The potential use of mimosa as fuel for power generation

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Abstract

In 1998–99, Biomass Energy Services & Technology Pty Ltd, the Northern Territory Department of Infrastructure, Planning & Environment and PowerWater Corporation, pooled resources, with the support of the federal government's Renewable Energy Industry Program, to investigate various techniques for using mimosa, *Mimosa pigra* L., as a fuel for the production of electricity and charcoal. This paper describes how that initiative led to the current proposal for a pilot electricity-generation plant that will use mimosa as fuel. It discusses the difficulties encountered, various options and issues that remain unresolved. The project is considered in the context of a weed-management tool and an electricity-generation facility. Conclusions will be drawn and reconsidered in the context of a much larger power station development.

Keywords: utilisation, pilot study, *Mimosa pigra*.

Introduction

In 1998/99, with the support of the Australian Government's Renewable Energy Industry Program (REIP), Biomass Energy Services and Technology Pty Ltd (BEST), the Northern Territory Department of Primary Industries and Fisheries (DIPF) (now known as the Department of Infrastructure, Planning and Environment: DIPE), and PowerWater Corporation (then the Power & Water Authority), pooled resources to investigate various techniques for using mimosa, *Mimosa pigra* L., as a fuel for the production of electricity and charcoal.

The project provides a case study that highlights the difficulty of converting potential into reality, particularly when the benefits that accrue from the project advantage more than one party. Under those circumstances, secular assessment of the benefits tends to diminish their gross value, complicating acceptance of the initiative as a valid investment. We also use the case study to review the technical, environmental and social considerations associated with the project.

In the electricity-generation industry, hydro generation can be used as an analogy for generating electricity from biomass. Water stored by a dam contains potential or stored energy that a generator can draw on whenever it suits. On the other hand, generating from a run of the river hydro set-up is much more opportunistic, with generation output being subject to the transient nature of stream flow. So then, is fossil fuel a stored biomass resource that the generator can draw on whenever it suits? Can mimosa be considered a potentially useful energy crop with generation output tied to the vagaries of seasonal behaviour?

Background

Mimosa is a native plant of Central and South America and probably entered the Northern Territory (NT) of Australia prior to the 1890s through

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the Darwin Botanic Gardens (Lonsdale *et al*. 1995). Mimosa is a leguminous thorny shrub that can grow to a height of six metres. It invades grassland communities on open floodplains, fringing paperbark swamps and billabongs, leaving only small remnants of open water. The invading weed forms a dense, practically mono-specific, tall scrubland in which the ground flora is sparse to non-existent (Braithwaite *et al*. 1989).

Mimosa is capable of totally displacing native species leaving bare mud behind if removed. It is a declared noxious weed with a range of common names including mimosa, prickly mimosa and giant sensitive plant. It is easily identified by the leaves, which immediately retract and fold up when touched.

It is now accepted that, due to budgetary constraints and the virile nature of the plant, mimosa will not be eradicated from the NT. Even its control relies on coordination of several complementary strategies, including tillage, herbicide treatment and biological control.

With an invasive weed, the commercial value of the biomass resource is zero. Because mimosa is a noxious weed that, in a commercial sense, renders productive land unproductive, its value as a resource is negative. In other words, its removal actually enhances the commercial value of the land.

The logic of using a noxious weed as fuel for generating electricity is twofold:

- the landholder is able to offset the cost of managing the weed against its value as a biomass fuel for power generation
- biomass as stored solar energy provides a traditionally acceptable option for PowerWater to meet its mandated renewable energy target of 2%.

An important aspect of the initiative is that the potential of the technology is not limited to areas where mimosa is endemic, and although this weed is the target species for this study, the potential for commercial application of the biomass processing technology in Australia is substantial. According to the Australian National Botanic Gardens <http://www.anbg.gov.au/weeds/index.html>:

> Plant species not native to Australia now account for about 15% of our total flora. About half of them invade native vegetation and about one quarter are regarded as serious environmental weeds.

The initiative commenced with a pre-feasibility study, carried out by PowerWater and BEST, which confirmed that mimosa was suitable for gasification. This provided the justification needed to conduct a full feasibility study.

The feasibility studies combined inputs from three sectors of industry. BEST provided its expertise to identify cost-effective techniques for producing fuel from mimosa, including briquetting, gasification of the briquettes and charcoal production. DPIE examined the logistics of harvesting the mimosa, including resource availability estimates. PowerWater provided a conceptual design of a prototype power station and grid interface, at the same time analysing the economic and environmental issues to derive possible mechanisms for commercialising the technology.

Approximately 1 tonne of chipped mimosa was delivered to BEST, this was then hammer-milled to a smaller size before being briquetted. The material also underwent a "conditioning" treatment, where it was dried and heated.

That study also examined the possibility of including urban green waste as a supplementary biomass fuel during the wet season, when access to the mimosa crop is difficult. There is sufficient material available at the Shoal Bay landfill site near Darwin, NT, to provide a useful supplement, but it includes a high percentage of second-grade biomass, mainly from palms, that would need to be separated from the better quality biomass before briquetting. These difficulties, in conjunction with the cost of transporting the briquettes to the power station, discount the value of this resource. Accordingly, its possible use was relegated to a later phase of the project.

Briquetting trials were successful and briquettes with densities ranging from 800–900 kg/m^3 were produced using mimosa screened to less than 8 mm. The briquettes that were formed, using conditioning temperatures greater than 220°C, showed very good resistance to water and were not very friable. That is, they withstood shocks similar to those experienced in handling and transportation without too much disintegration.

Two gasification trials were conducted. The first run had a specific gasification rate of approximately 2930 kg/hr.m^2 of throat area and ran for approximately 110 minutes. The range of air rates used for this test was between 0.25 and 0.4 Nm^3/s.m^2 cross-section area at the tuyeres. The thermal output was approximately 270 kW.

The second test had a specific gasification rate of approximately 1470 kg/hr.m^2 of throat area and ran for approximately 188 minutes. The thermal output was approximately 140 kW and the air rates used were between 0.16 and 0.18 Nm^3/s.m^2 cross-section area at the tuyeres. Table 1 shows the range of gas composition obtained from both gasification experiments.

Very little tar was produced in both gasification experiments, and there was only a small amount of char carry over. There were no problems with the operation of the grate and there was no build-up of slag. Thus, it can be concluded that briquettes made from mimosa are able to make a very good fuel source for gasification.

The results were used as a basis for cost estimates that confirmed the potential of the technology for electricity production. A proposal was prepared and government funding was provided for a proof-of-concept pilot-plant demonstration.

The NT Government through the Department Business, Industry and Resource Protection (DBIRD) concentrated on resource assessment. The Adelaide River floodplain system covers approximately 130,000 ha, fed by the Adelaide and Margaret rivers. The large river system drains the floodplain relatively early in the dry season, compared to other systems that lack major drainage structures. The infestation on the Adelaide River floodplain is the largest in the NT. Over 17,000 ha were mapped on the southern side of the Arnhem Highway, as part of the project. Pastoral leases account for the majority of the Adelaide River infestation.

The efforts of DBIRD failed to derive an accurate cost for harvesting the biomass of mimosa, and there are few relevant precedents to work from. Using available information, it seems that the price of this material may be in the order of $10 to $12 per tonne delivered to the power station. A "trial and error" process, best driven from the private sector by offering a price per tonne for harvested and chipped mimosa, is needed to determine the actual cost. It is expected that harvesting costs on day one will be much higher than twelve months later.

The recoverable yield per hectare of field-dried material is yet to be determined, and additional work is needed to secure an accurate estimate. Yields from stands of mimosa over five years old are known to be excellent, in the order of 35 to 45 tonnes per hectare, but this cannot be taken as representative. However, it is reasonable to expect the core stands of mature mimosa on the Adelaide River floodplain to yield an average of 20 to 30 tonnes per hectare.

With briquettes delivered to the power station, the average cost of generation for PowerWater is the limit within which the cost of the delivered fuel and its conversion to electricity must relate. In energy terms, this equates to the calorific value of the biomass, less any inefficiency in the process of converting the biomass to gas, less parasitic losses, less generator conversion efficiencies, less the cost of transporting the electricity to the market.

The research established that a kilogram of air-dried mimosa biomass has a net calorific value of 17.7 MJ. The gasification process is around 75% efficient, including losses due to unreacted char, with producer-gas having a typical calorific value of around 5,000 kJ/m^3. Conversion of that gas to electricity, at say 36% efficiency, produces around 1.25 kWh of electricity/kg dry biomass.

The proposed pilot plant

The project objective is to generate electricity from mimosa with a pilot plant of approximately 600 kW capacity, and feed the electricity into the Darwin/Katherine interconnected grid. The weed will be harvested in the dry season using existing techniques developed by farmers and DIPE, namely spraying and chaining with bulldozers. The area needed to provide sufficient biomass to power the 600 kW generator engine for a year can be chained in a few days. The cost of collecting the chained material for chipping is essentially unknown. Chipping costs are in the order of $5 to $8 per tonne.

Construction of a pilot plant will involve the following: government, finance sector, landholders, DIPE Weeds Branch (mimosa management), harvesting contractor, power station designer and builder, power station operator, and electricity purchaser/distributor/retailer.

The pilot plant (Figure 1) comprises:

- a storage area for briquettes
- a conveyor system from the fuel storage site to the plant
- a biomass gasifier
- gas treatment equipment
- a gas engine or turbine
- an electricity generator
- power conditioning and transportation infrastructure.

The feasibility studies concluded that the logical site for the prototype exercise is Beatrice

Table 1. Gas compositions (percentages by volume) of gasification tests.

		H_2	CO	CO_2	CH_4	N_2
Test 1	Range	13.8–21.8	16.8–21.4	9.3–12.2	0.6–1.8	48.3–54.9
	Average	18.0	18.6	10.9	1.3	51.1
Test 2	Range	9.6–18.1	19.6–23.9	9.3–11.8	0.7–1.9	48.8–57.9
	Average	13.7	21.5	10.5	1.3	53.0

Hill Station on the Adelaide River floodplain. Not only is this the heaviest infestation of the weed in the NT, but a 66 kV power line conveniently traverses the property adjacent to the infestation.

Central to the continuous operation of a mimosa-fed power plant is the ability to provide feed during the period of the year when the mimosa infestation is inundated with water or the ground is too wet for harvesting to take place. DIPE personnel have indicated that this non-harvesting period could last for up to six months at the Adelaide River infestation, depending on the severity of the wet season.

Sufficient harvested material will be chipped, dried, briquetted using the hot-briquetting process developed by BEST, and stored to overcome this problem. The briquetting process ensures that the stored mimosa does not become damp and composted during the wet season. The briquettes will be gasified in a downdraft gasifier to produce the fuel needed to run a conventional gas-engine generator.

It is estimated that the potential for the project to offset against the CO_2 that would otherwise be consumed in PowerWater's natural gas system, will be in the order of 620,000 tonnes over the 20-year life of the equipment, if the pilot project is expanded up to 6 MW.

The prototype might be expected to operate at around 80% capacity and, allowing a deduction of 10% for down-time due to the demonstration aspect of the project, should produce around 6 MWh/kW capacity/year.

The full implementation of this strategy will take three to six years, depending upon how quickly the cost of the harvesting can be reduced and higher output generators obtained.

Future issues

Major variables that the technology commercialisation process faces at this point in time are:

- What outstanding research and development into the process might reveal. We have yet to determine many aspects of the process, including what parts of the plant contain the most concentrated energy, is it possible to harvest the plant and prepare the fuel in a cost effective manner, do we need to improve the fuel conditioning processes, what are the most appropriate post harvest land management techniques, etc.?
- The impact of emerging technologies. For instance, the fuel cell. Mimosa produces a fuel that is high in hydrogen content. Conventional motors and turbines do not run well on fuels that contain a high percentage of hydrogen. Fuel cells do.
- The effect of other control measures, such as biological control, on the economics of the power station.
- Fuel access issues, including harvesting the weed from permanently flooded or boggy areas, harvesting it from stands other than the Adelaide River stand, and the possibility of integrating other biomass fuels such as green

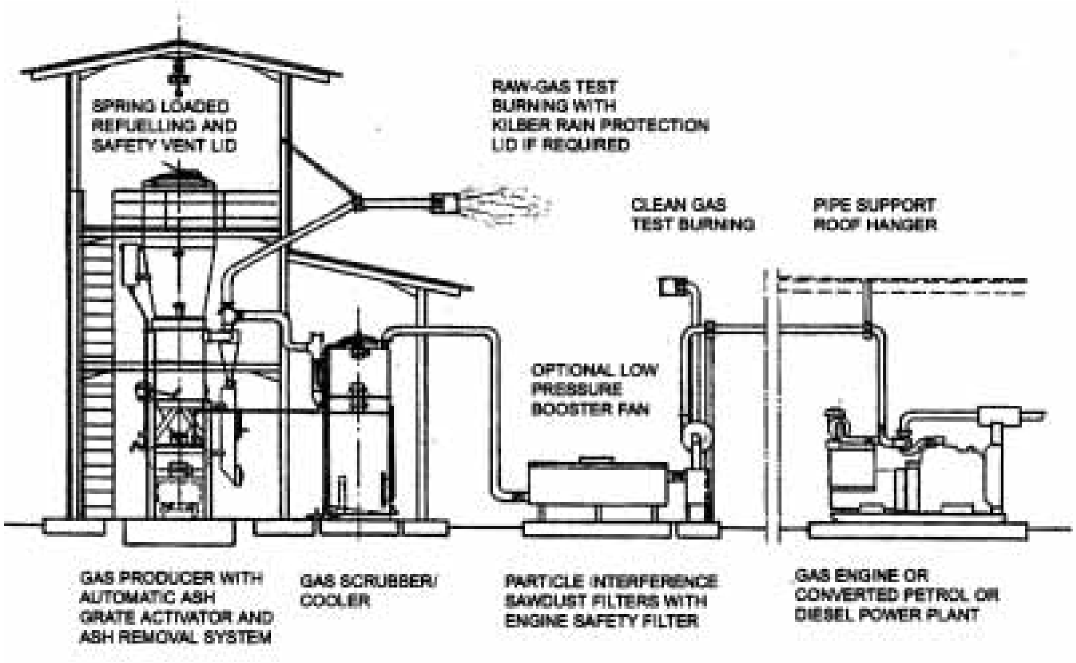

Figure 1. Conceptual pilot plant layout.

waste from the Darwin and Palmerston landfill sites.

- Technology deployment opportunities: using the technology for mimosa control elsewhere, as well as its applicability as a management tool for other weed control agendas.
- Impact of biological control. Preliminary data presented by Paynter (2004) indicates biological control is beginning to have a detectable impact on mimosa performance. If biological control is eventually successful, the resource available for power generation may diminish through time.

Conclusion

We have established that mimosa can be processed to produce a useful gas fuel, and that the gas can be converted to electricity using commercially available system components.

While valuable advances have been made with development of the technology needed to use mimosa as a fuel for power generation, it is only the start of a complex process. It will take genuine and sustained collaboration between a range of players, including landholders, the weed management authorities, the biomass industry, PowerWater, financiers, researchers and institutions able to support the education and training needs of the program, if we are to reap the potential rewards on offer.

If this effort is forthcoming, Australia stands to gain substantial rewards, including enhanced weed management outcomes, reduction of greenhouse gas emission, industry export activity, and the biomass industry may do for the NT what the Snowy Mountains hydroelectric scheme did for Australia half a century ago.

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