant using other feedstock raised the issue of the cost and/or accuracy of projects engineered by 'entrepreneurs', compared to those produced by the large engineering companies for small-scale projects of this type.

This issue is an important one, and needs to be investigated further through more rigorous design, engineering and feasibility studies, as this type of uncertainty will have a major impact on both project risk and viability.

Based on project proponent's costs, ethanol can be produced for as little a 24 cents a litre at a capacity of about 6 million litres a year.

The sensitivity of the ethanol production price was tested at double the base case capital cost. In this case ethanol could be produced for about 36 cents a litre.

The project appears to be approaching commercial viability, particularly if it is paid by the food processor to remove and process the wastes. This is so, even at the lower by-product credits and increased capital costs assumed here.

However, certain process issues, including the capability of the plant as defined to adequately perform the hydrolysis, solid separation and waste treatment functions need to be raised, as they are not clarified in the original design. The issue of liquid waste disposal from the distillation facility needs to be resolved, as the project plans to irrigate agricultural land with this high BOD waste stream.

6.5.2 Ethanol from Starch Processing Wastes

6.5.2.1 Introduction

Of the 19 million tonnes of cereal grains grown in Australia, approximately 4 million tonnes are consumed domestically, of which about 1 million tonnes are processed annually to starch, gluten and other food and industrial products.

The 1 million tonnes of processed wheat provides about 800,000 tonnes a year of flour, which is processed to between 500,000 and 600,000 tonnes a year starch and 200,000-300,000 tonnes a year gluten

There are four major starch processors in Australia, each processing approximately equal amounts of flour as feedstock. They are Manildra, Bunge, Goodman-Fielders and George Weston, Manildra being the largest.

Process technologies employed in processing flour to starch and gluten utilise substantial use of water for washing out starch fractions These milky starch solutions are then concentrated to provide the "A" and "B" grade starch products. The "A" quality starch accounts for between 80-90 % of the total starch produced, is used by the food, canned food and brewing industries. It is a pure high quality, low protein starch that has a high resale value. "B" grade starches, which sell at a significantly lower price, are smaller in granule size, less pure and used in some food applications as well as other industries, including the manufacture of adhesives. This quality would be between 10 and 20% of the starch produced.

Yield losses from flour processing are typically up to 15% of raw material input. About 60% of the losses consist of starch and fermentable solids.

The high volume, high strength water effluent that emerges from starch processing facilities contains these fermentable starches and sugars.

Manildra already process their effluent to ethanol for use in transport fuel and industrial applications. It would appear that their effluent contains not only the normal process losses of fermentables, but also the "B" grade starch, which is not included in their product mix.

This case study will examine the potential for ethanol production from processing wastes at a starch processing facility at a capacity typical of the industry in Australia, assuming that both "A" and "B" grade starch and gluten are in the product range marketed.

6.5.2.2 Feedstock Material

It is assumed that the starch plant processes about 100,00 tonnes a year of flour, with "A" and "B" grade starch and gluten as their primary products.

The process produces around 80 m^3 an hour of effluent, containing about 5% solids, 40% of which is fermentable. This feed composition is too dilute to ferment economically, so it assumed that "B" grade starch (approx. 15,000 tonnnes a year) is added to increase the concentration of fermentables to about 84 tonnes a day at a concentration of about 10.5%. The capacity of this plant would be approximately 15 million litres a year ethanol.

6.5.2.3 Capital and Operating Costs

Capacity: 15 m litres a year ethanol (45 m^3 a day)
Feed: 800 m^3 a day water
84 tonnes a day fermentables

The capital cost of this starch wastes to ethanol plant is estimated as $20 million. The operating cost is taken as $6 million a year for the plant.

6.5.2.4 Economics

Analysis of the 15 million litre facility based on the costs developed above and a 15% rate of return indicate an ethanol price of about 75 cents a litre, not talcing any credits or costs associated with raw materials and waste disposal into account.

A net credit from waste disposal savings of $130 a tonne of fermentables processed is required to manufacture and sell ethanol at 50 cents a litre and achieve a 15% ROI on the project.

6.5.2.5 Environment

The feedstock is waste water effluent from starch processing plants containing fermentable starches and sugars.

The starches and sugars will be converted to ethanol using a simple fermentation facility. It is assumed that dunder waste and wastewater from the distillation would be processed in the existing treatment plant before discharge.

The overall environmental impacts of the project are positive with respect to local and global impacts.

6.5.2.6. Summary and Conclusions

The production of ethanol from starch processing wastes appears feasible if ethanol enjoys its excise-free status and the starch processor can realise a credit of about $12 a tonne ($3.6 million a year) from the avoided cost of waste disposal.

Whilst care was taken to cost the ethanol processing facility capital and operating costs in this case study, it should be pointed out that experience in industry has shown that these plants can possibly be built for significantly less than the cost of the fully engineered grass roots facilities taken as the reference points for cost estimates in this case study. Further work should be undertaken with interested parties in industry to clarify economics.

6.6 ESTERS FROM VEGETABLE OILS

Australia produces between 800,000 and 950,000 tonnes a year of oilseeds, of which cotton seed accounts for about 630,000 tonnes, canola about 300,000 tonnes and other oilseeds (soyabean, sunflower, safflower) about 50,000 tonnes.

The vegetable oil industry has recently implemented an industry plan to enable the industry to achieve self-sufficiency in oil production over the next 5 years (it presently imports about 200,000 tonnes a year of oil) and to develop the export market potential for oils, seed and cake in the future.

Cargill Australia is this country's largest oil seed crusher, with a capacity totalling between 800,000 to 900,000 tonnes a year oilseed with plants in Victoria, New South Wales and Queensland.

Of the vegetable oils produced, about 80% go into the food industry and the rest find their way into a variety of industrial uses, including paints and lubricants. These include linseed and rapeseed oil.

There is little waste oil produced by the industry. Vegetable oils produced by the food and fast food industry leave those establishments with the foods cooked by them and the waste oils remaining are collected and recycled by specialist processors who refine them.

Pricing of both seed and oil is based on import parity of the commodity, using soyabean oil as the benchmark. Import duty is presently 3%, to be reduced to zero by 1996.

The CSIRO have developed an new variety of linseed, called Linola, which will provide an edible variety of linseed oil. This development is in the early commercialisation phase.

6.6.1 Esters from Canola and Cotton Seed Oil

6.6.1.1 Introduction

The largest oilseed crop produced in Australia is cotton seed, produced as a byproduct of the cotton growing industry. The 630,000 tonnes of cotton seed produced have an extractable oil content of about 18-19%.

Of the 630,000 tonnes a year seed produced, about 200,000 tonnes goes to the domestic market for animal feed. This market is limited. A further 180,000 tonnes a year of seed is exported as animal feed, again to a limited market. The remaining 250,000 tonnes of seed produced are crushed in Australia to produce cotton seed oil for both the domestic and export markets and meal for the domestic animal feed market.

The 250,000 tonnes of other oil seeds grown in Australia, principally canola, have a substantially higher oil content than raw cotton seed - typically 40%.

Presently about 200,000 tonnes a year of canola seed are crushed domestically, and the rest is exported as seed.

Compared to soyabean oil, canola oil is equivalent but slightly discounted by between $20 and $40 a tonne, and cotton oil is about equivalent and sunflower oil fetches a premium of between $10 and $110 a tonne.

Presently, canola oil can be delivered at $900 a tonne to a capital city, but prices can vary significantly ($625-$ 1050 a tonne).

Only 2% of cropped land is devoted to oilseed production. Canola is a suitable candidate for potential increased production in Australia in the same soil and climate zones where wheat is grown.

R&D into improved crop yields and oil content of oil seeds are expected to yield an improvement of between 5 and 10% productivity overall over the next 5 years.

Crude or pharmaceutical grade glycerol is produced as a by-product of esterifying vegetable oils to produce a fuel that can be substituted for diesel. There is a shortage of crude glycerol in the domestic and export market according to Unichema. Crude glycerol (80% glycerol) will fetch between $700 and $950 a tonne in Australia (ex plant) as by-product credit.

6.6.1.2 Resources

Canola and cotton seed oil were selected for the case studies.

Canola production can be expanded to 0.5 - 1.0 million tonnes a year should markets demand it, and if returns to farmers are competitive with alternative crops such as wheat or other cereal grains.

Prices for canola oil, from a crushing plant in Melbourne is $860 a tonne. Full utilisation of existing capacity, expanded capacity and movement in world oil prices could lower the price to $800 a tonne.

Cotton seed oil availability is contingent on increased cotton production, predicted to rise from a present average of 1.8 million bales a year to between 2 and 2.5 million bales a year due to increasing world demand.

Cotton seed oil is priced at equivalent to soyabean oil at $900 a tonne. Its price could fall to between $650 and $750 a tonne in Australia in the future if excess seed is produced and crushed (to fully utilise local crushing capacity) without an increase in demand in export markets.

6.6.1.3 Vegetable Oil Ester Plant Capital and Operating Costs

The vegetable oil ester plants would be located alongside the existing canola pressing facility in Melbourne and alongside the existing cotton seed oil pressing facility at Narabri. It is assumed that there is a 'toll processing' arrangement for the supply of raw oil to the ester plant in both locations, and that the supply price reflects the required returns to the processor.

A plant capacity of 30,000 tonnes a year methylated oil and 3,600 tonnes a year crude glycerol by-product was chosen, requiring 32,250 tonnes a year of vegetable oil and 3,480 tonnes a year of methanol. It is assumed the methanol is derived from natural gas, and costs $280 a tonne.

The capital cost of the gross-roots plant is $32.4 million and the operating costs are $3.54 million a year.

By-product crude glycerol is expected to fetch $700-950 a tonne.

6.6.1.4 Economics

The economic analysis of a 30,000 tonne a year ester plant indicates that diesel substitute produced from canola seed oil at $860 a tonne in Australia will cost $1.38 a litre. Using cotton seed oil at $650 a tonne produces the ester at $1.12 a litre. In both cases, the crude glycerol by-product provided a return of $700 a tonne.

The price of the ester drops to $1.09 a tonne for cotton seed oil at $650 a tonne and a glycerol by-product price of $950 a tonne.

For the price of the ester to drop significantly towards the ex-refinery price of diesel fuel (20cents a litre), vegetable oils must be lowered to under $50 a tonne, even at a by-product glycerol price of $950 a tonne, as the table below shows.

Vegetable oil price $/tonne	Ester price (ex plant) $/tonne
650	1.09
500	0.91
200	0 55
100	0.42
50	0.36

The effect of the glycerol price on the production price of the ester at a constant vegetable oil price of $650 a tonne is shown in the following table:

Glycerol price $/tonne	Ester price (ex plant) $/litre
950	1.09
1,200	1.06
2,000	0.95
4,000	0.68

6.6.1.5 Environmental

The feedstocks are canola oil and cotton seed oil. Canola oil is produced by crushing Canola seed which are grown specifically for oil production whilst the cotton seed oil is derived as a by-product of the cotton industry. Canola production is a competing product with wheat and other cereal grains with similar climatic and soil requirements. The major potential environmental issues with canola production will relate to agricultural land management, including soil erosion, land degradation, water use and chemical use and disposal. There are a number of environmental issues associated with cotton seed processing which include occupational health and safety issues; hazardous chemical use, such as fumes from hydrochloric acid for delinting; the use of toxic chlorine gases; and inappropriate disposal of pesticide wastes.

The wastestream from the plant produces oils, solids comprising of free fatty acids and fat, and waste activated carbon. It is assumed that these wastes will be used to fuel the boiler plant. Approximately 2,500 ML a year of waste water are produced by the Vogel and Noot process, the composition of which is not known. It is expected that the waste water will be treated by aerobic biological purification before discharge or disposal to land.

The main end use of vegetable oil esters is as an alternative fuel for diesel engines. It is known as biodiesel and is being used in public transport systems and taxis in Europe and tested in ferries. Whilst vegetable oils have a lower carbon content than diesel, which means lower CO_2 emissions per kilometre travelled, they have lower energy content which will result in overall CO_2 emissions from vehicles similar to those from diesel. However, hydrocarbons and particulates are significantly reduced with the use of biodiesel, whilst NO_x emissions are generally regarded as higher for biodiesel than diesel. There is concern over the production of polyaromatic hydrocarbons during the combustion of biodiesel which result in higher vehicle emissions than from diesel. Life cycle energy and greenhouse gas balances reported by the IEA (1993) indicate that biodiesel production from vegetable oils, methanol from natural gas and cogeneration electricity would require 63% of diesel life-cycle energy use; would produce 46% of diesel life-cycle CO2 emissions and 71% of diesel life-cycle greenhouse gas emissions.

Consequently, biodiesel use has the potential to significantly reduce CO, HC and CO_2 emissions within urban areas where transport use is intensive and provide an amelioration in urban air quality. The increased polyaromatic and NO_x emissions are a tradeoff for air quality since SO_x and particulates are significantly reduced. In addition the use of biodiesel to power harbour, port and lake waterway vehicles would reduce the occurrence of diesel fuel spills and the associated impacts on the marine environment since biodiesel is biodegradable. The local environmental impacts from waste water discharges from the Vogel and Noot plant are considered to be of minor impact as they are aerobically treated.

However, it is important to consider the environmental sustainability of the agricultural practices employed in the production of canola and cotton seeds.

6.6.1.6 Summary and Conclusions

Vegetable oil esters can be produced at between $1.09 and $1.38 a litre using commercially produced cotton seed and canola oils.

Under the scenarios tested, the diesel substitute could not be made competitive with either the ex-refinery price of diesel fuel which is about 20 cents a litre, or the taxed price of diesel which is about 50 cents a litre.

7.0 STRATEGIC ISSUES AND ACTIONS

7.0 STRATEGIC ISSUES AND ACTIONS

7.1 INTRODUCTION

This chapter raises a number of issues associated with each of the candidate biomass systems which were selected as a result of the process discussed in the chapter on Systems Selection and illustrated in the case studies outlined in the preceding chapter.

The discussion of these issues leads to a program of actions for each of the major biomass systems.

The chapter covers the two energy forms arising from the use of biomass resources:

- ethanol as a liquid fuel or as an additive to liquid fuel
- electricity

The markets for these energy forms are discussed as well as the economics of the various systems as revealed from the analysis undertaken in the course of this study. The extent of the market for these energy forms is assessed primarily in terms of the extent, availability and location of the resources used as feedstock to the systems as well as the environmental and technology issues associated with each.

On the basis of this specific actions are outlined which could be undertaken by the partners funding this study to overcome the barriers to the introduction of these systems to the marketplace.

These actions include further analyses of biomass resources, research, development and demonstration programs, support programs to encourage further market development and government subsidisation programs.

The commentary in this chapter uses information from all the case studies with the exception of ester production from vegetable oils, which has not been considered further.

The case study on vegetable oil esters from cotton seed and canola oils shows production costs of $1.09 to $1.38 a litre including glycerol by-product credits. Clearly, vegetable oil esters are far from competitive with conventional diesel, illustrating the problem of starting the process with a food crop. In Australia, primary producers have diesel fuel excise rebated, resulting in a cost to them of about 30cents a litre before transport costs. These transport costs would have to be very high indeed to make esters a viable proposition.

For each of the systems discussed below an attempt has been made to quantify the employment impact. This has been done by estimating the maximum extent of the market possible for each system expressed in terms of facilities and multiplying this by the number of jobs associated with each facility. This provides an estimate of direct employment effects.

It has been assumed that there will be a further indirect employment effect arising from increased economic activity following the introduction of these facilities. This has been put conservatively at 50% of the direct employment benefit.

Quantifying the exact size of this indirect employment effect would require an economic model for each region in which a biomass facility is to be located. The employment effects associated with the construction of each facility are harder to estimate because it will depend on the complexity of the plant and equipment and skilled labor requirements. The indirect effect of the construction phase of facilities will be less than that of the operating phase as a significant proportion of plant and equipment is likely to be imported. A crucial issue in the development of biomass industries in Australia will be the extent to which the plant and equipment can be sourced in regions where biomass sites are located or elsewhere in Australia rather than being imported.

Economic and employment effects will be maximised if overseas technologies can be licensed to enable the manufacture of plant and equipment in Australia and indigenous technology is retained for manufacture in the country.

Similarly the benefits of job creation associated with the operation of biomass plants can be maximised if it is sourced from the unemployed rather than by people shifting from one job to another. If this can be done it would have significant effects on unemployment in certain regions.

If biomass sourced energy replaces domestic production of traditional fuels there could be unemployment created as traditional plants are taken out of operation. These job losses are likely to be small and concentrated in urban areas where job prospects are better.

If ethanol produced from biomass displaced imports of liquid fuels this could have significant benefits for Australia's balance of payments. This would be enhanced if export markets are developed for ethanol. Any improvement in the balance of payments offers scope for sustainable higher rates of economic growth where the benefits are distributed widely across the economy.

7.2 ETHANOL FROM BIOMASS

7.2.1 Markets and Prices

The major liquid fuels used in Australia are petrol and diesel for transport.

Ethanol produced from biomass could enter the market for these fuels either as a direct substitute for petrol and diesel, that is, as 100% ethanol, or as a blend of up to 20% with petrol and diesel. In the latter case ethanol also acts as an octane enhancer.

Liquid fuels are traded internationally on a very large scale, with world benchmark prices, such as that for West Texas Intermediate crude oil, currently about A$27 per barrel. The ex-refinery price of petrol and diesel in Australia is about 20 cents a litre. This cost of production would not vary widely between countries, given that crude oil is internationally traded and refinery costs are broadly similar. There is also a well established refining and distribution network for these products.

In Australia the wholesale price of petrol and diesel includes excise and taxes which bring the price up to a total of 50 cents a litre. Currently ethanol does not attract these additional charges. It is imperative that this continue whilst competitive technologies are being developed.

Octane in Australia is presently supplied through the addition of light aromatics and increasingly overseas, by the addition of MTBE and other oxygenates. It has proved difficult to obtain definitive information on the price of these additives in Australia. Industry sources indicate that MTBE is sold in the USA around 1.3 to 1.6 times the price of petrol ex-refinery, we assume therefore that the price in Australia is around 30 cents a litre.

According to ABARE, in 1992-93, there were 17,000 megalitres of petrol and 10,000 megalitres of diesel sold in Australia. This is the total theoretical market for ethanol as a transport fuel. As an octane enhancer the theoretical market size is 5,400 megalitres (ie 20% of 27,000 megalitres).

In the case of ethanol as a neat fuel, special vehicles and a modified distribution network would be required: the fuel-flexible vehicle has been demonstrated in the US and is making commercial penetration into the Californian market through the major US, Japanese and European car manufacturers.

Regulations mandating the use of cleaner fuels to address local pollution in US cities together with Federal and State subsidies are creating this market.

The US is therefore a world leader in the utilization of ethanol as an alternative fuel, with about 10% of its unleaded gasoline fuel already blended with ethanol. A large potential export market exists there for leading edge technologies for ethanol production. Other possible export markets for technology include Korea and other Asian countries with fast developing economies .

It should be noted that although ethanol burns more efficiently than petrol, it has substantially lower energy density. Hence 1.3 litres of 100 per cent ethanol will drive a given vehicle about the same distance as 1 litre of gasoline when used as a neat fuel. In blends of up to 20%, ethanol has equivalent performance to petrol.

7.2.2 Ethanol from Food Processing Wastes

There are starch, sugar and cellulose containing wastes from the food industry which can be converted to ethanol and where the price of the resource is not the major issue.

Ethanol produced from food processing wastes is the process most competitive with petrol and diesel fuels.

This study examined the costs of ethanol production from wastes produced in the potato and starch processing industries as case studies for wider application to other wastes.

For a 3 million litre a year plant processing potato peeling wastes, the cost of production is 40 to 45 cents a litre, and for a 6 million litre a year plant, this drops to 20-25 cents a litre. Turning to other food processing wastes, the analysis shows that for plant utilising starch processing wastes on a plant capacity of 7 million litre a year ethanol, the price is 75 cents a litre. For a 15 million litre a year plant, the price is 50 cents a litre.

These figures are based on capital and operating costs developed by industry, which were considerably lower than those estimated by formal engineering companies. These discrepancies need to be understood, as they have a substantial impact on ethanol economics.

The total potential volume of ethanol from these industries was estimated as about 20 million litres from the potato processing industry if fresh discarded potatoes are included, and about 40 million litres a year from the starch processing industry, based on the present content of starch in waste streams. Manildra, the large starch processor in NSW is presently the only ethanol producer from wastes in Australia and is expanding production to an estimated 100 million litres a year by utilising "B" grade starch.

The resource assessment studies identified other potential ethanol from wastes, including those from the milk processing and cheese making industry, the fruit processing industry and the fruit juice and canning industries. It was difficult to obtain accurate information on the quality and volumes of these and other potentially interesting waste streams, as they all have site specific characteristics depending on the technologies utilised by the food processor and the nature of the industry. In addition, little has been done to review and assess these wastes nationally and there is very little published information.

Based on available information, there is at least a potential to produce 200 million litres of ethanol a year. It is likely that there is room for at least a further 100 million litres a year, and possibly a total capacity of up to 500 million litres.

Assuming a single plant capacity of 15 million litres, the total number of plants could range from 13 up to 33. This implies a workforce associated with these plants of between 150 and 400 people. To this should be added a further 75 to 200 jobs arising from the indirect effects of the introduction of these plants. This however, does not take into account any job losses arising from any transport fuel production facilities displaced.

Food processing plants are often located in regional areas, so while the impact of introducing these plants at a national level is small, the impact on regional economies could be significant. Any job losses are likely to be within the major metropolitan areas where there is greater scope to find new employment.

Ethanol from sugars and starches is well-established technology. Despite this, discussions with potential project initiators have indicated that the uncertainties with dealing with the sugars and starches in wastes contaminated with other components require a case-by case evaluation. This should at least be in the laboratory to minimise the process performance risks associated with the establishment of a commercial facility.

An ethanol plant using food processing wastes can be essentially regarded as a waste treatment process.

Some food processors are indicating an interested in examining the possibility of saving on waste treatment costs, adding value to the waste product and gaining the cost savings made by recycling water by installing this type of waste treatment facility, particularly if it is seen to be allied to core business interests.

In other cases, investment in this type of facility is attracting entrepreneurial investment, typically where the food processor regards waste disposal both as a nuisance and an unnecessary but unavoidable cost to production. In this situation, it appears that it is relatively easy to get agreement for a third party either to remove the waste for free or even to be paid to dispose of the waste, particularly if the cost of disposal to the factory is less than other options and the responsibility for the waste disposal is transferred elsewhere.

Other issues raised in the case studies related to the capital and operating cost estimates of this type of ethanol facility. Estimates made by the industry were significantly lower, by a factor of two or three, than those made from the formal engineering approach developed in this study. It is of importance to understand whether this type of plant can be built cheaply and this issue needs to be clarified by demonstration as its potential impact on project returns is of some importance.

The conversion of food wastes to ethanol raises environmental issues. The use of ethanol in place of petrol or diesel fuels results in reduced greenhouse gas emissions from vehicles, and the utilisation of food processing wastes to produce the ethanol is positive with respect to disposal of the waste, which would otherwise be discharged to landfill or dumped into the environment. However, the ethanol plant produces essentially two waste streams itself The solid wastes, containing yeasts, essential amino acids and other food values can sold as animal feed. The liquid wastes will be relatively high in oxygen demand and probably require aerobic treatment before being recycled or disposed of as irrigation water. These requirements will vary from site to site, and evaluation is important before a project is initiated, given the additional investment that might be required on small projects of this type.

On the basis of this analysis, the major actions required are:

the instigation of further work to compile an exhaustive inventory of food processing wastes in Australia

the initiation of a program promoting and explaining the benefits of ethanol production and encouraging the food processing industry to adopt the technology

an examination of current waste disposal practices and charges to see if there is scope to change these in such a way as to encourage the adoption of this technology

the initiation of a program to provide financial support for feasibility studies the support of a project to demonstrate actual construction costs, the benefits of the technology, and waste stream outputs and treatment needs.

7.2.3 Ethanol from Lignocellulose

Ethanol produced from lignocellulose is less competitive than ethanol from food industry wastes. However, the potential volumes are very large, based on the resources presently available from cereal and wood production and from possible future agroforestry wood production.

The cost of ethanol produced from lignocellulose on a large scale (50 to 120 million litres a year) ranges from 70 to 85 cents a litre. This is based on the use of a mix of fully costed cereal and agroforestry wood at a price of $40 a dry tonne for cereal straw and $118 a dry tonne for wood, the average price of the mix being $60 to $75 a tonne.

Using agroforestry wood recovered as a residue from pulpwood or sawlog harvesting, or as a residue from eucalyptus oil extraction, ethanol can be produced at between 60 and 70 cents a litre. The cost of the resource in this case ranges from $20 to $36 a dry tonne, resulting in an average price of the mix of between $26 and $42 a dry tonne.

To match the ex-refinery price of petrol at 20 cents a litre, the cost of producing ethanol from lignocellulose must drop by between 30 and 60 cents a litre. To match the price of petrol at the pump (50 cents a litre), the cost of production only needs to fall by between 4 and 20 cents a litre.

Against this background, the lignocellulose to ethanol case study analyses a mixture of feedstocks including lignocellulose from agroforestry, cereal production and saline land rehabilitation. It is estimated that in the Esperance area, this could support a 120 megalitre per year plant and that there are a further 12 to 20 sites in Western Australia, plus many more for the whole of Australia. As an example, 50 plants would produce 6,000 megalitres a year of ethanol, which is about one third of the 17,000 megalitres a year of petrol sold in 1993 in Australia. Thus the problem is not total resource availability but the price of this resource.

The potential for employment creation from operating 50 plants is 3,000 persons, with another 1,500 jobs created as an indirect effect of the introduction of these plants. Constructing these plants would cost $8.6 billion.

The technology for producing ethanol from lignocellulose is still in development and likely to be commercial late this decade. The case study uses the US developed National Renewable Energy Laboratory (NREL) technology, in which significant process improvements are expected in the next three years. However, financial analysis indicates that the expected process improvements, whilst useful, are not the key issue related to reducing the ethanol production price.

The expected improvements will reduce the capital cost of the plant by 12% and the production cost by approximately 10%.

The largest cost items in the lignocellulose plant are the feedstock handling and pre-treatment stages (approximately 22% of total facility cost) and the simultaneous saccharification and fermentation stage (approximately 15%). They therefore offer areas for further potential cost reduction.

In addition, there is a reasonable degree of uncertainty with regard to the capital and operating costs of the ethanol plant made in this study, given its state of development and the uncertainties of costs reported in the literature.

Construction of the NREL demonstration facility presently underway in the US should help clarify this, as will the design studies being undertaken in Australia by APACE Research. The APACE Research study will incorporate their selection of the best technologies from a variety of developments presently being undertaken. It will include the fermentation technology being developed by the University of New South Wales, as well as the as yet undemonstrated APACE Research ethanol recovery and waste treatment process.

Ethanol costs are more sensitive to feedstock prices and by-product credits than to technological improvements.

Little research has been carried out in Australia on the potential for intensive biomass production for energy.

The US is targeting the cost of delivered biomass from intensive biomass production, including production, harvesting and transport, at US$34 a dry tonne for later this decade. The biomass costs that closest approach this US target in Australia are those of cereal and agroforestry residues, at between $40 and $55 a dry tonne.

Little work has been done in Australia to assess and reduce the cost of biomass production, harvesting and transport for energy. Given the importance of low biomass costs in providing competitive ethanol prices, the following could provide opportunities to further develop lower cost biomass resource systems for energy:

* innovative one-pass harvesting and transport techniques to minimize resource costs (wheat straw, forest, wood residues)

* assessing the potential of multiple product tree crops for energy and other, perhaps higher value products

* assessing the potential benefits and costs of high yield dryland and irrigated coppice farming of energy crops for environmental and energy purposes

* determining a value for the environmental benefits achieved from biomass grown for environmental purposes (eg greenhouse gas and land rehabilitation objectives)

Potential income from high value by-products, such as lignin reflected significantly and positively on the ethanol price. However, a preliminary investigation did not confirm any immediate potential market for lignin other than as a boiler fuel. The review of future opportunities to realise by-product income is important.

The most pressing environmental issue for agriculture in Australia is resource degradation through salinity and erosion. An ethanol from lignocellulose plant can use a combination of feedstocks, the most obvious in the near to medium term being cereal residues from wheat production, agroforestry using low growing bushes, high growing shelter trees, and salt tolerant bushes and grasses on marginal agricultural land. Issues arising in the assessment of these are, in the case of:

cereal straws: leaving sufficient on the land to provide organic matter and protection from erosion and to maintain agricultural production on a sustainable basis. In such cases there will be a process-specific trade-off between maximising the feedstock available for conversion to energy and agricultural sustainability

agroforestry: measures to retard or reduce salinity, including planting of low-growing eucalypts, shelter trees, salt-tolerant grasses and salt bush.

salt tolerant grasses and bushes: coppice harvesting techniques are required with deep-rooted perennial species.

Like any process, ethanol from biomass will produce effluent streams. The issues here include the extent to which lignins are soluble in the liquid waste streams and whether there anaerobic waste water treatment facilities. These facilities need to maximise energy recovery and purify to sufficient quality to enable the use of the waste stream as recycled process water or its safe disposal as irrigation water.

The International Energy Agency (1993) have estimated that for fuel ethanol from wheat straw would use only 21% of energy used in the production of gasoline and produce only 18% of life cycle CO_2 emissions and 26% of life cycle total greenhouse gas emissions compared to gasoline.

It is important to note that the greenhouse gas emissions from the ethanol combustion process in vehicles are similar to those for gasoline combustion but are carbon neutral if the equivalent type and quantity of biomass is regrown to sequester the carbon which is eventually released through fermentation and combustion.

It is useful to note the total potential cost of losses in land values and agricultural production in the Esperance case study region due to the expected effects of environmental degradation (expanding salinity and land erosion problems). The loss in land value is estimated at about $63 million and the total lost production in wheat about $20 million annually.

The issues arising from the discussion of the above and requiring actions are:

> For Government to confirm that the present tax break for ethanol fuels in Australia will continue, enabling its market as an octane enhancer and fuel extender to develop with confidence
>
> Further work is required on quantifying and valuing the net benefits of agroforestry biomass production and biomass production for environmental purposes and the extent to which these benefits can be allocated to ethanol feedstock production
>
> Examine the potential for cost savings arising from the introduction of innovative one-pass techniques for harvesting and transport of wheat straw, forest, wood residues
>
> Assess the potential of multiple product tree crops for energy and other higher value products

Assess the potential benefits and costs of high yield dryland and sewage irrigated coppice farming of energy crops for environmental and energy purposes

Assess the potential for developing and demonstrating a leading edge ethanol from lignocellulose technology able to process a range of feedstocks

Support research aimed at significantly reducing the costs of both the feedstock handling and pre-treatment stage and the simultaneous saccharification and fermentation stage of the process

Investigate innovative high-value opportunities for lignin utilisation

Particular attention should be paid, once a demonstration plant is operational, to quantifying the costs associated with treating the waste streams from this process.

7.2.4 Ethanol from Waste Paper

Production of ethanol from waste paper could reduce pressure on landfills, because, of the 2.8 million tonnes of paper consumed annually in Australia, only around 1.1 million tonnes are recycled. It could also be possible to use the wet pulp which is an effluent stream from manufacturing recycled paper.

However, the case study indicates that ethanol produced in this way costs between 78 cents to $ 1.00 a litre for a plant size of 6 million litres a year using 22,000 tonnes a year of paper. This cost is likely to be significantly less for a larger plant, with a capacity of, say, 30 million litres a year.

The scope for producing ethanol from wet pulp wastes is limited, being no more than about 5 million litres. Similarly there appears to be little opportunity to divert a significant amount of the waste paper stream going into the manufacture of recycled paper and cardboard. Currently there is little incentive to recover further amounts of paper from solid waste streams as the cost of landfill in Australia is relatively cheap compared to other countries. If the price of landfill rises to levels such that this becomes economic, there is potential resource of some 800,000 tonnes, which can produce 225 million litres.

That from recycled telephone books is about 20 million litres annually.

This means that 8 plants can be built around Australia of 30 million litres capacity to process this potential resource.

The conversion technology utilised in the case study is the NREL process, and the same problems exist with this as discussed in the previous section. Other technologies are in development to convert waste paper.
The two main issues arising out of that work are the effect of inks and paper fillers on the fermentation process, and the necessity of producing a technology cheap enough to install in a plant requiring a small local capacity, as illustrated in the case study considered in this report. The cost estimate of the facility analysed here is uncertain, having been based on downscaling a large ethanol from wood facility.

The feedstock resources are processing waste from waste paper recycling plants comprising wet pulp and recycled telephone books. There are considerable environmental benefits from the recycling of these waste products, including reduced landfill disposal and a reduction in the need for new forest plantations.

The major environmental impacts of the NREL process plant are the organic rich distillation wastewater which has a high BOD and the solid organic residue. The wastewater will require comprehensive treatment prior to discharge.

The conversion of waste paper and waste paper processing sludge to ethanol provides a direct environmental benefit through recycling wastes. From a national perspective, the environmental benefits derived from the net reductions in greenhouse gas emissions as a result of the displacement of fossil fuels with ethanol can only be significant if there are widespread waste paper to ethanol conversion plants. The re-used paper for ethanol production results in a net reduction in biogas emissions from anaerobic breakdown of paper wastes in landfill sites. If the potential of these ethanol plants is small scale then the local/regional environmental impacts will most probably outweigh the small offset in the greenhouse gas emissions.

The actions arising out of the investigation of producing ethanol from waste paper are:

a study should be conducted into the impact of landfill charges on the economics of recovering additional paper from waste streams

more information should be obtained on technologies being developed specifically to convert waste paper to ethanol with a view to assessing whether they would be viable in Australia.

7.3 ELECTRICITY FROM BIOMASS

7.3.1 Markets and Prices

Electricity generation is moving from a situation characterised by monopoly producers in single markets to nationwide markets supplied by electricity generating companies competing with each other. The purpose of government reforms is to increase competition leading to greater economic efficiency and lower prices. There are major interconnected systems between most European countries and across the United States and Canada. In Australia, the States of NSW, South Australia and Victoria are interconnected, with prospects of Queensland and Tasmania being added to this system.

This provides a considerable challenge for biomass-based electricity. However, cost-reflective transmission pricing could result in increased prices to end users in remote areas, thus providing a niche market for biomass. However, fully cost-reflective transmission pricing is a highly political issue and has yet to be introduced anywhere.

Australian electricity prices are the fourth cheapest in the OECD, averaging out at about 8cents a kWh to commercial and industrial users. Busbar costs i.e. costs where the power station links to the network, are around 3 to 4cents a kWh for existing coal fired stations and 5 to 7cents a kWh for new coal-fired stations, with gas-turbine stations around 6 to 8cents a kWh. Marginal costs can be as low as 1.5cents a kWh, for Victorian brown coal-fired stations.

The National Grid Management Council (NGMC) is considering network pricing methods. One of its publications indicates that the fully cost reflective method could result in network prices as high as 8cents a kWh to a user 250km from the nearest generating station, based on line maintenance costs and line losses as high as 20% in some cases. Moreover, diesel-fired generating sets in remote areas may cost 7 to 20cents a kWh.

It is also important to note the difference between rates at which cogenerators buy electricity and that which they are paid for selling electricity surplus to their own needs. These 'buyback' rates are often substantially lower than selling rates, principally because electricity utilities argue that they have in any case to maintain standby plant, since the cogenerator is less than 100 per cent reliable. This is a hotly-debated topic fundamental to the viability of all cogeneration projects, not just those from biomass.

Reliability of supply is an issue in some country centres in Australia, especially to manufacturers and commercial operators. Brown-outs or supply outages can cost companies substantial losses. Local or on-site supply is perceived as a way of addressing this problem - with cogeneration also offering the potential to replace imported LPG for heat production purposes when needed in manufacturing.

Studies undertaken by industry interests have identified more than 300 sites around Australia where residues are available or have problems with the disposal of wastes that could be utilized for power generation.

The extent to which there is a market at those sites needs confirmation.

The potential for the application of electricity from biomass gasification technologies in the export market would appear to warrant quantification. Extension of the grid and reliability of supply are also significant issues in the developing Asian economies, offering opportunities. The focus of studies should be Europe and closer to home, Indonesia, Korea, Philippines and Malaysia.

The local and export market potential for technology to produce electricity from anaerobic digestion systems could be significant. The increasing costs of water and environmental clean-up from intensive animal rearing facilities and the food industry are catalysts to market development. Key markets overseas include the US, Malaysia, Korea and the Philippines.

7.3.2 Electricity from Direct Combustion and Gasification

The electricity case studies have electricity production costs at or near competitive prices, at least for replacement of electricity now purchased, and especially at end-of-grid or stand-alone sites.

A study examining the economics of a 10 MW grid-connected direct combustion power plant at Orbost in Victoria reports that biomass feedstock is required to be purchased at $10 a tonne to be viable. The feedstock totalling about 120,000 tonnes a year is expected to be made up of sawmill wastes and forest residues. A second project of capacity 5 MW based on direct combustion of rice hulls at a rice mill was viable. Another direct combustion project using MSW is being examined for the City of Heidelberg in Melbourne. Under present conditions the project is marginal being sensitive to the cost of landfill and the price chargeable for steam and the return expected by the owner.

A industry-based case study examined a gasification project to cogenerate heat and power from wood wastes for a timber products factory in NSW. The project requires free feedstock to be competitive.

Case studies were examined for gasification processes using the BEST/TREElectric gasifier with cotton stalks and gin trash as the biomass resource. Power production costs are in the range 3 to 6cents a kWh, while the SECV gasifier is estimated to produce energy at about 4.5cents a kWh. As discussed at length elsewhere in this study, care must be taken in use of cost estimates for technology now at laboratory scale. In addition, whether exports to the grid are also economic will depend on the contract conditions which can be agreed with the utility.

In this study it is estimated that residues from harvesting of timber in forests total about 15 million tonnes a year. A 2MW plant requires about 20,000tonnes a year, depending very much on moisture content, so 15 million tonnes could theoretically fuel 1,500MW of capacity.

Information provided by TREElectric indicates that there are 500,000 tonnes of cotton stalks and gin trash produced each year in NSW. If half were used for electricity generation, this could support an installed capacity of about 50MW in 25 plants. However, it is likely that significantly less will be available for environmental reasons.

The Heidelberg site uses 30,000 tonnes a year of MSW for a plant around 1MW and on the basis of this, 450 MW is the capacity available from processing the total Australian MSW of 14 million tonnes a year in around 450 such facilities.

The theoretical maximum generating electricity from wood residues is 1,500 MW (or 150 plants of 10 MW), from cotton stalks and gin trash is 50 MW, and from MSW is 450 MW. This is a total of 2,000 MW or about 5.5% of current installed capacity in Australia. If all these plants were introduced the direct employment created would be about 2000 with a further 1000 jobs resulting from the increased economic activity.

The issue of scale is also important for electricity from biomass. The installed capacity of the present Australian electricity generation system is 35,000MW. The largest biomass based plants now under consideration are about 40MW, while the plants in the case studies examined were in the range 100kW to about 5MW.

This situation regarding the state of development of biomass combustion and gasification technologies to some extent parallels that for coal-fired technologies, where pulverised fuel combustors are fully commercial, in power stations up to 2,640MW in Australia and larger overseas.

However, coal-fired Integrated Gasification Combined Cycle (IGCC) is at the demonstration stage, with several plants at the 250MW scale either in service or under construction.

The combustion technologies selected in the biomass case studies required careful matching to the feedstocks used. For example, rice hulls present particular difficulties, as described in that case study. Even combustion of woodwaste can result in substantial fouling, with maintenance costs and reliability areas requiring further attention. Such issues are not R&D but rather part of the normal process of commercial development.

The woodwaste, rice and MSW case studies considered the use of gasifiers but rejected them due to a lack of capital and operating cost information as the technology was not commercially available. However, the technology is presently in the demonstration stage in the US and Europe for woody biomass, with no process taking the lead as yet. In addition, there is an interesting technology being developed in the US for the gasification of MSW which is claimed to be environmentally friendly. This area is emerging as one of great interest to the utilities in the US, given the potential to access a feedstock that will be at zero or even negative cost because of high and increasing landfill charges.

Gasifiers, for biomass as for coal, have the potential to achieve higher thermal efficiencies and lower emission levels than combustors.

The SECV in Victoria is developing a large scale gasifier for firing with brown coal as a candidate for the next generation of clean coal technologies for power generation. Given the characteristics of brown coal, this concept could be modified for biomass-firing, including such feedstocks as wood, cereal residues, MSW and other wet wastes. No work has yet been done by the SECV in this area. The early stage of development world wide of this technology presents a market opportunity for applying this process to biomass.

The BEST/TREElectric small-scale gasifier technology is interesting, as an Australian development in the l00kW to 1MW range. It appears that this niche has not been filled by overseas technologies. The unit consists of a gasifier, a system for removing particles and tar from the gas stream, plus an engine generator and heat exchangers to use the waste heat to dry the fuel. The system is unique in that part of the engine exhaust gas is re-injected into the gasifier.

The concept is promising and the local and overseas market for a gasifier able to operate on a range of biomass feedstocks is potentially large.

However, it must be emphasised that the project is still at the laboratory stage.

Whether gasification of cotton stalks and gin trash has net local environmental benefits will depend on maintenance of the sustainability of cotton growing, which is already an intensive user of fertiliser and irrigation water.

The Heidelberg site is particularly interesting from an environmental viewpoint. On the one hand, landfill is becoming increasingly costly and sites are facing mounting community opposition. Energy from landfill gas is becoming commercial, with apparently little public debate. On the other hand, incinerators are the focus of strong community concern about their environmental impact.

The Heidelberg site is also an interesting case study from the global viewpoint. The net reduction in carbon dioxide emission of about 50,000 tonnes a year, about 45 per cent below previous levels. The principal reductions are from transport of brown coal from the LaTrobe Valley to Heidelberg Hospital, as well as the combustion of that brown coal.

The recommended actions arising from the analysis of electricity produced by direct combustion/gasification are

- further work should be undertaken to identify those primary resource processing facilities such as sawmills and cereal processors which have access to wastes at no cost, to promote this technology. This should concentrate particularly on end-of-grid locations

- the demonstration of small-scale gasification cogeneration technologies should be supported

- the development and testing of the gasification of biomass fuels, including MSW, using the SECV process should be supported

- export opportunities for demonstrated gasification technologies should be identified and facilitated

- further studies of export opportunities, with a focus on Indonesia, the Philippines, Korea and Malaysia should be undertaken

7.3.3 Electricity from Anaerobic Digestion

The case studies on this technology examined the construction and operation of a regional biogas waste treatment facility to process the putrescible portion of sorted municipal waste, industry wastes from the food processing industry and from intensive animal rearing facilities.

The cost of electricity produced is 5c a kWh for a 10 MW plant provided the project is paid to dispose of wastes and markets can be found for the cogenerated heat and fertiliser. At larger capacities, such as the plants considered here between 45 and 75 MW, the financial performance is much less dependent on by-product income.

The cost of energy as biogas from a waste treatment plant at a winery could be made competitive with natural gas, provided the savings from the disposal of the waste by other means and from the recycling of the treated water are more than $4 a cubic metre.

Fertiliser sales are critical to project viability. Whilst there is anecdotal evidence on the use and performance of the fertiliser in Australia the issue of its market value remains unresolved

The energy potential from MSW totals some 600 million cubic metres of biogas a year, with an energy potential of 90 million GJ, which could be produced in 50 digestor facilities with a capacity of 32,000 cubic meters a day, or about 45 Mwe.

This would create directly 250 jobs and around another 125 jobs indirectly.

There are at least 15 to 20 wineries in Australia that are large enough to install anaerobic digestors to treat their wastes, with a total energy potential of more than 70,000 GJ of energy. The potential market is several times this if the food processing industry is considered as a whole.

No regional plants using a mixture of animal, industry and MSW have been built in Australia, although a plant is operating successfully on wastes from an intensive piggery and other single feedstock plants have been built that are operating on food industry wastes and human wastes. The technology for treating MSW is still fighting for a place in the market, given competitive options of gasification and combustion discussed in the section above. Those plants built elsewhere, particularly in Denmark and Germany, have not operated viably because they have been based on existing single feed plants, with the technologies adapted to accept the new mix of waste resources being processed.

The case study indicates opportunities in both country regions and in semi urban regions in their early stages of development, such as exists in the Pakenham region.

Such plants should be built at sites to maximise the possible return from process by-products: in particular where there is a ready market for the gas, for the hot water produced in a cogeneration system and for the digested sludge to be used as a fertiliser.

The environmental implications are mainly benefits to the local and regional communities in the provision of a centralised waste treatment facility and the potential for capturing untreated waste water and other waste products presently disposed of on land or to landfill sites.

Problems associated with landfill sites include the organic contamination of groundwaters. In the regions of Australia which already have salinity problems and high water tables, these are exacerbated by the irrigation practices using untreated or partially treated industrial and animal wastes. The major source of waterway nullification is the use of inappropriate effluent disposal techniques, runoff of nutrient rich water and leaching of nutrients into the shallow groundwater table from pig and dairy farms.

Wastewaters produced may require further treatment before being disposed of to either irrigation drains or to land as irrigation water. Careful siting of wastewater disposal and pondages will be required to avoid leaching to groundwater.

To maximise environmental benefits piping the waste to the conversion facility would be preferable to road transport. At a national level there are large potential benefits to improve water quality and excessive leaching of nutrients to the groundwater table.

Other environmental benefits include the reduction in CO_2 and CH4 gas emissions from the decay of the solid fraction of the biowastes effluent, and the production of electricity for export to the regional grid. A qualitative analysis would suggest that there is the potential for significant savings in energy and greenhouse gas production.

The actions recommended in this area of biomass to energy system development are:

Further work should be done on the price and demand for by-products, in particular organic fertilizer

A plant demonstrating grid-connected regional biogas production from a mixed waste stream should be supported

The potential markets for the application of anaerobic technologies developed in Australia should be identified and demonstration encouraged in key market ruches

Export opportunities for demonstrated technologies should be identified and facilitated, with particular emphasis on the US, Korea and Malaysia.

8.0 STRATEGIC PLAN

8.0 STRATEGIC PLAN

8.1 INTRODUCTION

This Strategic Plan sets out a program of activities to develop and promote the biomass-based energy industry in Australia. These activities range from market development both in Australia and overseas, through to research, development and demonstration of promising technologies.

The Strategic Plan is based on the findings developed in the preceeding sections of this report, which showed that the most promising biomass-based energy systems in Australia are

- liquid fuels production from food processing wastes and lignocellulose
- heat and electricity production from lignocellulose and a number of waste streams, including municipal solid waste, food processing and other industrial wastes, and animal and human wastes.

These systems are at varying stages of development in Australia. For those that are at the commercial stage or close to it, the major activities required to promote them are industry and market development. For other systems, including leading edge Australian technologies, further research and development is required. Support for demonstration projects would assist the adoption of all these systems in the domestic market and make access to overseas markets easier.

The most abundant biomass resource for energy production was found to be lignocellulose. There will be competition for this resource from both the liquid fuel and heat and power biomass industry. The energy product produced at a particular site will ultimately be determined by local and regional factors.

For both conventional and alternative energy systems in Australia, government programs can have a substantial effect on the cost of raw material inputs as well as the price of the final energy product. Government policy stances will be important therefore in determining the short and medium term viability of the biomass-based energy industry in Australia.

This Strategic Plan is organised around three major programs. These and their constituent activities are as follows:

(i) Industry and Market Development Program

Biomass-Based Energy Industry Association

Market Development Activities

Lowering the Cost of Lignocellulosic Biomass Resources

Quantifying the Environmental Benefits of Agroforestry

(ii) Liquid Fuels from Biomass Program

Maintaining the Tax Free Status of Biomass Derived Liquid Fuels

Developing the Market for Fuel Ethanol

Promoting Ethanol Production from Food Industry Wastes

Demonstrating Ethanol Production from Food Industry Wastes

Reducing the Costs of Ethanol Production from Lignocellulosic Feedstocks

Demonstrating Ethanol Production from Lignocellulosic Feedstocks

(iii) Heat and Electricity from Biomass Program

Promoting to Key Target Markets

Demonstrating Small Scale Gasification

Developing and Demonstrating Large Scale Gasification

Promoting Anaerobic Digestion Systems

Demonstrating Anaerobic Digestion for Mixed Waste Streams

For each of these programs a summary is given of the relevant conclusions from the Study in order to provide a context for the specific project activities within each program. For each project, the Strategic Plan provides the following information:

- objectives for the project
- brief description and rationale

- a list of stakeholders
- a list of required actions, and
- expected outcomes

8.2 INDUSTRY AND MARKET DEVELOPMENT PROGRAM

Objective

The objective of this program is to undertake activities to strengthen and develop the biomass-based energy industry in Australia and to develop markets in Australia and overseas.

Description

One of the main barriers to the growth of the biomass-based energy industry is that the industry is at a very early stage of development and the main players in the industry are generally very small organisations. Because of this there has been a lack of an effective focal point to promote the industry to Government, potential investors and other decision-makers who have influence over the course of the industry.

This barrier can be overcome by the creation of a Biomass-Based Energy Industry Association (BEIA) with support from key stakeholders including Government.

Because the industry is characterised by small organisations with limited resources the identification and development of market opportunities has been unco-ordinated and unsystematic. One of the main activities of the BEIA therefore should be to provide resources for planned market development in Australia and overseas.

Activities

The four activities in this program are:

8.2.1 Biomass-Based Energy Industry Association

8.2.2 Market Development Activities

8.2.3 Lowering the Cost of Lignocellulose BiomassResources

8.2.4 Quantifying the Environmental Benefits of Agroforestry

8.2.1 BIOMASS-BASED ENERGY INDUSTRY ASSOCIATION

Objective

The objective of this project is the creation of a Biomass-Based Energy Industry Association to promote the interests of the industry in Australia.

Description

The Study found that there are quite a few organisations with an interest in the development of the biomass-based energy industry in Australia. These organisations include

- companies interested in selling and/or developing biomass-based energy systems
- research organisations developing these systems in whole or in part
- government organisations interested in promoting these systems for market development, environmental and other reasons
- electricity generation and distribution agencies
- liquid fuel manufacturers and distributors
- other energy producers and distributors
- biomass resource producers

While many of these organisations are members of industry associations covering the energy sector or other resource sectors, there is no one association in Australia which concentrates solely on promoting and steering the development of the biomass-based energy industry. The formation of a **Biomass-based Energy Industry Association** will help to overcome some of the barriers to the creation of a flourishing industry which can achieve significant market penetration both in Australia and overseas. These barriers include the small size of most of the companies involved in the industry, the lack of awareness of the benefits of biomass-based energy systems among potential customers, and the lack of a single voice promoting the industry to Government. The Solid Fuel and Wood Heating Association may provide an appropriate model for the BEIA.

Stakeholders

The Energy Research and Development Corporation (ERDC)
The Department of Primary Industries and Energy (DPIE)
The Grains Research and Development Corporation (GRDC)
The Rural Industries Research and Development Corporation (RIRDC)
The Department of Environment, Sport and Territories (DEST)
The Department of Industry, Science and Technology (DIST)

and the industry and research groups listed above.

Actions Required

The stakeholders, or a subset of them, should convene a meeting in the second half of November 1994 of interested parties to discuss the formation of a Biomass-Based Energy Industry Association. They should:

- identify the key industry groups that would form a nucleus for the proposed BEIA.
- convene a workshop to define the objectives of the BEIA, structure, composition, mode of operation and funding options.
- appoint a full-time officer to develop a business plan for the association and obtain industry and government support.
- if sufficient support is gained, establish the BEIA and appoint a full-time CEO

Outcomes

It should be an aim to have the BEIA established with agreed objectives, strategic plan, budget and membership by end of June 1995.

8.2.2 MARKET DEVELOPMENT ACTIVITIES

Objective

The objective of this project is to undertake activities to develop the market for biomass-based energy systems and products in Australia and overseas.

Description

The Study identified the key markets for the following biomass to energy technologies in both Australia and in export markets:

In the short term they are

- heat and/or power from direct combustion
- gas, heat and/or power from anaerobic digestion
- ethanol from food processing wastes

In the medium to long term they are

- heat and power from gasification
- ethanol from lignocellulose.

The main players in the industry individually do not have enough resources to identify and exploit fully the market opportunities in Australia and overseas.

One of the main functions of the Biomass-Based Energy Industry Association therefore should be to follow-up on the market opportunities identified in the Study by developing detailed marketing plans based on the capability of the industry in Australia and the market opportunities identified in the Study in Asia, the United States, and Europe.

The co-operation of Austrade should be sought for this. A model for this activity exists in both the energy and environmental management industries which formed Austenergy and Austemex to identify and develop export markets for these industries.

Stakeholders

ERDC/DPIE
DEST
Austrade
Australian International Development Assistance Bureau
DIST

Actions Required

This activity should be funded by the stakeholders.

Two full-time appropriately qualified market development officers, one for the domestic and one for export, should be recruited by BEIA for a year in the first quarter of 1995 to develop a marketing plan for short to medium term opportunities. The appointments should be reviewed at the end of the contract period.

Once the marketing plan has been developed, the BEIA should discuss with Austrade how to locate an export market development officer in an Austrade office in one of the key export markets to capitalise on opportunities.

Outcomes

The marketing plan should be finalised by June 1995.

Target levels should be set for the amount of business identified by the marketing plan.

8.2.3 LOWERING THE COST OF LIGNOCELLULOSIC BIOMASS RESOURCES

Objectives

The objectives of this project are

(i) to identify opportunities for cost reductions in the production and delivery of biomass to achieve a delivered cost of less than $20 a dry tonne for biomass energy production.

(ii) to introduce these opportunities and demonstrate low cost biomass production in a regional case study project.

Description

The Study found that there are sufficient lignocellulose resources presently available in the form of

- agricultural residues
- forestry and plantation residues
- primary processing residues
- urban green wastes, and
- paper and paper processing wastes

to support the development of a sustainable industry producing liquid fuels and heat and power from biomass that could be of national significance in the short to medium term.

However the Study found that the management techniques and environmental implications of the removal of residues from native forests need to be assessed.

Future resources could include biomass from agroforestry and that grown to rehabilitate marginal degraded land which is presently unproductive.

Ultimately, local and regional issues will determine which energy product is the most appropriate to produce at a particular site.

The development of agroforestry is being hampered by a lack of information on the net environmental and economic benefits to farmers and by a lack of markets for residues from wood sold for sawlog or pulp and paper production and for surplus wood. Perennial woody shrubs and grasses to rehabilitate marginal land need to be continuously harvested and could provide a further source of biomass feedstock.

Coppice farming of trees has the potential to provide a low cost source of biomass for ethanol production. Because little work has been done in Australia in this area, a study should be undertaken to assess the potential of high productivity coppice farming of trees.

A barrier to the use of the residues listed above is their high cost.

The Study determined that average delivered cost of biomass to a commercial facility using currently available lignocellulose resources is between $60 to $75 a dry tonne if fully costed, and between $26 and $42 a dry tonne for residues, depending on the ethanol plant capacity.

Urban green wastes offer a low cost biomass, but are presently landfilled. The price of disposal to landfill is not yet high enough to provide an incentive to recover the 800,000 tonnes of paper from the solid waste streams that are disposed of in this way.

A study should be conducted into the impact of landfill charges on the economics of recovering additional paper from waste streams.

There are opportunities to reduce resource costs through increased productivity, by utilising residues resulting from the harvesting of higher value products, by the use of multi-crop species, and by developing more efficient harvesting, collection, storage and transport techniques.

Stakeholders

DPIE
ERDC
DEST
RIRDC
GRDC
Timber industry
Primary producers

Actions Required

The relevant study funding partners should commence jointly funded studies in early 1995 to:

- examine the potential for cost savings arising from the introduction of innovative one-pass techniques for harvesting and transport of wheat straw, forest and plantation wood residues, and support the development and demonstration of promising technologies
- assess the potential of multiple product agroforestry tree crops for high value products which will produce low cost residues for energy production
- assess the potential benefits and costs of high yield dryland and sewage irrigated coppice farming of crops grown for energy purposes
- determine the best way to demonstrate state of the art low cost biomass production at a regional site such as Esperance in Western Australia, using the findings of the above studies.

A study should be commenced by the end of 1994 into the impact of landfill charges on the economics of recovering additional paper from waste streams.

In addition, a study should commence by mid 1995 to:

- assess the impacts of additional lignocellulose harvesting for energy production on the nutrient cycle of multiple use native forests and the attendant long term environmental and economic impacts
- assess the impacts of a lignocellulose market on native forest management techniques and consequent social, economic and environmental impacts

Outcomes

Identification and demonstration of the potential to reduce delivered biomass costs to less than $20 a dry tonne by end of 1997.

8.2.4 QUANTIFYING THE ENVIRONMENTAL BENEFITS OF AGROFORESTRY

Objective

The objective of this project is to determine the net environmental benefits of the use of agroforestry and other biomass in improving farm productivity, salinity and erosion control and land rehabilitation.

Description

The Study found that the cost of producing energy from lignocellulose is affected significantly by the cost of the lignocellulose feedstock.

One possible source of this biomass is residues from agroforestry and other biomass grown for salinity and erosion control, and marginal land rehabilitation. There are potentially large environmental and other benefits from the widespread adoption of this approach.

These environmental benefits need to be quantified as far as possible to determine whether there is sufficient justification for the Government to subsidise this type of activity. If this proves to be the case, the Government may also wish to direct that the biomass residues arising from the harvest of this resource be provided at low cost to ethanol production facilities.

Stakeholders

DEST
RIRDC
Forestry organisations
Landcare
Land and Water Resources Research and Development Corporation (LWRRDC)

Actions Required

Resources should be provided by the stakeholders for a study to commence in early 1995.

Outcomes

A comprehensive understanding of the net environmental and other benefits by the end of 1995.

8.3 LIQUID FUELS FROM BIOMASS PROGRAM

Objectives

The objectives of this program are to develop and promote a viable liquid fuels from biomass industry in Australia and to develop export markets for expertise and technologies.

Description

This program consists of a number of activities designed to develop the biomass-based liquid fuels industry in Australia. These activities are aimed at simultaneously building a market and distribution system for these fuels as well as encouraging targeted industry sectors to build liquid fuels production facilities.

This is backed by a range of research, development and demonstration projects designed to enhance the competitiveness of the industry and expand its scope.

Emphasis is given to ethanol because an opportunity exists in Australia competitively to produce and use biomass derived ethanol as a fuel extender and oxygenate in low blends with petrol and diesel without changes to the existing vehicle fleet. The size of this market is around 5,400 megalitres per year. In the longer term furans and other products, such as ETBE, derived from biomass also have the potential for use as an oxygenate. The development overseas of flexible fuel vehicles and engines dedicated to the use of neat or high alcohol blends with petrol will open further market opportunities.

If technology and industry development take place, opportunities will arise to export technologies to Asia, the US and other parts of the world.

The opportunity to develop this industry in Australia arises because the wholesale price of petrol and diesel includes excise and taxes which bring the price up to a total of 50 cents per litre when delivered to the retailer. Fuel ethanol is presently exempt from these charges. The Study has shown that ethanol produced from food processing wastes can be supplied to the retailer at this price or lower. The maximum amount of ethanol available from this source is estimated to be 500 million litres per year.

A key factor in the development of the industry is the maintenance of the tax advantage for ethanol and for other biomass-derived liquid fuel products in the future.

In addition there are a number of barriers to be overcome in developing a market for these fuels.

Petrol retailing is controlled to a large extent by the oil companies who have a commitment to the production and sale of conventional liquid fuels and are reluctant to blend ethanol for a variety of perceived technical and economic reasons.

A strategy should be developed to identify and overcome any real technical and economic barriers to the acceptance of ethanol by the oil companies.

There are however a small number of independent distributors who account for a small percentage of the market. One of these distributors is selling a 7% ethanol blend at the same price as unleaded petrol, using ethanol produced by the Manildra Group which is presently Australia's only producer of fuel ethanol. A demonstration project blending ethanol with diesel is underway using an Australian developed emulsifier.

A route to increased market penetration is therefore to promote the uptake of ethanol by other independent distributors and selected oil companies.

The market for ethanol as a fuel could also be enhanced if major motor vehicle fleet operators could be encouraged to switch to ethanol blends, or if they could be encouraged to utilise flexible fuel vehicles or vehicles installed with dedicated ethanol engines.

The distribution and marketing of neat ethanol fuels offers opportunities to independants similar to those already established in Australia by CNG or LPG suppliers. These opportunities are already being taken up in the US by the alcohol producers.

As demonstrated by Manildra, food processing wastes containing sugars and starches are a low cost feedstock for fuel ethanol production.

Ethanol production should be promoted to targeted companies in the food processing industry as an economically and environmentally attractive option for the treatment of waste.

As part of this, assistance should be given to projects that demonstrate viable production from a variety of waste streams.

Ethanol can also be produced from resources containing lignocellulose such as agricultural and forestry residues, the green component of municipal solid wastes, and waste paper.

The competitiveness of ethanol production using these resources is more difficult to assess as no commercial facilities are in operation. The Study estimated however that costs are likely to be in the range of 60 to 85 cents a litre depending on the cost of the resource and the technology used.

The competitiveness of this process can be improved by reducing the costs of the biomass resources used and by improvements to various stages of the conversion process.

In Australia the Study estimated that the maximum capacity of a plant would be around 150 million litres a year given resource densities and transport costs. This limits the extent to which costs can be reduced through economies of scale.

Reductions in resource costs can be obtained through a research and development program to improve harvesting, growing and transport systems.

There are a number of ways to reduce the cost of lignocellulose conversion. These include:

- reducing the capital cost of the plant by improving process technologies
- improving the yields and efficiencies of various stages of the process
- reducing the operating costs of the plant.

As there are currently no facilities of this type operating in Australia, a demonstration facility based on the best emerging technology should be built. This would enable more accurate cost estimates to be obtained as well as a better understanding of the engineering and environmental issues to be resolved.

This would also provide the best vehicle for a research and development program aimed at reducing ethanol production costs.

The economic attractiveness of ethanol production can be further enhanced if markets can be found for by-products so a study should be undertaken to identify these opportunities.

There are significant environmental benefits associated with the introduction of ethanol as a fuel including land rehabilitation as a result of biomass feedstock production, and reductions in both greenhouse gas production and other air pollution.

The Government should assess the extent to which these environmental benefits can be quantified and, on the basis of this, decide to what extent the production cost of ethanol should be subsidised due to these externalities.

Activities

The activities to be undertaken in this program are.

8.3.1 Maintaining the Tax Free Status of Biomass Derived Liquid Fuels

8.3.2 Developing the Market for Fuel Ethanol

8.3.3 Promotion of Ethanol Production from Food Industry Wastes

8.3.4 Demonstration of Ethanol Production from Food Industry Wastes

8.3.5 Reducing the Costs of Ethanol Production from Lignocellulosic Feedstocks

8.3.6 Demonstrating Ethanol Production from Lignocellulosic Feedstocks

8.3.1 MAINTAINING THE TAX FREE STATUS FOR BIOMASS DERIVED LIQUID FUELS

Objective

The objective of this project is to ensure that biomass-derived liquid fuels do not attract the taxes and excises currently levied on petrol and diesel.

Description

The Study showed that biomass derived fuels can be competitive with petrol and diesel when delivered to the retailer. This is because taxes and excises are levied on the ex-refinery price of petrol raising the price from around 20 cents a litre to 50 cents a litre to the retailer. Fuel ethanol, for example, does not currently attract these charges which opens an opportunity to supply ethanol to the retailer at about 55 cents a litre. The same advantages should be sought for other biomass-derived liquid fuels including ETBE and furans.

It is important therefore that biomass derived liquid fuels not be subject to any taxes or additional charges levied by Governments while the market for them is being developed over the next ten years. This will enable the industry to develop with confidence, for technological improvement to reduce the cost of production from biomass to be pursued, for the effects on government revenues to be monitored, and the net environmental and other benefits to be assessed.

Stakeholders

DIST
DEST
DPIE
BEIA
Department of Transport (DOT)
Department of Finance (DOF)
Department of the Treasury (DT)

Actions Required

The stakeholders should review legislation and regulations relevant to the tax-free status of fuel ethanol to ensure its continuity for ten years.

The BEIA should consult with other interested organisations and lobby to achieve bipartisan support for the continuation of this tax-free status.

Outcomes

Achievement of agreement by all political parties to continue the tax-free status of ethanol as a liquid fuel until 2005.

8.3.2 DEVELOPING THE MARKET FOR FUEL ETHANOL

Objectives

The objectives of this project are

(i) to establish a distribution network for supply of ethanol to the retail market for liquid fuels.

(ii) to obtain commitment by one or more operators of large motor vehicle fleets to use ethanol as a fuel extender.

(iii) to develop and implement a publicity and marketing program to increase consumer demand for fuel ethanol as an extender.

Description

The Biomass Study has demonstrated that ethanol can be competitive with petrol and diesel in the liquid fuels market provided the excise free status is retained. However there is reluctance among the existing distributors to accept ethanol as a blended component with these fuels. The reasons cited by the oil industry are the vapour pressure characteristics of ethanol in petrol blends, the cost of modifying refinery and distribution infrastructure and the potential damage to the existing fleet. The Manildra Group and its independent distributor/retailer, Bowen, in NSW are marketing ethanol as a 7% splash blended mixture with petrol at no extra cost to the consumer. They claim that these problems have not been encountered but rather that vehicle performance is enhanced and consumers prefer a more environmentally friendly fuel.

The performance and consumer acceptance of using ethanol in the market should be evaluated, based on the experience of Manildra as a supplier and Bowen as the distributor/marketer.

A program should be undertaken to convince other independent fuel distributors to accept and market ethanol to consumers.

A program should also be undertaken to identify those major oil companies that are in a position to exploit the potential of ethanol fuels and to facilitate the purchasing and marketing of ethanol as a transport fuel through their existing retailing networks.

A significant proportion of the market for liquid fuels is accounted for by large fleet operators in both the private and public sectors. Market penetration would be enhanced if one or more of these made a commitment to using ethanol fuel blends in their vehicles.

A program should be mounted to convince one or more large fleet owners of the benefits of using ethanol blends and to gain their agreement to purchasing and using ethanol in significant quantities.

There is also a potential for developing a market for high ethanol blends or neat ethanol in automotive engines. A neat fuel market could be developed through a separate distribution system to that for conventional fuels systems operated by the oil companies. This is already being done in Australia for CNG or LPG. This type of development is taking place in the US as a result of oil company resistance. Flexible fuel vehicles and dedicated ethanol engines have been developed to utilise neat ethanol.

The possibility of using ethanol in flexible fuel vehicles and demonstrating ethanol use in dedicated engines should be explored with vehicle and engine manufacturers and with existing and potential ethanol producers, with a view to developing a strategy for further market development.

A publicity and marketing program should be initiated regionally and nationally publicising the benefits and success of the both the Manildra marketing program and programs set up as a result of achieving the first two objectives of this project.

Stakeholders

DPIE
DEST
Ethanol producers
Independent liquid fuel distributors and retailers
Oil companies
Large motor vehicle fleet operators
Vehicle and engine manufacturers

Actions Required

The Government should jointly fund a study beginning in early 1995 to:

- evaluate the performance and customer acceptance of ethanol-petrol blends currently being marketed and the ethanol-diesel blends currently being tested
- identify the best ways of promoting the benefits of fuel ethanol blends to independent distributors and facilitating their participation in marketing the product, contingent on the above evaluations
- identify appropriate oil companies for an ethanol blend marketing program
- identify one or more large fleet operators with a view to obtaining their commitment to purchasing ethanol as a fuel.

Programs should be funded and commence in the second half of 1995 to implement the recommendations of this study.

Discussions should commence in early 1995 with ethanol producers and vehicle and engine manufacturers with a view to demonstrating flexible fuel vehicles and dedicated ethanol engines in vehicles, and exploring the potential of developing further markets for ethanol as a neat fuel.

Decisions should be made by the end of 1995 on how to exploit the opportunities arising from these discussions including, if necessary, a regional and national publicity and marketing program .

Outcomes

A market for ethanol fuel in vehicles of at least 500 million litres by the year 2000 through the establishment of marketing networks with at least one additional independent distributor and one major oil company.

Demonstration of the acceptability of ethanol in flexible fuel vehicles and as a neat fuel in dedicated engines by 1997.

8.3.3 PROMOTION OF ETHANOL PRODUCTION FROM FOOD INDUSTRY WASTES

Objectives

The objectives of this project are

(i) to identify opportunities for the utilisation of agriculture and food processing industry wastes in Australia for ethanol production.

(ii) to promote these opportunities to the industry and facilitate their introduction to achieve a fuel ethanol production from this resource of 300 million litres annually by the year 2000.

Description

Wastes produced by the food processing industry often contain high amounts of carbohydrates suitable for conversion to ethanol. The Study has shown that there is considerable potential for promoting these systems to food processing companies interested in recovering the significant costs involved in the disposal of these wastes.

The Study has identified potential for ethanol plants in the starch processing, potato processing and other parts of the food processing industry.

A complete inventory of food processing wastes needs to be compiled based on the information in the Study and other surveys such as that undertaken in Tasmania. This inventory would identify, quantify and characterise wastes and their suitability for ethanol production and identify key locations for ethanol facilities.

Using the information provided by the inventory, a program should be designed to promote the benefits of ethanol production to the food processing industry. These benefits include avoidance of waste disposal costs, revenue from sale of ethanol and by-products, and recycling of water to food processing operations or farm irrigation. The experience of the Manildra operation in southern NSW would provide valuable information for this promotion.

Given the diverse nature of food processing wastes, they require case-by-case pre-feasibility studies and evaluation in the laboratory to assess key process design and performance parameters. This would minimise investment risks in the establishment of commercial facilities.

Stakeholders

ERDC
DEST
RIRDC
Horticulture Research and Development Corporation (HRDC)
GRDC
Food processing companies
Ethanol producers
Ethanol distributors and marketers

Actions Required

A study should commence in early 1995 to develop a comprehensive inventory of food processing wastes suitable for ethanol production.

A program should commence in mid 1995 to promote the benefits to food processing companies.

Resources totalling $150,000 on a dollar-for-dollar basis should be made available from mid 1995 for up to 10 pre-feasibility studies across a range of food processing industries. These funds would be used to facilitate and assist, where necessary, with simple laboratory evaluation of feedstock fermentability, process design, ethanol plant waste treatment requirements and securing marketing agreements for the ethanol fuel produced.

Outcomes

The production of an inventory of wastes suitable for ethanol production by June 1995.

The facilitation of a total installed production capacity of at least 30 fuel ethanol plants using food industry wastes over the next five years.

8.3.4 DEMONSTRATION OF ETHANOL PRODUCTION FROM FOOD INDUSTRY WASTES

Objectives

The objective of this project is to demonstrate fuel ethanol production as an economically feasible, low cost waste disposal option for food processing wastes.

Description

The Study found that waste biomass resources produced in the food processing industry and used for ethanol production will usually result in a production price between 25 and 50 cents a litre using small plants in the capacity range 5 - 20 million litres a year. This price is very competitive with the price of petrol to the fuel distributor or retailer.

The lower end of the production price range can be achieved by building low cost 'build-own-operate' projects located at the site where the wastes are produced and made available to the ethanol plant at no or low cost to reflect a credit for its disposal as a waste product.

Whilst the technologies for ethanol production from starch and sugars are proven, the key requirements for a viable project are low capital and operating costs for the plant and confirmation that the effluent produced by the process is acceptable for disposal into the environment.

Capital investment estimates made by industry for 'build-own-operate' projects of this type are claimed to be significantly lower, by a factor of two or three, than those made from the formal engineering company approach developed in the Study.

It is of importance to understand whether this type of plant can be built as cheaply as claimed as the potential impact on project returns is of major importance. The successful demonstration of the technical, economic and environmental performance of this type of project will enhance acceptance of this technology as a viable waste disposal option by the target market.

Stakeholders

DPEE
ERDC
DEST
RIRDC
GRDC
Food processors
Potential ethanol producers

Actions Required

The study funding partners should examine in detail project studies presently being undertaken to produce fuel ethanol from food processing wastes with a view to selecting one project, other than a starch processing facility, for financial support as a demonstration project by mid 1995.

Outcomes

The construction of low capital cost, economic and environmentally viable demonstration project to produce at least 10 million litres of fuel ethanol from food processing wastes by December 1995.

8.3.5 REDUCING THE COSTS OF ETHANOL PRODUCTION FROM LIGNOCELLULOSIC FEEDSTOCKS

Objectives

The objectives of this project are

(i) to undertake a research and development program aimed at reducing the costs of producing ethanol from lignocellulose.

(ii) to investigate innovative high-value opportunities for by-product production and utilisation.

Description

Technologies for the conversion of lignocellulose to ethanol are presently emerging and unproven, with cost estimates indicating ethanol production prices of between 60 to 85 cents a litre , depending on the average price of delivered biomass. Reducing these costs to about 50 cents a litre will open up a potential supply of resources for fuel ethanol production of national significance.

The choice of process, the capital cost of the plant, the cost of production and any potential income obtained from by-products can all contribute significantly to the net production cost of ethanol.

The largest capital and operating cost items in the lignocellulose plant are the feedstock handling and pre-treatment stages, and the hydrolysis and fermentation stages. They therefore offer the best potential for cost reduction.

Maintaining high yields in the conversion of carbohydrate components in the biomass to alcohol are also extremely important.

Native Australian woods are likely to exhibit particular problems given their high content of oils and other aromatic components. There may be opportunities to remove these and other useful chemicals for recovery as saleable by- products in novel pretreatment processes.

A multidisciplinary research and development program should be undertaken to address these opportunities for reducing the cost of ethanol produced from lignocellulose.

Potential income from the sale of by-products, which could include lignins, electric power from cogeneration boilers using processing and other biomass wastes, sugar derivatives, wood oils and aromatic chemicals will assist in reducing the ethanol price.

A review of potential opportunities to realise by-product income should be undertaken.

ERDC, together with other funding partners, is undertaking a worldwide review of research, development and demonstration in the area of lignocellulose to ethanol technologies which is expected to identify the key issues dealt with above in more detail than this Study.

Stakeholders

DPIE
ERDC
Technology developers
Research organisations

Actions Required

Based on the current review of ethanol from lignocellulose technology development being undertaken worldwide, funds should be allocated totalling $200,000 to undertake the following activities:

- assess, analyse and clearly understand in detail the key technical and economic relationships affecting the viability of ethanol from lignocellulose processes
- instigate a round table of stakeholders to identify innovative solutions that will address these key relationships
- identify priorities for development
- design programs for implementation in Project 8.3.6 of this Strategic Plan.

Outcomes

Identification of key areas which offer a significant potential to improve fuel ethanol production economics by March 1995.

Develop and refine these key concepts by December 1995.

8.3.6 DEMONSTRATING ETHANOL PRODUCTION FROM LIGNOCELLULOSIC FEEDSTOCKS

Objectives

The objectives of this project are:

(i) to demonstrate the most appropriate state of the art technology for fuel ethanol production from lignocellulosic biomass in Australia.

(ii) to develop and demonstrate innovative technologies that will significantly reduce the production cost of fuel ethanol from lignocellulose to below 50 cents per litre.

Description

The technology for producing ethanol from lignocellulose and waste paper is still in development phase. Several processes are reaching the demonstration phase world-wide that have been developed as integrated pretreatment, hydrolysis and fermentation systems.

Full scale design and feasibility studies for at least three technologies and construction of demonstration facilities for at least two processes are presently underway in the US.

One such design study is being carried out in Australia by APACE Research, incorporating fermentation technology being developed by the University of New South Wales and the APACE Research ethanol recovery and waste treatment process.

The Study has shown that there are a number of ways to reduce the cost of producing ethanol from lignocellulose feedstocks. These include:

- reducing the capital cost of the plant by improving process technologies
- improving the overall efficiency of each process stage
- reducing the operating costs of the plant

As there are currently no facilities of this type operating in Australia, a demonstration facility based on the best emerging technology should be built. This would enable more accurate cost estimates to be obtained as well as a better understanding of the engineering and environmental issues to be resolved.

This would also provide the best vehicle for a research and development program aimed at reducing ethanol production costs.

Stakeholders

DPIE
DEST
ERDC
Technology owners
Process developers
Process design and contractors
Potential ethanol producers

Actions Required

The stakeholders should

- support and facilitate the construction of an appropriate pilot/demonstration facility in Australia, built using both private and public sector funds

- facilitate the allocation of the 18 cents a litre ethanol bounty to cover all ethanol produced in the facility and used as fuel

- allocate funds, totalling $2 million already set aside by the Federal Government for construction of a research and development facility, to develop and demonstrate the key technology and economic improvements identified in Project 8.3.5

Outcomes

Allocation of the research and development funding by November 1994

Allocation of the ethanol bounty by July 1995

Complete design, construction and commissioning of the demonstration ethanol from lignocellulose facility by December 1995

Completion of research and development for innovation by April 1998

Scale up of the demonstration facility to 50 million litres a year incorporating the improved technologies completed by December 1998.

8.4 HEAT AND ELECTRICITY FROM BIOMASS PROGRAM

Objectives

The objective of this program is to develop a sustainable industry in the production of heat and/or electricity from biomass resources.

Description

This program is a set of activities aimed at overcoming the major barriers preventing the development of a viable industry in the production of heat, steam and electricity from the combustion and gasification of biomass, principally wastes.

The domestic wood heating industry is well developed and presently the largest biomass-based energy industry sector in Australia. World standard low emission appliances are being manufactured in Australia and companies are seeking to develop export markets. Opportunities exist to promote the industry within the domestic and export markets.

The market for commercial and industrial systems is estimated at 2000MW or about 5% of the Australian electricity market.

The principal barrier to the development of the industry is that electricity generated by coal, gas and hydroelectricity in Australia is relatively cheap.

The Biomass to Energy Study found that on average the price of electricity in Australia was about 8 cents per kilowatt hour to commercial and industrial users with the cost of production being as low as 3 to 4 cents a kWh. Reforms to the electricity generation and distribution industries are likely to reduce the price for urban users and raise the price for users in areas remote from generation facilities or at the end of the distribution grid. In the latter case this is because of high maintenance costs and high line losses.

New technologies to generate electricity from conventional resources are likely to reduce prices. The current excess capacity in electricity generation will also act to keep prices down

Opportunities for biomass-based systems will therefore be greatest in those country locations where there is an increasing demand for grid-supplied power and there are bottlenecks in the distribution system.

The demand for these systems will be highest where there are industries requiring complete reliability of supply or have heat and power demands that can be suitably matched to biomass cogeneration systems.

The Study showed that biomass-based systems will be most attractive when they can use a residue or waste product which is available free or where the user is paid to take the waste. In these situations the production of energy from biomass is often motivated by a desire to recover some of the costs associated with waste disposal as well as finding a cheaper source of energy than LNG or diesel fuel used to run generators. Interest in these systems will be stronger the higher is the cost of waste disposal.

While the Study has gone some of the way to identifying these potential users, further work should be undertaken to identify those primary resource processing facilities which have access to waste at little or no cost, can use the energy on site and are at end-of-grid locations.

Biomass-based systems should also be attractive to electricity distribution agencies faced with the high cost of extending or upgrading the distribution network to meet increased demand.

Local government authorities responsible for disposing of municipal solid waste are a potential target market for combustion and gasification systems for converting this waste into energy for use in their localities.

While the size of the facilities which these users can introduce will depend on the circumstances, it is expected that they will be of two types: small-scale systems in the range of 100 kW to 5 MW and larger systems in the range of 5MW to 50 MW.

The price barrier can also be reduced by improving the efficiency of combustion technologies and introducing the more efficient integrated gasification combined cycle turbine systems. These latter systems also have the advantage of being more environmentally friendly and can be applied to a wide range of biomass types.

Unlike combustion technologies which are relatively mature, technologies for gasifying biomass are only just emerging.

Both small-scale and larger gasification development and demonstration projects should be supported to more accurately assess their net economic and environmental benefits.

Heat and electricity can also be produced by anaerobic digestion of animal and human wastes, fermentable organic industrial wastes and the putrescible proportion of municipal solid waste. There are considerable environmental benefits from applying these technologies to treat these wastes.

Potential users are interested in these systems because of their potential to recover some of the costs of waste disposal through the sale of energy and by-products such as fertiliser. These have a significant impact on the economics of these systems.

These systems have been demonstrated on a small scale for animal wastes and should be promoted to the intensive livestock rearing industry. They should also be promoted to the food processing industry.

A large scale project should be supported to demonstrate the efficacy of using a mixed waste feedstock in these systems. If this proves economic it will enable these systems to be used in a greater variety of locations, particularly where there is a large local demand for heat and power.

Considerable potential exists for the export of this technology so key export markets should be identified and facilitated.

Activities

The activities to be undertaken in this program are:

8.4.1 Promoting to Key Target Markets

8.4.2 Demonstrating Small Scale Gasification

8.4.3 Developing and Demonstrating Large Scale Gasification

8.4.4 Promoting Anaerobic Digestion Systems

8.4.5 Demonstrating Anaerobic Digestion for Mixed Waste Streams

8.4.1 PROMOTING TO KEY TARGET MARKETS

Objectives

The objectives of this project are to:

(i) develop the domestic wood heating market in Australia by improved promotion.

(ii) encourage the installation of biomass-based heat and power systems by a targeted promotion program aimed at appropriate organisations in the primary resource processing and electricity generation industries.

Description

Domestic Wood Heating Market

The selection process for biomass systems focussed on heat and power production from commercial and industrial systems.

However the domestic wood heating industry is well developed and presently the largest biomass-based energy industry sector in Australia. It is supported by an active industry association, the Solid Fuel and Wood Heating Association (SFWHA) and technical research base in industry and the universities.

World standard low emission appliances have been developed and are being manufactured in Australia. Appliance accreditation mechanisms are in place to provide consumers with safe technology and installations, efficient appliances and low emission flue gases.

Surveys carried out by the industry indicate that market development has been hampered in recent years by consumer confusion with regard to the environmental acceptability of both using wood fuels and the technology.

Opportunities exist to support the industry and further develop the market for these appliances by promotion of the economic and environmental benefits of these technologies, and to educate the market place on fuel choice and environmentally acceptable operation.

Commercial/Industrial Market

The Study found that systems for converting biomass into heat, steam and electricity would be most competitive against conventional systems in certain markets. Electricity prices are or will be highest for users at the end of the distribution grid and for those a long distance from the point of centralised power generation. These users often face unreliable supply, high supply costs, and a need for power which is usually obtained by burning relatively expensive LPG and other non-renewable fuels. In these circumstances installing stand alone combustion and/or gasification systems to produce heat and electricity is an attractive option.

These systems will also be attractive to power generation organisations in situations where supplying electricity to customers from centralised generators would involve substantial cost in upgrading or extending the distribution network.

The other major market for biomass-based systems is in the processing of municipal solid waste. Local government authorities or their subcontractors are faced with rising costs for the disposal of this waste to landfill and are under increasing pressure to adopt environmentally better ways of handling this waste stream.

The technology for direct combustion of biomass to heat and electricity is well understood so the main activity for these systems should be their promotion to target markets.

A program should be undertaken to promote biomass-based systems in those rural locations with characteristics outlined above. Some of these locations have been identified by the Study and include East Gippsland, North Eastern and Wimmera regions in Victoria, Northern New South Wales, the Esperance region in Western Australia, the Eden, Tumut, Namoi and Leeton regions in New South Wales, and Northern Tasmania.

Within these locations, priority should be given to promoting these systems to organisations which either have significant wastes arising from their own production processes, such as forestry plantations, sawmills, woodchip operations, and wood product manufacturers, or have ready access to these wastes free or at low cost.

These systems should be promoted to the major electricity generation and distribution agencies and to local government authorities.

These promotional activities should be undertake in conjunction with the demonstration projects discussed elsewhere in this plan and should be coordinated with the market development activities of the proposed BEIA.

The active involvement of regional development agencies covering locations with the characteristics described above should be sought with a view to the efficient identification of target clients for these systems.

Stakeholders

The main parties expected to be interested and involved in the domestic wood heating market project are:

DEST
EPA
SFWHA
Local government
Energy Information Centres
Regional development agencies

The main parties expected to be interested in the commercial/industrial market project are

DPIE/ERDC
DEST
BEIA
Electricity generation and distribution agencies
Local government authorities
Regional development agencies

Actions Required

The stakeholders should undertake responsibility for the domestic wood heating market project directly through SFWHA and BEIA, with the project commencing by the end of the first half of 1995.

The project should:

- clarify the technical, economic and environmental issues relating to the industry, including those concerning the sustainability of fuel wood
- address any outstanding key issues that require resolution
- come to a common consensus on the required consumer messages

- promote these to the industry, stakeholders and the general public.

The Government should undertake responsibility for the commercial/industrial market project either directly or through BEIA with the project commencing by the end of the first half of 1995.

The project should be targeted at the locations mentioned above and further work should be done to identify other suitable locations.

Contact should be made with appropriate regional development agencies during the third quarter of 1995.

Outcomes

The domestic wood heating market project should aim to have a common framework for a national promotion program in place and begun promoting the benefits of industry by the end of 1995.

The commercial/industrial market project should aim to have identified at least twenty prospective commercial/industrial clients and begun promoting the benefits of these systems to them by the end of 1995.

8.4.2 DEMONSTRATING SMALL SCALE GASIFICATION

Objective

The objective of this project is to set up a demonstration facility to assess the net economic, technical and environmental benefits of an Australian developed gasification technology for small scale systems for converting biomass into heat, steam and electricity.

Description

The Study found that there is a significant potential market for biomass to heat and electricity systems in the range of 100kW to 5 MW electricity .

Direct combustion systems for this purpose are available in the market and their economics is well understood.

There is considerable opportunity to improve the performance of these systems through the application of a gasification stage prior to energy production. This has the potential to improve efficiency, lower the costs of production and to reduce environmental impacts.

A small scale gasification technology has been demonstrated at laboratory scale in Australia but its net benefits need to be shown at commercial size in-situ. The gasification technology being developed by Biomass Energy Systems and Technology Pty Ltd (BEST) and TREElectric Pty Ltd should be reviewed as a candidate for this demonstration project.

The expected cost of such a 1 MW demonstration plant is $1 million. The Commonwealth Government through ERDC should provide funding of around $200,000 for this project.

Stakeholders

DPIE/ERDC
DEST
Electricity generation authorities
Regional development agencies
Technology developers and marketers

Actions Required

The BEST/TREElectric technology should be assessed by March 1995.

Expressions of interest in managing, constructing and operating such a facility should be sought either by general advertisement or by approaches to organisations in locations targeted for the promotion program described in Project 8.4.1.

Expressions of interest should be submitted by end of June 1995, evaluated and the most suitable proposal chosen with a view to commencement of construction in the fourth quarter of 1995.

Outcomes

It is expected that it will be possible to demonstrate the viability and net benefits of small scale gasification based energy systems by the end of 1996.

8.4.3 DEVELOPING AND DEMONSTRATING LARGE SCALE GASIFICATION

Objective

The objective of this project is to set up a development and demonstration facility to assess the net economic, technical and environmental benefits of large scale integrated gasification combined cycle systems for converting biomass into heat, steam and electricity.

Description

The Study found that there is a significant potential market for biomass to heat and electricity systems in the range of 5MW to 50 MW electricity and above.

As is the case for small scale systems, direct combustion systems at larger scales are readily available and their economic and other characteristics are known.

The gasification of biomass for larger scale systems is an emerging technology world-wide with demonstration projects in progress overseas. HRL Limited has developed and successfully demonstrated brown coal-fired Integrated Gasification Combined Cycle (IGCC) technology which might be easily adapted to the gasification of biomass.

If superior economic and environmental benefits can be demonstrated for gasification systems there is significant potential for introducing large scale IGCC systems to convert low cost biomass to energy, particularly municipal solid waste.

A research and development program should be undertaken to adapt the HRL technology for systems converting biomass into heat and electricity and a 5MW capacity plant should be built to demonstrate its benefits.

Stakeholders

DPIE/ERDC
Electricity generation and distribution authorities
HRL Limited
Local government authorities
Regional development agencies

Actions Required

Funds should allocated for the research and development program which should begin not later than June 1995.

Once proven at the pilot plant stage, expressions of interest in managing, constructing and operating a demonstration facility should be sought either by general advertisement or by approaches to organisations in locations targeted for the promotion program described in Project 8.4.1.

The stakeholders should aim to have received expressions of interest by end of June 1996, to evaluate these and choose the most suitable proposal with a view to commence construction in the fourth quarter of 1996.

Outcomes

It is expected that it will be possible to demonstrate the net benefits of a large scale biomass IGCC system by the end of 1998.

8.4.4 PROMOTING ANAEROBIC DIGESTION SYSTEMS

Objective

The objective of this project is to promote anaerobic digestion systems that produce energy from biomass, principally animal and human wastes, and municipal solid waste.

Description

The Study has shown that anaerobic digestion systems are an attractive option for treatment of a range of animal, human, food processing and municipal solid wastes. These systems enable potential users to recover much of the cost of waste disposal as well as the opportunity to use the energy generated to replace conventional sources of energy. They also have important environmental benefits.

The return on the investment in these systems depends on the cost of alternative waste disposal methods and the price obtained from the fertiliser, cogenerated heat and other by-products.

As noted elsewhere such systems become more attractive where there is a waste disposal problem and a use for the gas and power on site. The economics of these systems are also favourable when the user is distant from conventional sources of energy and higher prices are paid for this energy.

The net benefits of these systems have been demonstrated in Australia and should be promoted to those organisations which produce a predominantly homogeneous waste stream. Several of these such as piggeries and other intensive livestock rearing operations, animal slaughtering operations, and food processing facilities such as wineries, starch processors, and potato processors have been identified in the Study. Further information should be sought as part of Project 8.3.2 about the location and potential for other similar industries such as confectionery manufacturers, soft drink manufacturers, and fruit and vegetable juicers and canners.

Stakeholders

DPIE/ERDC
DEST
BEIA
Pig Research and Development Corporation
Meat Research and Development Corporation
Grape and Wine Research and Development Corporation

Actions Required

These promotional activities should be carried out by the market development officer recommended for the BEIA (Project 8.2.2). They should commence in mid 1995.

Outcomes

It is expected that at least twenty opportunities be identified and ten systems be introduced by the end of 1996.

8.4.5 DEMONSTRATING ANAEROBIC DIGESTION FOR MIXED WASTE STREAMS

Objective

The objective of this project is to demonstrate the benefits of using anaerobic digestion systems for generating energy from mixed waste streams.

Description

The application of anaerobic digestion systems to homogeneous waste streams such as that produced by piggeries has been demonstrated and the net benefits in such situations are relatively well understood. There are opportunities however to extend the market for anaerobic digestion systems to organisations responsible for handling mixed waste streams such as municipal solid waste. These systems have been built in other countries such as Germany and Denmark but not in Australia. The viability of plants operating at around 0.5 to 1 MW electricity needs to be demonstrated so that these systems can be promoted in Australia.

Expressions of interest should be sought for building and operating a system . An anaerobic digestion system of this sort would cost around $3 million to build and funding of $0.5 million should be provided by the stakeholders.

Stakeholders

ERDC
Local government authorities
Regional development agencies

Actions Required

Expressions of interest should be sought by end of June 1995 with a view to building commencing by end of September 1995 with plant being operational by June 1996.

Outcomes

Information on the net benefits of an anaerobic digestion system handling a mixed waste stream should be available for promotion to target markets by the end of 1996.

BIOMASS IN THE ENERGY CYCLE

FINAL REPORT

ERRATA

MAIN REPORT

Page 56 Line 9 The words "150 KWe downdraft unit" should read " 150kWe entrained flow unit".

Page 63 Table 4.7 Column 2 Row 2 "BEST/EDL" should read "BEST/TREElectric".

Page 83 Paragraph 2. This should read

"Work in this area is also taking place in Australia on a 150kW unit to develop a commercial package for the 0.4-4MW range. Developed by Australian companies BEST and TREElectric, the units will be linked to power generating systems."

APPENDICES

Page 86 Paragraph 5 should read

"Energy Developments Limited (EDL) area active in power generation from landfill gas and claim to have 12 projects totalling $50 million either developed or under development in Australia. As a power producer, EDL are now expanding into other areas including wood waste utilisation."

Page 86 Delete Paragraph 6