INTERNATIONAL ENERGY AGENCY
TASK 17 MEETING IN WESTERN AUSTRALIA,
7 TO 9 MARCH 2000

CONTENTS

PREFACE

The present proceedings are the results of a meeting within **TASK 17: SHORT ROTATION FORESTRY FOR BIOENERGY** within the frame of **IEA, Bioenergy**. The meeting was held in Albany, Western Australia and was organised by John Bartle (Department of Conservation and Land Management, Locked bag 104, Bentley Delivery Centre, Western Australia) 6-10 March 2000. The excursions took place on the area between Albany and Perth. Minutes from the business meeting and descriptions of the excursions can be found at the end of this Proceedings.

Overview of Task 17:

Definitions, Aims, and Objectives

(a) *Definition:* 'Short Rotation Crops' means woody crops such as willows, poplars, Robinia and Eucalyptus with coppicing abilities as well as herbaceous crops such as reed canary grass, switchgrass, Miscanthus, Donax, Sorghum and others.

(b) *Objective:* The objective of the short-rotation crop Task is to meet the need for bioenergy by industry through technical improvement of biomass crop production technologies, through documenting and disseminating information on the potential environmental benefits of biomass crop production systems, and through developing information to enhance market development in collaboration with the private sector. The overall aim is to further develop the existing short rotation biomass production systems, to improve the awareness of the bioenergy production potential of the concept, and to promote use of biomass for energy in participating countries. The intention is to strengthen the contact and co-operation between scientists, equipment developers, entrepreneurs in the production chains, and end users, with the aim of improving the understanding of problems and to finding means to solve them.

The aims of the Task as formulated during the meetings at Uppsala, 1998 and Auburn, 1999 are:

- to stimulate the full-scale implementation of energy crops in participating countries
- to strengthen the contacts and co-operation between participating countries, scientists, biomass producers, machine developers, entrepreneurs, and end users
- to select the most urgent research and development areas, and to suggest projects of co-operation
- to deliver Proceedings from the meetings
- to inform members and the Executive Committee

Task 17 was active from 1 January 1998 to 31 December 2000.

Earlier meetings within Task 17 were held in Uppsala, Sweden, Los Banos, The Philippines (joint meeting with IUFRO group Short-Rotation Forestry), Auburn, Alabama, USA. After the meeting in Albany, Western Australia, Task 17 held meetings in Noordwijk, The Netherlands, and Örebro and Hedemora, Sweden

Proceedings from meetings can be obtained from

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BARRIERS AND POSSIBILITIES FOR LARGE-SCALE IMPLEMENTATION OF ENERGY CROP PRODUCTION AND USE IN DENMARK.

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Background

The last Task 17 country report for Denmark gave a general overview of the Danish policy on energy crops and of ongoing research projects (Kjeldsen, 2000). The present paper therefore focuses on barriers and possibilities for large-scale implementation in general and describes in more detail the aspects of one specific demonstration project on full-scale production and utilisation of an energy crop.

Denmark has an energy policy which includes energy crops from the year 2005 as a measure to increase the contribution from renewable resources (Ministry of Environment and Energy, 1996). The tax system on energy and the recent new regulation of the power market (The Danish Parliament, 1999) which requires the power companies to include a certain amount of renewables as a public obligation, both help in making bioenergy competitive with other energy resources.

However, the production of energy crops depends just as much on agricultural policy and on future land use planning. So far there has been no coordination of energy and agricultural policy in Denmark, and most farmers have been reluctant to establish any significant areas of energy crops. Neither has there been any kind of public campaign or the like to call on farmers to participate in the substitution of fossil fuels. If in the near future an implementation policy for energy crops is launched and a campaign to inform and encourage farmers is run, there are good chances that significant areas may be established. This judgement is based on the facts that:

- The production economy of biomass from energy crops is just about competitive to prices of biomass residues (Parsby & Rosenqvist, 1999) and prices of conventional crops (grain and oil seeds) are falling.
- Many farmers have shown interest in growing energy crops but have felt a lack of good incentives and of long term security.
- There are good opportunities for combining the production of energy crops with other environmental actions, such as the reduction of nitrate losses from agriculture to ground or surface waters (Jørgensen, 1997).
- The technical bottlenecks for the implementation of energy crops are not severe; it is more a question of continued cost reduction and of environmental optimisation.

What is necessary to initiate a process of commercial energy crop development?

First of all, the Danish farmers and the energy industry needs to get a clear signal from the Government on its future (favourable) intentions on energy crops, which can indicate that long-term investments in crops and in harvesting equipment are reasonable. The whole energy crop chain has to be analysed for administrative and legislative bottlenecks that may hamper a commercial development, and the government must present the study and the administrative alterations deriving from it. More specific legislative initiatives can be:

The implementation of the most environmentally friendly energy crops into the legislation on support for rural development (EU-regulation 1257/99), specifically the part on ’financial incentives needed to encourage farmers to make agri-environmental undertakings’. Here annual area payments of up to 900 EUR are allowed for ’specialised perennial crops’. The commitment period for perennial crops shall preferably be at least 10 years to ensure that the investment in crop establishment can be paid back. If a long commitment period is achieved it is likely that area payments of about 140 EUR above the set aside payment will be enough to interest farmers to plant energy crops.

The initiation of a few full-scale, commercial demonstration projects, where the learning and development process can continue. Here farmers from other areas can get a real impression of how energy crop production can be done, which aspects are most important for success and which bottlenecks still have to be addressed. Such projects will need some public support, which may be done by restricting point 3 to these demonstration areas.

The implementation of the EU-regulation 1624/98, which allows national authorities to cover up to 50 % of the investment costs associated with establishing perennial crops intended for biomass production. This will reduce the high financial need for farmers in the early part of the production period. This should not be a permanent regulation, as with time the production of energy crops should be economically feasible without specific subsidies. However, it can be a very efficient measure to push the development and to reduce farmers' risk in the initial phase where a learning process is taking place and the risks of mistakes and failures are high.

A demonstration project on the production of Miscanthus for a CHP plant.

Miscanthus is a C_4-crop with a potentially high yield even in the cool temperate climate of Denmark (Jørgensen, 1996). It can be harvested with conventional agricultural machinery (Kristensen, 1997b) and handled in the power and/or heating plants on the existing straw bale lines. However, at harvest in Spring (April) when the straw is dry and can easily be stored, about half of the produced biomass is lost as the top and leaves of the crop falls off during winter (Fig. 1). Another bottleneck to miscanthus production has been the high costs of establishment when planting greenhouse-raised plantlets and problems of first winter failure of the crop. However, these bottlenecks have recently been successfully addressed, as detailed below.

At the combined heat and power plant at Masnedø (SK Energy, 8.3 MWe) a test firing of loose harvested miscanthus from the winter season was conducted in 1999 with a good result (Kristensen & Fenger, 1999), which indicated that it may be possible to operate a continuous feeding system during winter with direct delivery of miscanthus from field to plant. Thus the costs for storage are avoided and furthermore the yields will be increased, as more leaves will be harvested. Harvesting through the winter will increase farmers flexibility and demand man-hours in a period where no other field operations has to be done in agriculture. The higher content of K and Cl in winter harvested material (Fig. 1) did not disturb the combustion at Masnedø, which is constructed from a concept that is not very sensitive to problems of slagging and corrosion.

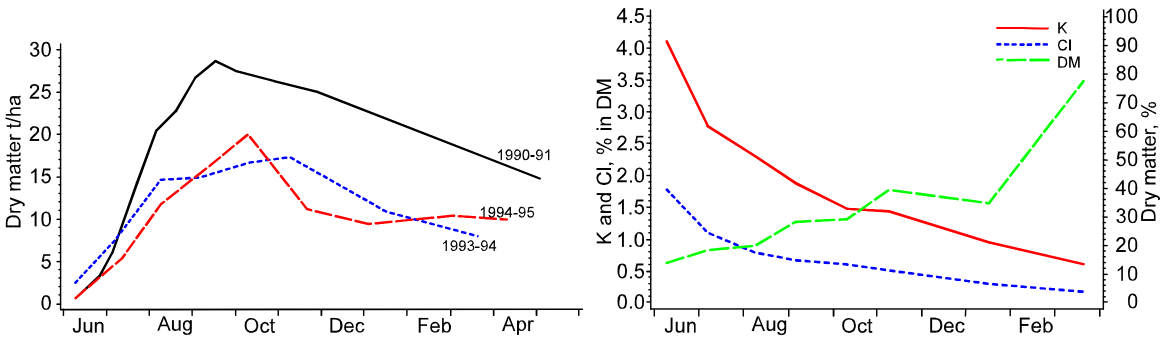

Figure 1. Biomass accumulation of *M.* 'Giganteus' in three years and concentration of K, Cl and dry matter in one year (from Jørgensen, 1996).

Forage choppers with row independent maize headers are found suitable for the harvest (Kristensen, 1999a), and the harvesting costs are significantly lowered if the material is not to be baled. However, the low density of the loose material increases transport costs, and the system is mainly suitable for short transport distances. Low costs storage of the chopped material in outdoors piles is possible, but due to the high moisture content there is a risk of heating (Kristensen, 1999b).

Instead of raising plantlets of miscanthus in greenhouse, the direct planting of rhizomes in the field can be a much cheaper option. Experiments have shown good establishment and first winter survival from not too small rhizome pieces (Schwarz et al., 1999). For large scale plantings a mother field is rotary cultivated and rhizome pieces are collected with a stone picker (Venendaal et al., 1997). For the subsequent planting a special machine has been developed by the company Hvidsted Energy Forest (Kristensen, 1997a), which can load c. 3 tonnes of rhizomes and plants 2 rows at a time with a working speed of up to 8 km/h. Rough calculations indicate that with this system costs of establishment can be reduced to c. 550 euro per ha, but this needs further documentation (Jørgensen, 1999).

In order to test this knowledge obtained in research projects in a larger scale a process of bringing together and matching the elements of the production and utilisation chain was initiated in late 1999. The aims are to obtain real information on the logistic chain to test the crop under commercial conditions and get experience with farmer attitudes towards the production of energy crops. Some external funding is expected necessary as costs of initiating a totally new production will be too high in the beginning.

A number of parties (farmers, power company, public authorities and research) have been involved in the process, the price of the feedstock has been negotiated, and some funding for the crop establishment seems possible. However, it seems that time does not allow that the project will be initiated this spring (April 2000). Some of the bottlenecks that have been or will have to be addressed are:

- Contracts over more years (at least 5 years) between power plant and farmers as the perennial crops have a long payback period.
- Fear of agricultural advisors to get involved in new projects that have a risk of failure.
- Learning the farmers about the production, problems and possibilities of a totally new crop.
- Energy crops are not specifically included in the agricultural policy or in the agri-environmental regulations.
- Agriculture in Denmark is still not directly involved in the national greenhouse gas balance, which will however soon be the case as agriculture is given a key role in a very recent national climate strategy (Ministry of Environment and Energy, 2000)

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COUNTRY REPORT FROM THE NETHERLANDS

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Assessment of the availability of biomass and waste

In the second half of 1999 an extensive study on the availability of biomass and waste in The Netherlands has been carried out by a consortium of research institutes, universities and consultants, in order to identify potential resources for bioenergy. For the future large scale deployment of bioenergy social acceptance of the resource is considered a key factor. At pressent, in The Netherlands there is already a lively market for various kinds of waste products, some of which could be allocated as a potential feedstock to bio-power plants. Some categories of biomass and waste potentially available, however, are subject to debate. From a total of 150 PJ of biomass and waste potentially available, which is needed to meet the government objectives for renewable energy in The Netherlands, 34 PJ is socially acceptable without any discussion; for 50 PJ, which includes manure and some biowaste products, there is some discussion; for 45 PJ there is lots of discussion (e.g. sludges and most of the municipal solid waste fall under this category) and about 22 PJ, consisting mainly of waste paper, is socially not acceptable as a source for bioenergy. Most waste paper is already being recycled.

From scenario studies it was concluded that market regulation by the government may have a large impact on the actual availability of waste and biomass. At present the market for agricultural products and the market for wastes are subject to direct government regulation. Contrary, the energy market in Europe is increasingly being liberalized. If left at the mercy of the free market, very few bioenergy initiatives will effectively be deployed. Certification of the whole chain of custody was identified as a valuable tool to counteract some of the negative consequences of a free market in biomass and waste. Such certification schemes should pay attention to the issues of biodiversity, sustainability and emissions. However, government support will still be needed to stimulate extension work, pilot projects on multiple land-use and multiple products, technology development and cascading over supply chains.

Status of the Flevo-project

Research and development on energy crops in The Netherlands has developed from on station testing in experimental plots the size of a few hectares, to a pilot stage of a few dozen hectares in 2000. In three years time the area planted with SRC will increase to 200 hectares, supplying 10% of the annual feedstock of a CHP plant in Lelystad (i.e 1500 odt/a). In the Flevo-case social acceptance was considered most crucial. Many parties were involved: State Forest Service, Netherlands Organisation for Energy and the Environment, Shell company, Environmental organisations, province, municipalities and several consultants, who all have signed a letter of intent. The working out of a business plan in which 12 different product-market combinations were presented in detail, was another means to enhance the social acceptance of this project. A so called SWOT analysis (strength, weaknesses, opportunities and threaths) identified the most appealing and most viable ones. Based on these analyses, in the summer of 1999 the parties involved took a positive decision about the implementation of the Flevo-project, based on the concept of integrated and multiple-landuse. The first 50 ha have been established by the spring of 2000. So far, the learning process has focussed on the integration of functions, communication, project coordination and on funding. The chalenge now is to keep the momentum and to motivate all parties to continue. Additional funds are required to scale up to 200 ha. We definitely need political support for the next stages and the aquisition of land remains a crucial factor, due to the complicated land-use planning procedures in Holland.

Some results on salt uptake by willows

In addition to the first year growth data on the container test of willows growing on dredging sludge, which have been reported last year at the Auburn meeting, some additional analysis on salt uptake have been done with very significant results. The sludges were contaminated by mineral oil, PAC's and heavy metals and were classified as slightly brackish, with salt contents of about 1050 mg/liter (550 mg/kg). Sixteen different willow varieties have been tested and first year growth was measured, as a result of which a clear ranking followed. In the following table the top 10 are presented:

Table: Top 10 in biomass growth	Salt uptake (mg Cl/kg)
Salix alba ‘Het Goor	1600
Salix alba ‘Lievelde’	2200
Salix triandra ‘Black Hollander’	3800
Salix alba ‘Belders’	3200
Salix triandra ‘Zwarte driebast’	5600
Salix dascyclados ‘57/57’	2700
Salix dascyclados ‘Loden’	3000
Salix fragilis ‘Belgisch rood’	4100
Salix triandra ‘Grisette’	3300
Salix rubens ‘Bouton aigu’	3000

These data suggest significant clonal differences in salt-uptake by willow. Even between species there seem to be differences in salt-uptake: Salix alba and Salix dascyclados had the lowest chloride contents; whereas Salix viminalis and Salix fragilis had the highest salt-uptake. This may offer perspectives to selection and breeding.

Other relevant issues

An important issue when considering large scale imports of biomass will be: How to guarantee that the biomass production takes place under sustainable management regimes? In some countries guideliness have been developed for good practise guideliness based on consensus (e.g. the Bioguide). But certification too may be an appropriate tool to consider: especially certification schemes approved by the Forest Stewardship Council (FSC) may be helpfull in this respect. The question is: should we (i.e. IEA Task 17) develop a draft FSC standard for energy crops? If so, which adjustments are needed? And what are the consequences?

The Dutch FSC standard for plantation forestry requires that in all plantations at least 10% of the area is planted with mixed indigenous tree species. Half that area (i.e. 5 %), e.g. located at the edges, along watercources or adjacent to more natural areas is not to be harvested at all. A second important requirement is that the ecological disadvantages associated with monocultures and clear felling will have to be compensated for by additional requirements, such as the ones stated under Principle 10 of the FSC standard. These include:

- Not allowing the use of pesticides , unless the necessity has been clearly demonstrated to the satisfaction of the certifier;
- The size of felling areas has to be limited to 5 ha;
- For plantations over 20 ha, felling has to be restricted to an area not exceeding 25% in the last 5 years;
- Temporary plantations are excluded from the FSC standard.

The scale of operations suggested here (i.e. limited to 5 ha) will result in a mosaic of stands with different age and structure over time. According to FSC, this could make a significant contibution to landscape diversity. Are these FSC requirements reasonable and acceptable to us or should we develop our own standard for energy crops? This could be an interesting issue to discuss in our next annual meeting.

PROGRESS AND PROBLEMS WITH IMPLEMENTATION OF SHORT ROTATION CROPS IN THE UNITED STATES

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Abstract

While progress is being made implementing short rotation crops (SRC) for energy in the United States; there remain technical, economic, and institutional challenges to using SRC for energy. Presently there are projects in New York, Alabama, Iowa, and Minnesota to utilize SRC for co-firing with coal to generate electricity. However, energy users are looking for low cost feedstocks. Additional benefits, such as reducing SO_x and NO_x emissions in electric power plants, may be necessary to make utilizing SRC feedstocks for energy feasible, at least in the short run.

Progress is being made with regard to use of short rotation crops (SRC) in the United States. Fiber markets for both woody and non-woody crops are increasing. Several bioenergy demonstrations using SRC are in place. The crises in the farming sector (low prices) is forcing the U.S. government to consider changes in policy that would facilitate bioenergy and biobased product markets. Research and development (R&D) has produced several new higher yielding plant materials suitable for bioenergy.

However, there are problems with implementation of SRC. Bioenergy markets are stalled under current economic and policy conditions and existing projects can only afford the lowest cost biomass residues. Fiber markets for SRC are increasing, but companies prefer to own land and plant their own crops. Integrated biobased product and bioenergy production is being encouraged by government, but economics and technologies are yet to be proven. Because these technologies are not yet proven, commercialization is difficult. Different conversion technologies will be optimized by different feedstock types, so R&D focus is difficult.

Presently there are a number of integrated bioenergy projects with SRC. 1) In New York state, willow and waste wood are to be co-fired with coal in an existing power plant. 2) In Iowa, switchgrass is to be co-fired with coal in an existing power plant. 3) In Alabama, switchgrass is to be co-fired with coal in a pilot plant and an existing power plant. 4) In Minnesota, alfalfa was to be used to produce co-products; leaf meal and bioenergy in a gasifier. The Departement of Energy has discontinued support of the project due to lack of industry cost-share. 5) Also in Minnesota, hybrid poplar is being grown potentially for both energy and fiber markets. While a hybrid poplar energy project has been granted approvals, funding is still needed. The four projects still moving forward are described in the following paragraphs.

In western New York state, at a 485 MW utility power plant, modifications have been completed and plans are to co-fire up to 15% wood with coal. This is an R&D project cost-shared by the Federal Government. There are plans for 400 ha of willow, with about 50 ha planted to date. There is no history of co-firing by the utility. For cost reasons, the utility is starting with wood residues. Collaborators include a university and a state agency. Utility motivations are environmentally based with a strong interest in reducing SO_x and NO_x. State agency motivations are economic, with an interest in keeping energy dollars in the state. There are a number of challenges for willow in New York. 1) Utilities require willow prices competitive with coal, which translates to delivered prices of $20 per dry Mg. Achieving that price would require a target yield of approximately 15 dry Mg/ha of delivered feedstock, and very low cost or government subsidized land. 2) Co-firing technical feasibility must be demonstrated to utilities. Utilities want to see no slagging and fouling, decreased SO_x and NO_x, no de-rating of the boiler, reliability of biomass supplies, and availability of markets for mixed wood/coal ash. 3) Farmers want to see profit potential before committing land to willow production. This likely requires the utilities to offer long-term contracts with annual payments. Willow demonstrations must prove reliability of willow production and harvest technology. Biomass supply brokers must build mutually beneficial partnerships with farmers.

At a location in middle Alabama, a large coal facility requires modification for co-firing trials using switchgrass. A pilot-scale boiler is being used to test injection of coal and switchgrass in a pulverized coal power plant. Auburn University is testing harvesting and handling methods for improved efficiency and decreased cost. Alamo switchgrass is planted on 330 acres of typical Alabama farmland (poor soils). Challenges in the Alabama switchgrass project are: 1) The utilities wants delivery of switchgrass at prices similar to coal. This requires cost reductions in the harvesting, processing, handling, and transport systems for switchgrass. Using chopped switchgrass instead of bales is believed to be a partial solution. Low cost or subsidized land is also required for low costs. 2) The utility wants to see the same co-firing technical feasibility elements demonstrated as in the New York project plus they want the feasibility of feeding chopped switchgrass to be proven. The co-mingling of coal and grass has already proven not feasible, and separate injections ports are now being tested. 3) To achieve commercial scale-up of switchgrass production systems, superior seed must be available at scaled-up levels and market guarantees are needed. One farmer is already involved and others are interested.

In east central Iowa, at a 785 MW utility power plant, facility modifications have been started to allow co-firing of 15% switchgrass with coal. One thousand six hundred ha of subsidized land with pre-existing switchgrass are dedicated to the project. The subsidized land is in a watershed with a lake supplying drinking water for 20,000 homes. The project is investigating water quality, soil quality, and wildlife benefits, as well as supply logistics issues. A farmer cooperative has been formed to share information and develop alternative products and markets. A building has been built to resolve storage problems for bales needed for co-firing tests. However, there remain a number of challenges. 1) To reduce yield variations and increase yields in pre-existing stands requires innovative fertilization options. 2) To develop cost-effective harvesting systems and methods for transporting bales as much as 120 km between the federally subsidized land where the switchgrass is being produced and the power plant. 3) To demonstrate the technical feasibility of co-firing, the same issues as with the New York state and Alabama projects must be addressed.

In Minnesota about 2500 ha of hybrid poplar was established in 1994-1996 in north central and northwest Minnesota with state and federal support. All 2500 ha was planted on subsidized land. The fiber industry has since established as much as 4000 ha with plans for up to 15,000 ha. A biomass power project of 50 MW has a power purchase agreement and state approval, but funding is not yet secure. If the 50 MW project proceeds, up to 25,000 ha of land will be planted to hybrid poplars in southeast Minnesota. There are challenges that must be met if the Minnesota hybrid poplar is to proceed. 1) The 2500 ha of hybrid poplars already planted do not have a secure market, nor are they within economic haul distance of the planned biomass power project. 2) The location of the biomass power project is in an area with somewhat higher value land, and relatively little federally subsidized land near the facility. 3) The project needs 10- to 20-year supply contracts from farmers and farmers in the project area need to be convinced of the profit potential of growing hybrid poplar. Getting commitment of farmers to the energy market may be difficult. 4) The Minnesota forest products industry consumed 4.8 million cords in 1997 for fiber production and fiber prices have increased from $8/cord in 1993 to $32/cord in 1997. 5) The biopower project developer is counting on innovative harvesting and handling technology to reduce feedstock costs.

Other bioenergy projects under consideration or development include: 1) chicken litter to bioenergy in Delaware, 2) sugarcane bagasse to ethanol in Louisiana and Hawaii using enzymatic hydrolysis technology, 3) switchgrass to ethanol using gasification and bioreactor technology in Georgia, 4) rice straw to ethanol in California using acid hydrolysis technology, and 5) urban wastes to ethanol in Pennsylvania using acid hydrolysis technology.

Progress is being made in demonstrating the feasibility of SRC for the production of bioenergy. Both potential producers and consumers need to be shown that the technology of growing SRC is feasible and reliable. However, that may not be enough to create the markets needed for SRC (unless government subsidies are available) since utilities appear to only be interested in low cost feedstocks. On the conversion side it is also necessary to prove the feasibility of utilizing SRC feedstocks. Ancillary benefits, such as reducing SO_x and NO_x emissions in electric power plants, may be necessary to make utilizing SRC feedstocks for energy feasible, at least in the short run. It is expected and hoped that these demonstrations will also have an effect on development of policies that will accelerate the implementation of bioenergy.

UK COUNTRY REPORT
ENERGY CROPS: PROGRESS AND PROBLEMS

Damian Culshaw – Border Biofuels Ltd

UK Renewable Energy Policy Context

The UK's electricity consumption is around 324TWh/yr derived from: 33% Coal, 33% gas and 26% nuclear. The UK government has set a target to generate 10% of the nations electricity from renewable energy by 2010. It currently stands at 3% with 5% expected by 2003 as a result of projects already being developed. Converting to 10% from renewables is expected to reduce CO_2 emissions by 2.6 –3 mt/year

UK Policies for implementing this target

Throughout the 1990s the UK government used at premium pricing mechanism on electricity sales to stimulate the introduction of renewable energy electricity generating capacity. This was funded by a levy on the electricity distributors and also imposed an obligation on them to supply a certain proportion of electricity from renewables. This market mechanism, operating in England was known as the Non Fossil Fuels Obligation (NFFO for short).

Under new arrangements for structuring the supply and distribution of electricity in the England, this arrangement is no longer appropriate. The proposed replacement for NFFO is an obligation placed on the generators of electricity who will be obliged to provide a government determined proportion of electricity from renewable sources. The proposal is that the generators will be allowed to generate form renewables themselves, contract others to generate the electricity or to buy out their obligation. This 'buy out' fund will be used to further stimulate the generation from renewables.

In parallel with these arrangements, a government funded research and development and demonstration programme will continue to operate and the funding for biomass development will run at around £1.8m/yr for the next few years.

There is currently no market support mechanism for biomass fuel to be used for heating. This market is more or less operating in the free market and no rapid increase in the use of biomass crops for heat projects is expected.

Energy Crops - Current Status

The following bullet points summarise the situation in the UK:

- 1000ha of SRC willow planted
- 500ha of SRC willow for the ARBRE power generation project planted with 700ha more in spring 2000
- Demonstration plots of Miscanthus (10-30ha)
- Experimental plots of other grasses
- Single stem poplar – an interesting energy crop with attractive grant support under the forestry support mechanism

In April 2000, the ministry of agriculture in England published a discussion document on support for energy crops that outlined its intention to offer planting grants for both willow and poplar coppice and Miscanthus. The details of this mechanism are currently being worked out but this is expected to be in place for spring 2001.

Border Biofuels – Current Status of the development of biomass for power generation

The bullet points below summarise the position:

- They hold NFFO contracts to generate 74MW of electricity from forestry residues and energy crops
- Secured large company backing
- Land use planning permission granted on first major plant to take 450,000gt of fuel/yr
- Demonstration plots of SRC willow now 5-6 years old
- Developed and demonstrated 'layflat' planting technique for SRC willow in conjunction with Danish partner

Border Biofuels – Currently developing

The bullet points below give an outline of company's main current development projects in the field of biomass crops:

- Developing energy crop production systems to compete with forest residues as a significant proportion of the fuel for Border Biofuels powers stations making best use of UK grant support mechanisms. Crops of interest include SRC willow, poplar and energy grasses.
- Developing a harvester for SRC willow to produce bundles / bales
- Gaining experience in planting Miscanthus at a commercial scale (around 20ha in spring 2000)
- Further demonstration and development of the layflat planting technique for willow SRC and comparisons with the step planter

UK Problems with developing Short Rotation Crops

The bullet points below summarise the main problems with development – the title of the meeting:

- Complexity of agricultural and forestry rules and support structure
- Slow development of power plants – planning permission, financing, advanced conversion technology
- Pest and disease risks – rust and willow beetles
- Expensive planting stock
- Uncertainty over harvesting equipment and storage of material needed for year round power generation

Conclusion

The UK has already carried out a great deal of development work in the field of energy crops majoring on the development of SRC willow largely following the Swedish model. Other crops such as single stem poplar, Miscanthus, and in the longer term, possibly other energy grasses are also being developed.

Under NFFO, several power stations are now operating on agricultural residues and biomass wastes and contracts have been let allowing the development of powers stations that will run on forestry residues and energy crops.

The government now has the framework in place to allow the further commercial development of energy crops for fuelling biomass power stations. Border Biofuels and other companies are taking the opportunity presented and are now developing commercial scale biomass plantations for electricity generation. The expectation is that thousands of hectares will be planted over the next few years.

SHORT ROTATION FORESTRY FOR ENERGY PURPOSES: CURRENT DEVELOPMENT IN SWEDEN

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Department of Short Rotation Forestry

Introduction

In Sweden, a research programme on willow short rotation coppice started in the mid-seventies and resulted in an early commercialisation during the late eighties. At present about 16.000 ha of willow coppice is used by farmers as an alternative crop, producing biomass for energy purposes. The main driving force behind the current development in Swedish willow short rotation forestry (SRF) is the combined value of SRF as a crop for energy purposes and as a system for phytoremediation.

The initial programme in the seventies focussed on basic research on a number of experimental sites, and research co-ordination was centralised. Today's research is scattered over a large number of independent projects and has an applied orientation that focuses on commercially established and managed stands.

Current national research proposals from the Department of Short Rotation Forestry comprise a wide range of basic issues in willow production biology as well as applied research on the performance of systems designed for phytoremediation. The project proposals mentioned below reflect the actual questions and ongoing development both in commercial willow growing and at different specific research fronts. At the same time, the multipurpose functions of willow SRF systems require a further development of interdisciplinary research efforts and co-operation between municipalities, entrepreneurs, farmers, investors and researchers. This resulted among others in a project application designed to bring the different actors in the field of willow SRF together.

Current project applications

Our current project applications can roughly be divided into the following categories:

1. Information, network creation.
2. Ecology, long-term performance of willow coppice.
3. Eco-physiology of Salix.
4. System features of importance for phytoremediation: nutrient and heavy metal circulation.
5. Others.

Most of the projects applied for are planned to start during the season of 2000 and are expected to run during two or four years. Several of the projects consist of co-operations between two ore more partners, and in several instances, municipalities and/or private companies are involved.

Information, network creation

Background: *Due to an increase in number of actors in SRF and loss of the initial willow programme structure, a renewed focus on information exchange and co-operation is necessary.*

Project proposal: establishment of a formal Swedish energy forum
The aim of the project is to structure an active and continuous forum for all actors in willow energy forestry and to organise activities that will enhance experience and knowledge exchange between the actors. A web-site will be developed to announce regular joint seminars and field excursions. Project updates and newsletters will be published on the web-site and actual links to other relevant sites will be provided.

Ecology, long-term performance of willow-SRF

Background*: Most experience of Willow SRF has been collected from stands in their first and second rotation period. In commercial practice, a high stool mortality and concurrent production decline has been noticed in later rotations. This problem is addressed by several projects.*

Project proposal: Avoidance of density dependent mortality during later rotations
The aim of this project is to provide an explanation – by means of long-term census data - for the 'sudden stool death' occurring during later rotations. Data are compiled from well-documented sites to see if current mortality can be predicted from management and stand performance during earlier rotations.

Project proposal: The physiological basis of 'sudden stool death'
The aim of this project is to develop a method to assess a plants actual viability, as related to the plants current and future performance. Factors on which this research will be focussed are the carbohydrate- and macro-nutrient status during active growth, winter hardening and hibernation.

Project proposal: Vitalisation of poorly performing SRF-stands
Many of the stands planted during the eighties were established on marginal soils with poor pre-planting weed control and no fertilisation whatsoever. Post-harvest weed control and fertilisation in different forms will be evaluated to find different means of restoring those stands.

Eco-physiology

Background: *Several eco-physiological issues with a potentially strong effect on biomass production are not sufficiently studied yet. Although such basic research at present receives little attention, it may well form the onset for important future application improvements.*

Project proposal: Ecological characterisation of willow clones
The aim of this project is to develop methods to test and characterise willow clones in an early phase. One of the main problems with today's clone selection is that it does not give an understanding of the mechanisms that lead to a certain performance in the field. A pilot study showed that it is feasible to obtain early measures of characters that determine plant performance in a later stage. The major focus is on water use efficiency and nitrogen use efficiency. An experimental design including treatments to test for insect tolerance is in an early development phase.

Project proposal: Effects of mycorrizal colonisation
The aim of this project is to evaluate the potential of mycorrizas to increase productivity in willow SRF. At present, very little is known about the effects of mycorrizal colonisation of willow. As willow coppice often are replacing agricultural crops that don't have the mycorrizal associations typical for trees, on sites that for a long time have been cultivated without trees, natural mycorrizal colonisation is expected to proceed slowly. If positive effects of mycorriza on willow growth are found, it may be considered to develop methods for inoculation at the planting stage.

Project proposal: Effects of N-supply on growth and frost hardiness of willow clones
Current observations not only show that ferilisation regime interacts with phenology, a late N-application causing plants to be more susceptible for autumn frosts, but also that the plant N-status may be positively correlated with frost hardiness. The aim of this project is to enhance plant nutrient status early in the season, thereby not disturbing frost hardiness development.

System features of importance for phytoremediation: Nutrient and heavy metal circulation

Background: *The economy of SRF biomass production can be improved by its use a s a multipurpose system. Nutrient requirements in willow SRF are high and many waste products such as sludge, ashes and reject water contain large amounts of nutrients. Willow as a vegetation filter system allows for turning those waste products - generally conceived as a burden - into a valuable resource for biomass production.*

Project proposal: Production and N-losses; SRF in comparison with annual agricultural crops
The aim of this project is to assess soil carbon and nitrogen budgets as a function of different cropping systems. Due to the high nitrate loads in many of the surface- and ground waters in Southern Swedish agricultural areas, cropping systems with low N-leaching need to be developed. Especially in the case of

energy crops, the ongoing debate on the pro's and con's of annuals versus perennials needs to be substantiated.

Project proposal: Application of sludge and wood ash mixtures to Salix on agricultural soils: Effects on biomass production, fuel quality and nutrient and heavy metal status of the soil.
The aim of this project is to quantify the flows of heavy metals and nutrients in the system if sludge and ashes are used as a fertiliser. Suitability of the waste products as fertiliser will be assessed in different treatments. Especially the long-term mineral nutrient and heavy metal content of the soil needs to be investigated, as the soils on which willow is cultivated may be used for the production of food crops in a later stage. Concentrations and amounts also will be measured to assess removal by harvest and to be able to link fuel quality - in terms of mineral nutient and heavy metal concentration - to the fertilisation treatments.

Project proposal: Treatment of reject water in willow vegetation filters.
The aim of this project is to quantify the nitrogen purification capacity of large-scale willow vegetation filters. N-leaching, N-mineralisation rates as well as N-removal by harvest of the stands will be estimated. The results will be used for deciding how future operational management, using vegetation filter systems, should be developed.

Project proposal: Nitrogen uptake, growth and phenology of willow under extensive nitrogen supply.
The aim of this project is to determine the optimal rates and timing of supplying N-rich waste- water to willow, and be able to counteract N-saturation in the system. The plant response will be estimated in terms of 1) accumulation of the N-pools of the plant, 2) seasonal growth rhythm (phenology), and 3) seasonal N-uptake variations. The results will be used to find the optimal methods for wastewater treatment using willow vegetation filters.

Project proposal: Development of models for design and management of wilow vegetation filters for wastewater treatment.
The aim of this project is to enable biological optimisation of planned vegetation filters at different scales, thereby reducing risks for biological and economic failures. At a number of test sites, wastewater is treated by means of willow vegetation filters. These sites differ in size, soil, climate, nitrogen supply rate and harvest regime. To enable design and management of vegetation filter systems, a conceptual model will be built that can account for the actual variables and allows for systematic comparison between the various sites.

Other projects

Background: *Expansion of willow SRF requires accurate production predictions, also in areas were willow SRF has not been applied previously. Much of the information gained during the development of willow SRF systems can be used for the development of systems with slightly longer rotation periods. Current experiments indicate that hybrid aspen and hybrid poplar would provide a suitable plant matrial for such systems.*

Project proposal: Development of methods to predict willow production over a wide geographical range, on basis of agricultural summary statistics.
Due to the ongoing commercialisation of willow cultivation, production data become available over a wide geographical range. This allows willow production to be correlated to a number of other data-sets which cover this range. Apart from soil information and climate data, production data of other agricultural crops such as winter wheat and potatoes may be tested as indicators for willow growth.

Project proposal: Development of commercial energy forestry with hybrid aspen and hybrid poplar.
The aim of is project is to provide the basic information needed to assess the suitability of hybrid aspen and -poplar systems as commercial systems for the production of energy-wood and pulp. This work includes an assessment of available plant material, production measurements in representative stands, site availability assessment and finally a formulation of management recommendations.

ENERGY IN AUSTRALIA

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Australia (current population 19 million) has an abundance of energy resources that have influenced the structure of the economy and trade profile, a dispersed population with a consequent high dependence of fossil fuel based transport, and a relatively fast rate of population growth. Australia's total energy consumption has increased on average by 2.6% per annum over the last 25 years and was estimated to be 4 810 PJ in 1997/98. In 1997/98, energy consumption was dominantly across three major sectors: electricity generation (28.3%), transport (25.2%) and manufacturing (24.9%), and was sourced from oil (34%), black coal (29%), natural gas (18%), brown coal (13%) and renewables (6%) (Fig. 1). In 1997/98, Australia had an approximate trade balance in oil, gas and petroleum products, but was a significant net exporter of energy, mostly as black coal (4 613 PJ) and uranium (3 015 PJ) (Fig. 2).

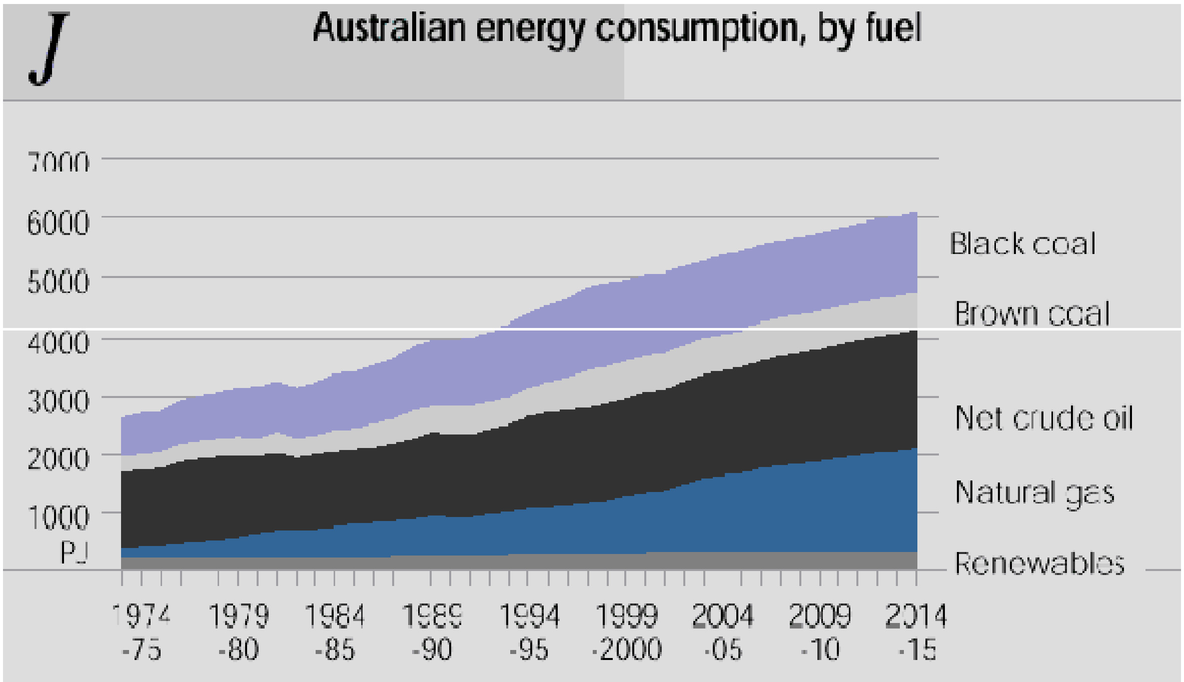

Figure 1. Australian energy consumption by fuel. Figure taken from Bush *et al*. (1999)

Australia contributes only approx. 1.4% of global greenhouse gas emissions, but per capita emissions rank third amongst industrialised countries. Excluding that associated with land clearing, Australia's annual net greenhouse emissions increased by 8.9% from 385 Mt CO_2-e in 1990 to 419 million Mg CO_2-e in 1996. In 1996, emissions were distributed amongst the sectors (Mt CO_2-e): Energy (331.8), Industrial processes (9.2), Agriculture (84.3), Waste (16.7), and Forestry & Other (but excluding land clearing) (-22.7) (Fig. 3). The dominance of the energy sector in emissions (79% of total), particularly that from stationary sources (55%), which includes power stations, is evident.

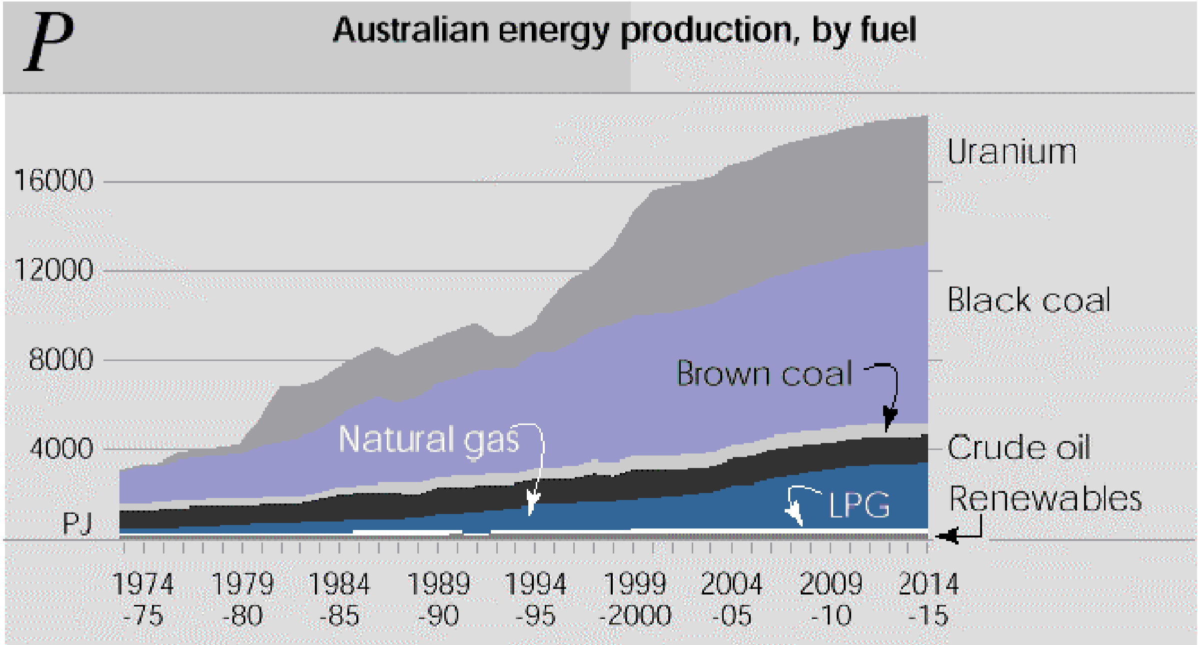

Figure 2. Australian energy production by fuel. Figure taken from Bush *et al*. (1999)

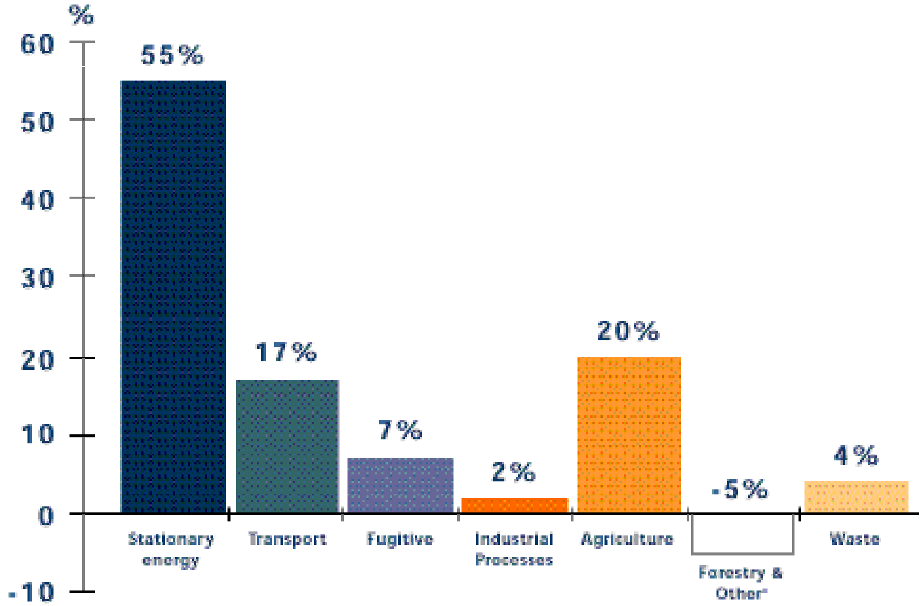

Figure 3. Share of Australian net CO2-e emissions by source. Figure taken from AGO (1998)

In the absence of measures to reduce emissions of greenhouse gases, Australia's emissions are projected to be approx. 552 million Mg CO_2-e in 2010, a 43% increase from 1990 levels. As a result of the Kyoto Protocol, developed countries, as a whole, will strive to reduce their greenhouse gas emissions from 1990 levels by at least five percent in the period 2008-2012. Australia's requirement is to limit its net greenhouse gas emissions in the first commitment period to no more than eight percent above 1990 levels.

Interest in renewable energy sources in Australia is largely driven by a need to respond to greenhouse issues, and to promote technological development, rather than energy availability and energy costs. Particularly, the Prime Minister's November 1997 statement *Safeguarding the Future: Australia's Response to Climate Change* included mandatory targets for electricity retailers and large electricity purchasers to source an additional 2% of their electricity from renewable or specified waste product energy sources by 2010. Amongst several objectives of this measure is the development of internationally competitive industries which could participate effectively in the Asian energy market.

The additional 2 per cent renewables target has stimulated electricity suppliers to develop *Green Power* schemes whereby consumers may choose to purchase electricity generated from renewable energy sources. A national accreditation system has been developed for this purpose. An emphasis in *Green Power* schemes is the development of new generators, and by the end of 1999 at least 60% of such power must be obtained from generators installed after January 1997. This required minimum proportion will rise to 80% from July 2001. Retail premiums for *Green Power* are typically 3 cents/kWh above current grid-electricity prices of approx. 10 cents/kWh.

In 1995/96, energy production from renewable sources in Australia was approx. 263 PJ (compared with total primary energy demand of 4495 PJ), and was dominated by (PJ): bagasse (90.3), residential wood (82.1), macro-hydro (54.8), industrial wood (27.6), landfill and sewage gas (3.8) and solar water heaters (3.7) (Table 1). The share of renewable energy in national electricity production was approx. 10-11% in 1996-97. Under the additional 2 per cent renewables target, approx. 10 000 GWh/year (36 PJ/year) electricity will be required from renewable energy sources in 2010, representing an increase of over 55% in renewable energy electricity production from the 1996-97 level. The potential increase in renewable capacity from using current identified renewable sources is estimated to be insufficient to reach the 2 per cent target, so more new investment in renewable sources will be required. The range of renewable energy sources including hydro, wind, solar voltaic, solar thermal, biomass, municipal solid waste and wastewater, marine, and geothermal have been recently analysed as to their potential to contribute to the 2 per cent renewables target (REM 1999a, b). The biomass sources include bagasse, pulping liquor from paper production, forestry residues and wood processing residues, energy crops, crop residues and wet wastes from agriculture and food processing. The analyses concluded that biomass energy sources have the potential to contribute significantly to the 2 per cent renewables target.

Table 1. Renewable energy use in Australia 1995/96

Source	Petajoules
Bagasse	90.3
Residential wood	82.1
Macro-hydro	54.8
Industrial wood	27.6
Landfill and sewage gas	3.8
Solar water heaters	3.7
TOTAL	260.3

References

Unless indicated otherwise, many of the statistics stated in this paper are taken from a recent analysis of Australian energy trends (Bush *et al*. 1999), the Australian Government's National Greenhouse Strategy (AGO 1998), and general analyses of the Australian renewable energy sector (REM 1999a, REM 1999b).

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HARDWOODS IN LAND TREATMENT SCHEMES: CURRENT STATUS OF NEW ZEALAND AND AUSTRALIAN RESEARCH

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Introduction

The interest in using a tree crop in land treatment schemes (usually effluent) has increased in the last decade. To date the research emphasis for ***Forest Research*** in New Zealand has been on trials involving the main commercial forest tree *Pinus radiata (*radiata pine*),* largely because existing pine forests have been adjacent to effluent sources and the research skills in ***Forest Research*** land treatment projects have been strongest in the pine genera. Hardwood tree species in land treatment schemes have not received as much research effort as radiata pine, but have been preferred in a number of schemes.

In Australia the research effort has focussed on native species; Eucalypts, although some work has been done on radiata pine.

The author undertook a short study tour of the main current land treatment trials in New South Wales, Victoria and South Australia in 1996 to observe the Australian research activities on their native hardwoods.
The status of the research activities in Australia and New Zealand provides an interesting comparison in research direction and this paper suggests directions for future effort.

Background

Interest in a number of hardwood species comes from their fast initial growth rate and in high wood density (Nicholas 1986). Consequently hardwoods produce more biomass at an early age than most conifers. This attribute is advantageous in land treatment systems, where fast early growth usually translates to greater water use and nutrient uptake (Roygard 1999). The high wood density is also suited to the production of fuelwood- an attractive market for products derived from land treatment systems.

Research Trials

Currently there are nine land treatment schemes in New Zealand (Table 1) and four in Australia (Table 2). While there are more schemes in New Zealand, few of them are currently being actively researched.

Table 1: Research status and main research activities at main scheme sites in New Zealand.

SITE	Year Planted	Status*	Effluent Type	Growth	Nutrient Cycling	Soils	Foliage	Wood Density	Biomass
Waitangi	1983	T	Community	✓					
Horotiu	1985	T	Meatworks	✓	✓				✓
Whakare-warewa	1990	C	City	✓			✓	✓	✓
Oringi 1	1987	T	Meatworks	✓	✓	✓	✓	✓	✓
Oringi 2	1991	T	Meatworks	✓					
Oringi 3	1993	C	Meatworks		✓				
Whitford	1992	T	Leachate	✓	✓		✓	✓	✓
Moutere	1989	M	Community	✓					
Whiritoa	1989	C	Community	✓	✓	✓	✓		

* T=terminated, C=current, M=monitoring

Table 2: Research status and main research activities at main scheme sites in Australia.

SITE	Year Planted	Status*	Effluent Type	Growth	Nutrient Cycling	Soils	Foliage	Wood Density	Biomass
Wodonga	1980	T	City	✓	✓	✓	✓		✓
Wagga Wagga	1990	C	Municipal	✓	✓	✓	✓	✓	✓
Shepparton	1993	C	City	✓	✓	✓			✓
Werribee	1989	C	City	✓	✓	✓			
Bolivar	1990	T	City	✓	✓	✓			✓

* T=terminated, C=current

Hardwood species under evaluation

Tables 3 and 4 outline the hardwood species which have been investigated in effluent schemes in New Zealand and Australia.

Further details on the New Zealand trial sites can be found in Carnus *et al*. 1994; Barton *et al.* 1991; Gielen *et al.* 1999; Guo and Sims 1999; Stace 1996; and Nicholas *et al.* 1994. Considerable information on most of the Australian trials is presented in the proceedings and field notes for the New Zealand Land Treatment Collective meeting in Australia in September/October 1996 (Baker *et al.* 1996a-c; Benyon *et al.* 1996a & b; Boardman *et al.* 1996; Stackpole *et al*. 1996), Stewart *et al*. 1988, and on the CSIRO web page (http://www.ffp.csiro.au/pff/effluent_guideline/publications.htm).

Table 3: Hardwood species under investigation at main scheme sites in New Zealand.

Site/species	Waitangi	Horotiu	Whaka	Oringi 1	Oringi 2	Oringi 3	Whitford	Moutere	Whiritoa
E. saligna	✓	✓	✓						
E. botryoides		✓	✓	✓	✓		✓		✓
E. camaldulensis				✓			✓		
E. ovata			✓	✓	✓	✓	✓		
E. nitens		✓	✓		✓			✓	
E. globulus			✓		✓	✓	✓		
E. grandis					✓		✓		
E. fastigata	✓								
E. fraxinoides		✓							
A. dealbata		✓	✓	✓					
A. melanoxylon	✓	✓	✓	✓					
J. nigra			✓~						
P. tomentosa	✓		✓~						
C. speciosa	✓								

~Failed at planting

Table 4: Hardwood species under investigation at main scheme sites in Australia.

Site/species	Wodonga	Wagga Wagga	Shepparton	Werribee	Bolivar
E. saligna	✓	✓#	✓	✓	
E. botryoides		✓#			
E. camaldulensis	✓	✓	✓	✓	✓
E. ovata					
E. nitens		✓#			
E. globulus		✓#	✓	✓	✓
E. grandis	✓	✓#	✓	✓	✓
A. dealbata					
A. melanoxylon		✓			✓
A. mearnsii			✓		✓
C. glauca			✓		✓
C. cunninghamiana	✓		✓		✓
E. viminalis		✓#	✓		
E. bicostata		✓#			
E. badjensis		✓#			
E. dunii		✓#			
E. regnans		✓#			
E. maidenii		✓#			
E. elata		✓			
E. amplifolia		✓			
E. robusta		✓			
E. maculata		✓	✓		
E. henryi		✓			
E. occidentalis		✓			
E. propinqua		✓			
E. microcorys		✓			
E. pilularis		✓			
E. triflora		✓			
E. pellita		✓			
E. cloeziana		✓			
E. cladocalyx		✓	✓		
E. dendromorpha		✓			
E. melliodora		✓			
E. paliformis		✓			
E. polybractea		✓			
E. dives		✓			
E. brookeriana			✓		
E. sideroxylon			✓		
Populus spp	✓	✓		✓	

top 11 eucalypt performers in trial

Discussion

Considerable research activity was undertaken in both New Zealand and Australia using hardwoods in land treatment schemes in the late 1980s and the early 1990s.

In 1996 there was little evidence to show that momentum is building for hardwood tree crop systems that include land treatment. A number of working schemes have been successfully established, but the success of hardwood plantings in land treatment schemes in both Australia and New Zealand appears stalled because of a lack of end use of the biomass produced. Thus, although the science behind many schemes is providing excellent scientific output, the next phase of industrial schemes running successfully is less certain.

The challenge for those in land treatment research is to learn from past experience. Two main points are:
(i) The emphasis in the past has been on nutrient cycling and water use, paramount questions in any land treatment scheme.
(ii) Little emphasis has been placed on utilising the biomass produced; the attitude appears to have been one of waiting and hoping that an option will open up later.

Researchers now have the opportunity to develop a systems approach that includes researching the interactions between:

- Effluent application
- Nutrient cycling
- Impact on environment
- Species selection
- Biomass production
- Tree management systems
- Biomass utilisation
- Biomass harvesting
- Economics
- Sustainability

Until there is a successful marriage of tree crop production and nutrient removal priorities, research activities on land treatment schemes in both New Zealand and Australia are likely to struggle to generate research activity to expand the concept of land treatment.

Research in Australia is providing valuable data on nutrient cycling with hardwoods, but many of these trials seem to lack long term funding support and are unlikely to be continued. In New Zealand effluent interactions with the tree crop have concentrated on pine rather than hardwoods, although there are exceptions, Massey University for example, with detailed physiological experiments incorporating lysimeters. For New Zealand, monitoring of schemes that include hardwoods is more usual than specific research trials on nutrient cycling.

Research on effluent application and nutrient removal appears to have driven the most active research in the past. Now this research needs to be taken further into well designed research trials in operating schemes, with more detailed evaluation of crop management options and environmental impacts, especially on soil and water.

Researchers in both countries have identified a number of preferred species for land treatment schemes, but as these can be very site specific, some care is needed in interpretation.
The performance of species is not always comparable across the Tasman because of climate and insect/disease differences between the two countries. For instance, within New Zealand, *E. grandis* has not been very successful, and *E. globulus*, although under review as a species for New Zealand conditions by those interested in pulp production, is usually outperformed by *E. nitens*. One very common thread across both countries is the poor growth performance of *E. camaldulensis*. Despite its wide recognition as a species very tolerant of effluent application, there seems no justification in including it where biomass production is of interest.

A process of identifying species with wood and biomass attributes suited to specific end uses will help the ultimate success of land treatment ventures. But the two key objectives in a land treatment system (wood fibre production and nutrient removal) may require conflicting plantation management techniques.

Short fibre pulp end users require stem wood of trees approximately 10 years old, while those interested in nutrient removal require young fast growing trees which should be felled before crown suppression occurs.
Australian researchers have also added another dimension, that of producing sawlogs for conversion to solid timber. For this they require quite large stem diameters to enhance sawing conversion, although that is species-dependent (G. Waugh, pers comm.).

If the emphasis is on nutrient removal, then very short rotations are required where crown growth is maximised. The most promising utilisation process to use this foliage mass and stemwood combined is conversion to energy. More data are required on growth rate, biomass trends with time, and economics, especially for harvesting, before options for conversion to energy can be better quantified. Then better predictions on optimum growing systems for utilisation and nutrient removal can be made.

The issue of sustainability is still important and to provide long term answers, must remain a main driver in the questions asked by researchers. For this, research in working schemes that incorporate harvesting, replanting etc. is needed.

Perhaps the greatest opportunity is for forms of energy production using whole tree biomass. Coppicing species and very fast initial growth may play a part in such schemes. Given the strong interest in short fibre production in both New Zealand and Australia, and in using hardwoods for land treatment, researchers have an opportunity to bring the two elements together, but they should not be developed in isolation.

Conclusion

- Many research trials were established in the late 1980s and early 1990s to investigate the opportunity for land treatment using a range of hardwood species. Over the last decade, very few of the research findings have translated into larger scale operations. This does not seem to be the consequence of the lack of species to grow in land treatment plantations, but rather the lack of commercial utilisation of the biomass produced.

- The interactions of climate and site result in a mix of hardwood species included in land treatment schemes. This means that it is difficult to identify a single species of hardwood as preferable for land treatment schemes in New Zealand or perhaps even in Australia. Thus species trials should remain a key part of any land effluent scheme of any consequence in either New Zealand or Australia.

- In the future, land treatment schemes should be associated with a utilisation processor to make use of the ability of selected hardwoods to produce substantial amounts of biomass in a short time, and to efficiently recycle or pump land treatment elements.

- Researchers should now move from process research to a systems approach in an operational type environment, where schemes or options should be evaluated for maximum utilisation potential and maximum nutrient removal, all in a sustainable framework. Research programmes should be initiated where trees can be processed and the nutrient cycles followed through several rotations at least.

- Information is still required on the commercial realities of effluent systems, especially for the tree crop, and its long term viability as an economic land use.

- Research effort and long term planning between the soil scientist and the silviculturist is required to generate the data for better understanding of the decisions required to develop working land treatment systems. Perhaps it is time to have more formal dialogue with the interested parties before the enthusiasm and data collected during the early 1990s is lost and forgotten, before the cycle starts again. Opportunities exist in both Australia and New Zealand to generate such research trials, but the single science emphasis of the past should be forgotten, and new multidisciplinary research effort is needed to take the research effort to new levels.

- The opportunity remains to create a win-win situation on many different scales from the small community base such as at Whiritoa, to larger scale plantings such as those seen at Oringi or specialist short fibre plantations seen in the Bay of Plenty and in Southland.
- Perhaps new developments such as energy production from biomass combined with land treatment will provide the way for integrated systems research in the future?

Acknowledgments

The assistance of those land treatment researchers in New Zealand and Australia who shared information on their research activities, and those in Australia who so generously showed me their trials, is very much asppreciated. The comments of Justin Ford-Robertson, Jean-Michel Carnus, and Bob Shula on a previous version of this paper were also extremely constructive, as were the comments of Michael Robinson and Guija Magesan on this revised paper. This paper was originally presented to the New Zealand Land Treatment Collective, Technical Session No. 15, Nelson April 1997. Although updated for the Perth IEA Task 17 Meeting, March 2000, the permission of the Collective Technical Manager Michael Robinson to republish the paper in this edited form is appreciated.

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MALLEE: A NEW SHORT ROTATION CROP FOR THE WESTERN AUSTRALIAN WHEATBELT

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Background

Agricultural development of the Western Australian wheatbelt region commenced in the late 1800s. Development was initially slow due to the very low fertility of the ancient highly weathered land surface of Western Australia. The discovery of cheap sources of phosphorus, trace element deficiency, and crop and pasture rotations including annual legumes, saw rapid acceleration in the rate of development. These advances came mainly after the second world war and the majority of the 18 million ha of agricultural land in the south west corner of Western Australia has developed since then. Development required the clearing of the native vegetation that consisted of forests, woodlands and shrublands but virtually no grasslands. After clearing large applications of phosphorus and trace elements were applied and introduced annual crops and pastures were sown. The agriculture became very productive and is a major part of the Western Australian economy. Current annual value of production is approximately A$4 billion.

However, the nearly total dependence on annual plants in the agriculture has caused a serious hydrological imbalance. The shallow rooted annual plants are not able to consume all incoming rainfall. In the generally very flat agricultural landscape most of the unused excess of rainfall infiltrates deep into the subsoil and accumulates as groundwater. Groundwaters fill to intersect the surface, mostly on the valley floors. This sets up a cycle of recharge and discharge of groundwater systems that was not active under the original native vegetation cover. The large storage of salts that was built up in subsoils under the native vegetation cover is mobilized and flushed from the landscape. The extensive discharge of saline water is a serious economic and environmental problem. Inadequate water use under the present agricultural system is the fundamental driving force of this salinity problem.

The problem occurs over virtually all the agricultural land of the south west. While land damage by salinity is a serious problem to the farmer, predicted to afflict more than 30% of the landscape within a few decades, downstream damage will be an increasingly serious problem for the community at large. The entire drainage network is being degraded leading to loss of water resources, loss of riverine and valley floor biodiversity, loss of amenity, increased stream flow volume and erosion, instability in valley floor infrastructure due to saturated foundations and increased flood risk.

Salinity has provoked much discussion about the ecological sustainability of agriculture. However, perhaps the greater concern for the farmer is that the present form of agriculture might not be politically sustainable. The downstream impacts of salinity appear severe enough to provoke political demand for comprehensive remedial measures to be developed and applied. Hatton and Salama (1999) recently overviewed remedial treatments and came up with pessimistic projections of the scale and response times required for such treatments. However, the political pressure for fundamental solutions, or at least a serious attempt at remediation, is unlikely to be deflected by the difficulty of the task.

Salinity can be manipulated by the water management practices adopted by agriculture. There is scope to increase water use by plants and to drain or pump water to reduce the amount in groundwater systems. The options to improve water management practice can be grouped into five categories (Salinity Action Plan 1998):

- increase water use by the annual crops and pastures that dominate current agriculture
- improve the health and vigour of remnant native vegetation
- collect, reuse and dispose of surface water
- drain or pump, reuse and dispose groundwater
- increase the range and proportion of perennial plant species used in agriculture

The Salinity Action Plan (1998) recognized that of these, perennial plants offer the best prospect for significant increase in water use within agriculture.

Perennial plant options

Historically, annuals have dominated Western Australian agriculture and surprisingly little has been done to develop perennials. There were many good ecological and economic reasons why annuals came to achieve their dominance. However, the emerging recognition of the full size of the salinity threat appears to be enough to justify much larger commitment to the development and use of perennials.

Perennial plants come in many forms. Table 1 gives an overview of the range of types and some examples in current use. The major division used in this table is between grazing plants and non-grazing plants. This is a convenient separation because it indicates very different management and product options. Within the grazing category there are well known herbs and grasses and some newer woody fodder shrubs. Within the non-grazing category the separation is between trees (with conventional timber producing options) and shrubs with a wide range of as yet little developed product options. The listing of ‘farm trees’ and ‘understorey’ reflects the wide interest restoring some of the natural biodiversity during revegetation. Non-grazing shrubs are divided into sprouters and seeders indicating a major management difference - sprouters can regenerate from the stump but seeders must be replanted after harvest. Both may be harvested on cycles as short as 2 years and are therefore called short rotation tree crops. The Australian flora is especially rich in sprouting species such as mallee.

Table 1: Overview of perennial plants types

PERENNIALS				
GRAZING		NON-GRAZING		
			SHRUB	
HERBS/GRASSES	SHRUB	TREE	Sprouters	Seeders
Lucerne Phalaris	Tagasaste Acacia saligna Saltbush	bluegum maritime pine farm trees	mallee melaleuca understorey	Acacia understorey

The scale of planting of perennials necessary to control salinity is in the order of millions of hectares. The cost of establishment will be measured in billions of dollars. To occupy land on this scale, and to attract the necessary capital investment, perennials will generally have to pay their way as well as improve water use. Hence the major question is 'which perennials have the best commercial potential?'

Perennials that already have a commercial track record are an obvious choice. Table 1 gives an overview of the current commercial perennials and the limits of their range.

Table 2: Current commercial perennial options

Perennial species	Plant form	Rainfall zone	Soil preference	Products	Development status
Bluegum	tree	>600 mm	deep fertile	pulpwood, saw logs	new crop, well demonstrated
Pinus radiata	tree	>600 mm	deep fertile	chipwood, saw logs	old established
Pinus pinaster	tree	>400 mm	light infertile	chipwood, saw logs	old, expanding to drier areas
Lucerne	herbaceous legume	>400 mm	deep freely drained, not too acid	grazing, fodder	old established, expanding to drier areas
Tagasaste	woody legume shrub	400 to 600 mm	light infertile	grazing	new, well demonstrated
Mallee (many species)	woody shrub	< 600 mm	full range	eucalyptus oil, wood, bioenergy	commercially unproven

Perennial grazing plants feed into already established sheep and cattle industries and are therefore available for immediate use by farmers. However, the soils and rainfall preferences of existing options are too narrow and grazing industries have suffered a long-term cost/price squeeze. It would be desirable to use the development of perennials as an opportunity to diversify the economic options available to farmers (Bartle et al 1996).

Table 2 lists three timber producing tree crops. These offer opportunity for entry into existing industries and provide economic diversification but they are only available where annual rainfall is 400 mm or greater. What is clear from Table 2 is that there are no existing tree crop options available for extensive use in the wheatbelt. The oil mallee project has been designed to fill this gap.

The challenge for new tree crops is the cost of development. Being 'new' there are few established practices and little relevant industry from which to take a lead. Hence the entire suite of establishment, management, harvest, processing, product and marketing options must be developed within a whole industry context. The costs and lead times are large. Hence the target tree crop must be very carefully selected.

The oil mallee development was initiated after a careful assessment process that systematically addressed the question 'why oil mallee?' The following discussion presents a brief review of the logic of this process.

Logic of the selection oil mallee for development as a tree crop

1. Market size

The extent of revegetation required to have an impact on salinity can be measured in millions of hectares. This inevitably means large volume markets to minimize the risk of oversupply. This does not exclude development of dozens of small industries based on tree crops producing specialist products like specialty timber, essences, flowers, fruits and nuts. However, it does indicate that we must also create some substantial new industries producing large volume commodities at world competitive prices to provide the base load for revegetation. The oil mallee development is a deliberate attempt to fill this role.

Eucalyptus oil has a small existing market of some 3000 tonnes worldwide used in a wide array of non-prescription pharmaceuticals and cleaners. This could be a useful market while scaling up but is trivial in relation to the production volumes we need to achieve to have a regional scale impact on salinity. Eucalyptus oil has good solvent properties and has potential to become a major industrial solvent (Barton et al 1997). The manufacture of a major industrial solvent, trichloroethane, was discontinued in 1996 under international convention because of its ozone depleting properties. Some 700 000 tonnes of this material were consumed annually. Solvent industries are busy developing replacement products while running down existing stocks of trichloroethane. Eucalyptus oil has the opportunity to enter this market. Table 3 shows planted areas required to supply the whole existing market, in relation to areas required to supply small proportions of the former trichloroethane market.

Table 3: Quantity and area of eucalyptus oil production required for various world market shares

	Existing oil market	**Former trichloroethane market**		
World Market Share	100%	1%	5%	10%
Production required for that market share (tonnes)	3 000	7 000	35 000	70 000
Area required at a yield of 100kg/ha/yr	30 000ha	70 000ha	350 000ha	700 000ha
Area required at a yield of 200kg/ha/yr	15 000ha	35 000ha	175 000ha	350 000ha

Perhaps the most exciting aspect of the oil mallee development is the potential to turn the large volume of residues into products. Given the potential scale and low cost of such residues there are many options. This will be discussed in a later section.

2. Amenable to extensive production systems

Wheatbelt farmers have highly mechanized, low labour input businesses. They are world leaders in applying new technology and generating economies of scale. They compete successfully in highly competitive world markets. These farmers will be keen to apply their comparative advantage in large-scale commodity production systems to new perennial crops. From this perspective it is unlikely that tree crops producing products like flowers, fruits and nuts will be at home in the wheatbelt.

Oil mallee can produce bulk commodity materials in extensive cropping systems. The plants are robust and easy to grow. They can be harvested and transported in mechanized systems not very different from conventional annual crop systems.

3. Transport horizon or local processing to improve value

Annual crops have products with values in the range $200 to $400/tonne. A 300 km trip to a coastal port represents less than 15% of product value and is not a serious constraint on the viability of the crop. In contrast, many raw wood products have values in the order of $30 to $50/tonne and cannot be transported very far without some form of local processing to add value.

Eucalyptus oil as a feedstock for solvent products will have a value of about $2000/tonne and could be efficiently transported downstream from the extraction plant. However, raw leaf will have to be transported in to the local extraction facility. The extraction cost of $20/tonne of leaf and an oil concentration of 3% indicates a raw leaf value of some $40/tonne and therefore a limited transport radius. This simple analysis ignores residue value and the option of leaf and wood separation in the field but it accurately indicates that the industry will be centred on local processing facilities.

An alternative scenario under investigation by the Oil Mallee Company will see if it is viable to produce eucalyptus oil from 'in the paddock' extraction systems thus avoiding the need for transport of raw leaf into a central facility.

The smallest operational plants are likely to require 100 000 tonnes/year of feedstock (leaf and wood). To produce 100 000 tonnes/year at a yield of 10 tonnes/km/year of standard hedge will require 10 000 km of hedge. In alley planting configuration this will require 50 000ha planted on 50 m spacing or 100 000 ha on 100 m spacing. Table 4 shows how transport radius will vary with the extent of adoption of oil mallee planting in these alley layouts to produce a volume of 100 000 tonnes/year. It shows that a quite viable 50 km transport radius requires only a modest level of adoption to produce the volume required for a minimum plant size.

Table 4: What planting area radius would produce 100 000 tonnes/year?

Radius	Total area	% adoption to produce 100 000 tonnes	
		in 50 m alleys	in 100 m alleys
20 km	126 000 ha	40	80
30 km	283 000 ha	18	36
40 km	503 000 ha	10	20
50 km	786 000 ha	6.4	13

4. Short rotation

The establishment cost and alternative annual revenue foregone on land occupied by tree crops imposes an economic constraint on the rate of adoption of tree crops by farmers. In other tree crop industries 'sharefarming' arrangements have been developed where an off-farm investor shares the growing costs and the harvest revenue with the land owner. Another way to facilitate adoption of tree crops is to select short rotation tree crops where harvest revenue starts early and comes regularly thereby maintaining farm cash flow and helping the farmer finance his own investment in tree crops.

On a whole industry level the investment required for short rotation tree crops will be less than long rotation crops and therefore a short rotation industry should be more readily developed.

Oil mallee is ready for harvest by age 5 and can then be cut on a 3 year cycle. In the wetter western wheatbelt these times might be reduced to 4 years for first harvest with 2 year cycle of harvests thereafter. Mallee is harvested to ground level and sprouts or coppices back from the subsurface 'mallee root' or ligno-tuber.

5. Residue use options

In oil mallee the eucalyptus oil fraction makes up less than 2% of whole-tree fresh weight. Not surprisingly, existing eucalyptus oil production industries are either a byproduct of forestry or at least use some of the residue as fuel to generate steam for extraction of the oil.

It is simply not credible to approach the development of a new eucalyptus oil industry without a strategy for residue utilization. At the scale of planting necessary to have some impact on wheatbelt salinity, production of residues could exceed 10 million tonnes/year. This material would be available in lot sizes between 0.2 and 0.5 million tonnes/year in many wheatbelt towns. Processing plant would have to be located in (or near) towns because the low value of the residue precludes transport to coastal centres.

Table 5 lists the range of product options for use of oil mallee residues. From the inception of the mallee project in 1992 CALM has carefully monitored developments in all these areas. All the product categories have the necessary market size to be relevant to the mallee industry, all are relatively undiscriminating on feedstock type and all seek large volume/low cost reliable sources of supply.

Table 5: Potential products from mallee residue

CATEGORY	PRODUCT
Reconstituted wood products	panel board (oriented strand board and fibre board)
Carbon products	charcoal, activated carbon
Energy	liquid fuels (ethanol, methanol) solid fuel for electricity
Chemicals	gasification (ammonia, methanol) fractionation (cellulose/lignin)

The greenhouse issue, and the Kyoto protocols which impose a ceiling on national carbon emissions, are likely to help renewable products and renewable energy improve their economic competitiveness in the medium term

The Oil Mallee Company has just completed a feasibility study to investigate the production of eucalyptus oil, activated carbon and electricity in a fully integrated plant. Plant integration is likely to achieve major economies, for example, waste heat can be utilized for steam extraction of the oil. It is anticipated that a plant size of 100 000 tonnes/year would deliver full economies of scale. If the feasibility investigation confirms viability several of these plants could be built across the wheatbelt.

The activated carbon option is attractive because it has a relatively small economic plant size. However, activated carbon markets are competitive. To achieve its ambitious objectives the oil mallee industry will have to diversify residue utilization industries. Larger economic plant size in other product areas, probably a factor of 3 or 4 times as large, should be more readily achieved on the back of success in activated carbon production.

6. Compatibility with present agricultural practice

The oil mallee industry is being developed to be complementary to traditional agriculture, in particular to provide a high water use option to help reduce salinity. To be effective in achieving high water use it will be necessary to have mallees widely dispersed across the farm. It is anticipated that the most common form of dispersal will be in the form of belts. Belts will permit efficient harvest while also achieving the objective of dispersal. The focus on belts gives rise to the frequent reference to alley farming.

Two particular problems of compatibility emerge with belt or alley planting systems.

In belts there is a large degree of exposure of the adjacent annual crop or pasture to competition from the perennial mallee. Shading is not likely to be a problem given that the mallee will be kept at a height of less than 2 m by frequent harvest. However root competition will occur.

Ideally mallees would have only deep roots exploiting water surplus to that required by the annual plants. While this ideal will not be achieved there is potential to select mallee species that have the strongest deep rooting ability. There is also the quite simple management option of ripping adjacent to mallee belts every few years to trim lateral root development and reduce competition. On the other hand, if mallee is economically competitive, the farmer can be indifferent as to whether revenue comes from mallee or the annual plants. Observation of mallee to age 6 shows that root competition with cereal crops is minimal.

The second problem with any tree crop arranged in belts is palatability. Fencing long narrow belts in alley farming systems to protect trees from grazing would not be viable. The only alternative is to choose unpalatable species. The initial assessment of low palatability of oil mallee has been confirmed in practice over the past 6 years. Young seedlings need protection and are generally established in conjunction with a crop. A light stubble grazing can be taken in the first autumn after establishment. Thereafter only minimal extra input to grazing management is necessary. There is little experience with grazing management of a coppicing crop but small plot observation shows no cause for concern. Finally, some variation in palatability between species is observed. The are many prospective commercial species and the option to exclude the most palatable types can be taken.

7. The advantage of natives species

A major period of development of new perennial woody plant crops is now emerging. If exotic species are used as the source of new commercial crops probably hundreds of species would need to be screened to locate several that may have commercial value. In such a process some of those tested may have potential to become weeds and may escape from cultivation to express their weed habit. For example, the desirable attributes of low palatability and rapid regeneration could be the makings of a successful weed. Weeds can cause economic loss through the need to impose controls or suffer the loss of use of land. Woody weeds also present a risk to the nature conservation value and biodiversity of the native bush.

Weed risk would be greatly reduced if new woody crop development first considers the potential value of native species. There is little risk of native species becoming weeds because they have evolved within the checks and balances of local ecology. The oil mallee project has embraced this principle.

There are also some strong commercial advantages in giving priority to native species.

Native species are adapted to the native environment and are unlikely to fail abruptly after some extreme climatic event or when they reach an advanced stage of growth. For example, blue mallee (*Eucalyptus polybractea*), the species that is harvested for oil in inland areas of NSW and Victoria, initially grows well but fails dramatically at age 3 or 4 years in the northern wheatbelt of WA. Also these perennial species must do an unusually difficult job i.e. develop deep root systems in what is clearly a harsh subsoil environment. It is therefore sensible to consider native species because they are well adapted to these conditions.

The WA flora is unusually diverse and rich in species containing high levels of extractive products such as gums, resins and oils. There has historically been some interest and commercial exploitation of these products but the potential remains largely untapped. Eucalyptus oil was harvested in the WA wheatbelt in small amounts several decades ago. Until the work by Brooker et al (1988) and subsequent work by CALM (Bartle et al, 1999) the potential was largely undefined. There are now known to be more than 20 mallee species with commercial oil potential. Species could be selected to suit particular environmental niches, to provide particular oil constituents or to meet particular management needs such as low palatability.

Progress in mallee industry development

1. Background

The extraction of leaf oils from *Eucalyptus* species has its origins in the first colonies in NSW and Victoria. Through its long history eucalyptus oil production has been a small-scale subsistence industry punctuated by very brief booms. Eucalyptus oil has established a world market mainly as a non-prescription pharmaceutical and cleaning agent with a market volume of some 3000 tonnes. Australia was formerly the major producer but China now dominates world markets.

The first significant step to take eucalyptus oil beyond its traditional 'cottage industry' status was by Professor Allan Barton from Murdoch University. He saw cineole, the major constituent of eucalyptus oil, as having chemical properties that could be developed for large volume industrial products, especially solvents. During the 1980s he undertook investigation of many aspects of mallee production including its potential role in salinity control.

In the late 1980s the Department of Conservation and Land Management (CALM) commenced development of bluegum as a commercial landcare tree crop for the greater than 600 mm rainfall zone of the lower south west of WA. By the early 1990s it was clear than this development was commercially viable and new horizons could be explored in pursuit of further benefit from the techniques and experience gained from bluegum. With a secure allocation of development funds the 'oil mallee project' started, re-commencing the work begun by Allan Barton. The objective was to develop a perennial crop for the wheatbelt and to commence building up a resource base with a view to creating a major new industry.

2. Progress

CALM sought interest from growers in six wheatbelt centres and pre-commercial planting commenced in 1994. In the first 3 years CALM helped finance seedling costs and provided leadership for the infant industry. Strong interest was generated. Growers formed an association to further their interests and took over management of the industry in 1996. As the potential for commercial development of harvest and processing became clear the Association sponsored the formation of the Oil Mallee Company (OMC) in 1997 to facilitate commencement of commercial operations.

The record of planting is given in Table 5. There are now some 800 growers and a solid base of establishment and management knowledge has been built up.

Table 5: Mallee planting statistics 1994 to 2001

Planting year	Seedlings planted (millions)	Number of growers	Area planted (ha)
1994	1.10	80	412
1995	2.05	170	769
1996	2.80	250	1050
1997	1.05	100	394
1998	2.00	200	750
1999	2.85	273	1069
2000[1]	4.72	429	1770
TOTAL	**16.57**	**800[2]**	**6214**

1. Estimated
2. Many growers have planted over more than one year and this total is not the arithmetic total of the column

The industry recently commenced its first commercial feasibility investigation in partnership with the state owned electricity utility Western Power. This project is evaluating a plant designed for integrated processing of mallee feedstocks to concurrently produce eucalyptus oil, activated carbon and electricity. The investigation looks promising and the partners have commenced assembling funds to construct a 20% scale pilot plant at an estimated cost of $5 million.

Mallees are eucalypts that have a characteristic multi-stemmed form (up to 12 m in height) with a large woody rootstock or ligno-tuber just below the ground surface. There some 200 species mostly occurring in the arid and semi-arid regions of Australia. The ligno-tuber has many dormant buds that enable the plant to regenerate (or coppice) prolifically after the above ground parts are damaged or removed by natural events like fire or drought, or by harvest. As mature stands they appear very slow growing but as coppice they can grow rapidly. In agricultural land where extra water and nutrients are available and when planted in belts designed to intercept subsurface water movement they can be maintained in the productive coppice mode of growth indefinitely under a regular (every 2 to 4 years) harvest regime.

Harvest of mallee can commence at age 4 or 5 and be repeated on a cycle or rotation of 2 or 4 years. Each new crop coppices back from the subsurface lignotuber or mallee root. Mallee biomass yields will be in the range 10 to 20 green tonnes/ha/year or 30 to 60 green tonnes/ha/harvest (for a three year harvest cycle). The oil is contained within the leaf fraction that constitutes 35% of biomass. Oil content will average 1% of whole green biomass or 2.9% of leaf biomass. With the availability of genetically improved seed the leaf oil content should increase to greater than 1.2% of whole above ground biomass or 3.4% of green leaf.

Major current areas of research investment include genetic improvement, harvest and handling system, processing and products.

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VEGETATION FILTERS IN SWEDEN – A SHORT COMMUNICATION

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Background

The amounts of municipal wastes of various types are increasing in most parts of the world. In many countries, almost no treatment of municipal wastewater exists at all or, in the best cases, a mechanical procedure for separating solid particles. Building of complex treatment plants or landfills which meet the needs of satisfactory handling of the wastes is costly, and many countries do not give priority to this type of functions. Therefore, it is necessary to find less expensive and more "natural ways" for the treatment, that still are efficient enough to satisfactorily solve the waste problems.

A more natural process is the use of vegetation filters, which are regularly harvested and thereby off-loading the system from unwanted, polluting subjects. One such type of vegetation is short-rotation willow coppice (SRWC) consisting of different species and clones of *Salix*. They have shown to contain many of the necessary functions of interest. A crop applied as a vegetation filter should neither direct nor indirect be used food crop, and that is another advantage of SRWC.

Generally, suitable plant communities, designed for management and treatment of municipal wastes, comprise vegetation filter systems. In Sweden, such systems mainly consist of SRWC, which have shown to be efficient in taking up nutrients, preferably nitrogen. They are also known for their enhanced evapotranspiration capacity, in terms of comparably high interception-evaporation and transpiration rates. In addition, some clones of willow are capable of taking up heavy metals and can therefore be used for soil remediation.

Due to the presence of pathogens in wastewater and sludge, great attention must be paid to storing and distribution of this type of wastes. In Sweden, trickle irrigation of wastewater is only occasionally accepted, and instead different types of drip irrigation techniques are adopted. Sludge has to be treated or stored long enough to be regarded as safe. Humans could be infected either after direct contact with the pathogens (during the storing phase, by droplets or aerosols after sprinkler irrigation, by consuming contaminated drinking water or by accidental take in of contaminated swimming water) or indirectly through zoonotic (via animals) transfer of pathogens. Therefore, when localising vegetation filter systems in the landscape, it must be ensured that no pathogens reach groundwater used for human consumption. Special efforts must also be made to reduce the exposure of livestock and pets to wastewater pathogens. The presence, survival and distribution of pathogens in vegetation filters of SRWC irrigated with wastewater is currently being studied in Sweden and other EU-countries within the framework of both national and international projects.

Conclusions

From our experiences and results so far, the following conclusion can be drawn:

- Nitrogen leaching from conventional short-rotation willow coppice (SRWC) is very low.
- SRWC can be used as an active filter for treatment of nitrogen rich drainage water, thus reducing the nitrogen leakage to watercourses and groundwater. The economical benefit still remains to be investigated.
- Vegetation filters of SRWC can be used for soil remediation, especially concerning cadmium (Cd). A net export of 5-10 g Cd ha^{-1} yr^{-1} is reached in Swedish studies. If the wood is used as bio-fuel, it should be purified from Cd during the process of combustion, otherwise there are risks of further spreading of Cd in the environment.
- SRWC vegetation filters are efficient in taking up nutrients from wastewater. The production in stands irrigated with wastewater is expected to be higher than in conventionally managed stands, partly depending on the fertilisation effect, partly on the irrigation effect. The wastewater should be distributed using drip irrigation in order to avoid aerosol spreading of pathogens.

- Using municipal sludges as fertiliser in SRWC is probably one of the best ways to utilise sludges without risking that different toxic compounds enter the human food chain.
- SRWC can also be used as vegetation filters for treatment of landfill leachates. The aim of such a treatment is not to purify the leachate, but rather to keep the pollutants within the landfill area by increased evapotranspiration.
- Treatment of wastewater, sludge and leachates in vegetation filters of willow can economically compete with conventional treatment.

Extract of literature of interest

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COSTS OF PRODUCING BIOMASS ON RIPARIAN BUFFER STRIPS IN THE DELMARVA PENINSULA, USA

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Abstract

Large quantities of poultry litter are applied to farmland in the Delmarva Peninsula of the United States. Runoff from this poultry litter, other agricultural activities (e.g. dairy farming, fertilizer, pesticides), and urban wastes and runoff contribute to the degradation of Chesapeake Bay. One means of reducing runoff from land-applied poultry litter is to use riparian buffer strips along waterways. Biomass energy (e.g. willows, poplars, switchgrass) could potentially be produced from these buffer strips. Cost of producing, harvesting, and transporting willows, poplars, and switchgrass are estimated under five different cost scenarios: (1) total economic costs, where everything is costed; (2) costs with Conservation Reserve Program (CRP) payments; (3) costs with enhanced CRP payments; (4) costs when buffer strips are required but harvest is not required; and (5) costs when buffer strips are required and harvest is required to remove nutrients. Delivered costs for willows, poplars, and switchgrass under the five scenarios range from s low as \$0.80/GJ (\$0.85/million Btu) in scenario 5 for switchgrass to as high as \$5.45/GJ (\$5.75/million Btu) for willow with a 10 year stand life in scenario 1. The circumstances under which biomass is grown has a large impact on costs. Willow is highest in cost in all scenarios; poplar is intermediate in cost in scenarios 1, 2, and 4; poplar and switchgrass are similar in cost in scenarios 3 and 5; and switchgrass is lowest in cost in scenarios 1, 2, and 4.

Introduction and Background

The Delmarva Peninsula is located on the east coast of the United States, just east of Washington, D.C., bordered on the west by Chesapeake Bay and on the east by the Atlantic Ocean. It is named the Delmarva Peninsula because it consists of parts of the states of Delaware (DEL), Maryland (MAR), and Virginia (VA). Chesapeake Bay is a highly productive, but degraded aquatic ecosystem, suffering from agricultural and urban runoffs and effluents.

In the Delmarva Peninsula over 500 million chickens (broilers) are produced annually and litter from this production is spread over agricultural fields. Poultry litter is often applied to fields at a rate to meet nitrogen requirements, so phosphorus is applied in excess of need. Runoff from this and other activities contribute to high levels of nutrient loading in Chesapeake Bay. One potential method of ameliorating runoff from poultry litter is the use of riparian buffer strips. Riparian buffer strips intercept overland flows of water, sediments, nutrients, and pollutants; and ground water flows of nutrients and pollutants.

In this paper costs are estimated for producing biomass from poplars (*Populus* spp.), willows (*Salix* spp.), and switchgrass (*Panicum virgatum*) from these buffer strips.

In the United States one means of addressing issues relating to sedimentation and water quality has been the Conservation Reserve Program (CRP). It was initiated by U.S. Congress in 1985 and initially was directed toward reducing soil erosion on highly erodible cropland. The 1990 Farm Act changed the goals of the CRP toward addressing water quality and other environmental concerns and the 1996 Farm Act increased the importance of goals other than soil erosion and in particular encouraged riparian buffer and filter strips where appropriate. Under the CRP, participants (land owners or farm operators) voluntarily remove land from crop production for 10 to 15 years and establish a permanent cover (usually grasses or trees) in exchange for an annual rental payment and half the cost of establishing the permanent cover (USDA/ERS 1997). Land in the CRP is generally not allowed to be harvested except under emergency circumstances. However, in southern Iowa switchgrass from CRP land is being harvested for use in a coal-fired power plant. Where one is trying to prevent nutrients from reaching water bodies, not allowing harvest may be counter productive, because without removal of biomass nutrients may built up in the buffer strip to an extent that no more nutrients can be removed by the buffer.

In 1998 in Maryland an enhanced CRP program, known as the Conservation Reserve Enhancement Program, was instituted. In this program the federal CRP and Maryland state programs, in cooperation with the Chesapeake Bay Foundation and Ducks Unlimited, pay up to 95% of establishment costs for riparian filter strips, make rental payments of 170% of prevailing rental rates for land planted to trees and

150% of prevailing rental rates for land planted to grasses, and pay a $12.35/ha ($5/acre) annual payment for buffer strip maintenance.

Filter strips and buffer strips are defined differently. A riparian buffer strip is an area of trees and/or shrubs and/or grasses adjacent to and upslope from water bodies. A filter strip is a strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff and wastewater.

Riparian forest buffers consist of three zones. Zone 1 begins at the normal water line or top of the bank and extends a minimum of 4.6 m (15'). Dominant vegetation consists of trees and shrubs. Occasional removal of some tree and shrub products is permitted as long as the intended purposes (e.g. bank stabilization) are not compromised by the loss of vegetation or disturbance.

Zone 2 begins at the edge of zone 1 and extends a minimum of 6.1 m (20'). The minimum combined widths of zones 1 and 2 are 30 m (100') or 30% of the geomorphic flood plain, whichever is less, but not less than 10.7 m (35'). Dominant vegetation in zone 2 also consists of trees and shrubs. Removal of trees and shrubs on a periodic and regular basis is permitted.

Zone 3 is up gradient of zone 2 and its purpose is to control concentrated flow erosion or mass soil movement (USDA/NRCS 1997b). Zone 3 is designed in accordance with criteria in filter strip standards.

A filter strip is defined as: “a strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff and waste water.” Its purpose is: “to remove sediment and other pollutants from runoff by filtration, infiltration, absorption, adsorption, decomposition, and volatilization, resulting in improved water quality and protecting the environment” (USDA/NRCS 1997a).

Zone 1, the portion of the buffer strip closest to the water body is basically undisturbed and is not harvested except when needed to maintain the function of this zone. In zone 2, managed fast growing introduced (e.g. poplars, willows) and/or native tree species are planted and periodic harvest are allowed. Whether poplars and willow in pure plantings would be allowed under buffer and filter strip regulations and whether poplars and willows can serve the functions required in the buffer (e.g. interception of nutrients in both surface and ground water flows) would have to be worked out and depend on the physical and hydrological characteristics at the site in question. If poplars and willows are allowed, then costs of producing biomass are estimated, under the scenarios described below. Zone 3 is a filter strip planted to herbaceous species for which switchgrass qualifies. The costs of producing biomass from switchgrass are also estimated under the same scenarios described below.

Costs

Costs are estimated for three biomass systems grown on buffer strips: willow at 15,300 trees/ha (6200 trees/acre); poplar at 1345 trees/ha (545 trees/acre); and switchgrass. Willows are established using mechanical tillage, mechanical planting, and chemical weed control. The first harvest is at four years and subsequent harvests at three year intervals. Coppice regrowth is assumed and stand life is varied from 10 to 22 years. Harvest uses modified forage harvesting equipment. Total establishment costs for willow are $2200/ha. Poplars are established using mechanical tillage, hand planting, and chemical and mechanical weed control. Harvest is at 10 years and no coppice regrowth is assumed. Harvest uses conventional forestry harvesting equipment. Total establishment costs for poplars are $750/ha. Switchgrass is established using mechanical tillage, mechanical planting, and chemical weed control. Harvest takes place once per year as bales of hay and stand life is 10 years. Conventional agricultural equipment is used. Total establishment costs for switchgrass are $250/ha. Details of the cost analysis can be found in Turhollow (2000).

Costs under five different scenarios are estimated: (1) total economic costs, where everything is costed [cash costs, noncash costs (e.g., depreciation), land rent, labor]; (2) costs with Conservation Reserve Program (CRP) payments (which pays 50% of establishment costs and an annual land rent); (3) costs with enhanced CRP payments (which pays 95% of establishment costs and an annual payment of approximately 170% of land rent for trees and 150% of land rent for grasses); (4) costs when buffer strips are required but harvest is not required [costs borne by biomass are for yield enhancing activities (e.g., fertilization), harvest, and transport]; and (5) costs when buffer strips are required and harvest is required to remove nutrients (costs borne by biomass are for yield enhancing activities and transport). In general CRP regulations would have to change to allow harvest.

Delivered costs of willow, poplar, and switchgrass [including transportation costs of $0.35/GJ ($0.37/million Btu) for switchgrass and $0.60/GJ ($0.63/million Btu) for willow and poplar] at 11.2 dry Mg/ha-year (5 dry tons/acre-year) for the five cases listed above are in Table 1 (see also Fig. 1).

Table 1. Costs of producing, harvesting, and transporting biomass (willow, poplar, and switchgrass) at a yield of 11.2 dry Mg/ha-year (5 dry tons/acre-year) under five cost scenarios

Cost scenario	$/GJ	$/$10^6$ Btu
1	3.30-5.45	3.45-5.75
2	2.30-3.80	2.45-4.00
3	1.70-2.45	1.80-2.60
4	1.75-3.00	1.85-3.15
5	0.80-1.50	0.85-1.60

The top of the range of costs is for willows with shorter (10 year) stand lives. The lowest costs are for switchgrass, and poplar costs are intermediate for scenarios 1, 2, and 4. In scenarios 3 and 5 poplar and switchgrass have similar costs. Willow costs for stand lives varying from 10 to 22 years compared to poplar and switchgrass are in Table 2. Even at 22 years of stand life, total economic costs for willows are more than poplars and significantly more than switchgrass. If planting density for willows is reduced from 15,300 trees/ha (6200 trees/acre) to 9000 trees/ha (3650 trees/acre), then total economic costs for willows at a 19 year stand life are only $0.15/GJ ($0.15/million Btu) greater than poplars.

Table 2. Total economic costs (scenario 1) for willow for varying stand lives, poplar, and switchgrass at a yield of 11.2 dry Mg/ha-year (5 dry tons/acre-year)

Willow stand life (years)	$/GJ	$/$10^6$ Btu
10	5.45	5.75
13	4.90	5.15
16	4.60	4.85
19	4.40	4.65
22	4.25	4.50
Poplar	3.85	4.05
Switchgrass	3.30	3.45

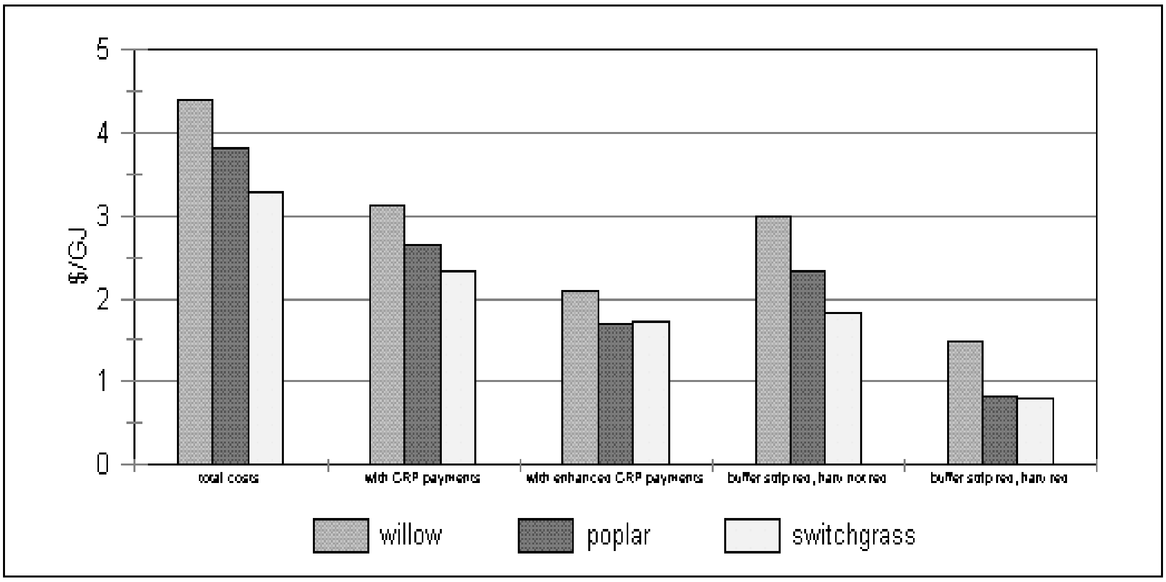

Figure 1. At yields of 15.7 to 17.9 dry Mg/ha-year (7 to 8 dry tons/acre-year), lower willow and poplar establishment costs, transportation costs of $0.30 to $0.45/GJ ($0.30 to $0.50/million Btu), and lower willow and poplar harvest costs, total economic costs (scenario 1) for willow, poplar, and switchgrass are $2.35 to $2.45/GJ ($2.50 to $2.60/million Btu). The potential production of biomass from riparian buffer strips in the Delmarva Peninsula ranges from 190,000 to 380,000 Mg (210,000 to 420,000 dry tons) per year.

Delivered costs for willows, poplars, and switchgrass under the five scenarios range from s low as $0.80/GJ ($0.85/million Btu) in scenario 5 (when buffer strips are required and harvest is also required) for switchgrass to as high as $5.45/GJ ($5.75/million Btu) for willow with a 10 year stand life in scenario 1 (total economic costs). As can be seen from Fig. 1, the circumstances under which biomass is grown has a large impact on costs. Willow is the highest in cost in all scenarios; poplar is intermediate in cost in scenarios 1 (total economic costs), 2 (with CRP payments), and 4 (when buffer strips are required, but harvest is not required); poplar and switchgrass are similar in cost in scenarios 3 (with enhanced CRP payments) and 5 (when buffer strips are required and harvest is also required); and switchgrass is lowest in cost in scenarios 1 (total economic costs), 2 (with CRP payments) , and 4 (when buffer strips are required, but harvest is not required).

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IEA TASK 17, MINUTES OF THE MEETINGS, WESTERN AUSTRALIA, MARCH 7 AND MARCH 9, 2000

Tuesday 7 March 2000, National Review Sessions

Chair: John Bartle

Introduction by Task Leader Lars Christersson

During the morning hours, the following speakers presented a review:

- Ulf Jörgensen, Denmark
- Leen Kuiper, The Netherlands
- Anthony Turhollow, U.S.A.
- Damian Culshaw, U.K.
- Theo Verwijst, Sweden
- Davorin Cajba, Croatia (presented by Lars Christersson)

In the afternoon, the following topical presentations were given:

Ian Nicholas, New Zealand. Effluent treatment in New Zealand
David Liversidge, Australia: Greenhouse gas abatement in Australia
Tom Baker, Australia: Effluent treatment in Australia
John Bartle, Australia: Oil Mallee growth
Rick Giles, Australia: Harvest and logistics
Colin Stucley, Australia: Whole tree processing
Don Harrison, Australia: The potential for bioenergy in Western Australia.

Thursday 9 March 2000, Specific Themes Update

Chair: Tom Baker

Sustainability and biodiversity. Anthony Turhollow (USA) presented the literature review and conclusions thus far obtained in the working group guided by Lynn Wright. Verwijst continued the discussion by stressing that the present sustainability issues have to be understood in the context of the historical development of our value systems in which 'value' has become subordinate to 'utility'.

Water and nutrient use efficiency. Ulf Jörgensen (Denmark) presented a draft paper by himself and Jens Bonderup Kjeldsen. He reviewed the concepts of WUE and NUE and extended the theory towards specific applications in willow SRF biomass production and landscaping.

Vegetation filters in Sweden. Lars Christersson presented a draft paper by Kurth Perttu. Current developments of willow-SRC in its role as a recipient of reject water, sludge and ashes were reviewed and attention was paid to the possibilities of systematic cadmium removal from agricultural soils.

Pest and Diseases. Leen Kuiper (The Netherlands) took up the issue of IPM (integrated pest management) in SRF and referred to the methods developed for conventional agricultural crops. Christersson continued by stressing the need of integration of pest research with our current Task

Education and Courses. Stig Ledin (Sweden) stressed the need to develop a formal course in the Framework of Task 17 to be able to disperse information compiled during our work. Different educational options were discussed in relation to the objectives of Task 17.

Thursday 9 March 2000, Task 17 Business Meeting

Chair: Lars Christersson

Secretary: Theo Verwijst

List of Participants to the Business Meeting: Tom Baker (Australia) , John Bartle (Australia), Lars Christersson (Sweden), Damian Culshaw (UK), Ulf Jörgensen (Denmark), Leen Kuiper (The Netherlands), Stig Ledin (Sweden), Helga van Miegroet (USA), Ian Nicholas (New Zealand), Helle Serup (Denmark), Anthony Turhollow (USA), Theo Verwijst (Sweden), Len van der Waag (Australia).

Lars Christersson opened the meeting with an introduction on oil reserves to production ratios for the different continents and stressed the need to pursue the work on SRF for energy purposes.

The agenda for the meeting was adopted and an issue raised by Leen Kuiper was added: Agenda items were:

1. Protocol from the IEA-Executive Committee meeting in Japan.
2. Publications of proceedings.
3. Publication of papers on high priority areas.
4. New applications
5. Proposals for co-operation
6. The role of education
7. Next meeting and press conference
8. Final report
9. Closing of session

The record of meeting is as follows:

Item 1. IEA Protocol

The protocol from the IEA Executive Committee meeting in Japan was discussed with regard to:

- recommendations for the next project application.
- Christersson will circulate the Executive Committee protocols in the future.

Item 2 Publications of proceedings

Proceedings from our previous meetings were recalled. LC stressed the need to complete the Auburn proceedings and proposed to use the proceedings from all our meetings to constitute our final report.

Manuscripts for the proceedings of the current meeting will be sent to John Bartle, preferably by E-mail, **BEFORE MAY 15 (2000)**, and will include the country reports. Publication then is likely to occur during October 2000.

Item 3 Publication of papers on high priority areas

The special contributions (see the morning session) are in different stages of development. The secretary will ask Lynn Wright to disperse the latest version of the paper on sustainability to all participants for comments.

- Ulf Jörgensen presented the paper on water- and nutrient use efficiency (co-author Jens Bonderup Kjeldsen). This paper is intended to be published in an international journal.
- Lars Christersson presented the work by Kurth Perttu on vegetation filters.

Lars Christersson intends to screen our proceedings to be able to compile material on large-scale implementation.

The following areas were considered to be high priority research fields:

- Efficient harvest and transportation.
- Demonstration projects
- Issues of soil sustainability
- Large-scale implementation
- SRF for both production and environmental functions

Item 4 New Applications.

According to Ulf Jörgensen, additional support for our task work could be obtained. Lars Christersson will contact our EU-assigned Task member (Ann Segerberg-Fick) to obtain the particular details.

Theo Verwijst and Stig Ledin are formulating a project discription that intends to carry our present Task 17 work into a new period (2001-2003). Within a week, a draft will be circulating for comments.

Item 5 Proposals for co-operation

To enhance cooperation with non-IEA countries discussion of particular themes was proposed as part of future meetings. Experts could be invited, including some from non-member state countries, to contribute to the themes. Leen Kuiper proposed to reserve financial means to involve experts.

Theo Verwijst and Stig Ledin have been in contact with Jim Richardson (task leader), Tat Smith and Rolf Björheden, of Task 18, to develop more formal cooperation between Task 17 and Task 18. During this meeting it was agreed that a joint meeting or workshop, preferably around a common theme and during the second year of the new project period is an appropriate way to foster cooperation. Possible themes for such cooperation are Alley Cropping and Harvest & Transportation systems. Verwijst will contact Richardson to further explore cooperation between tasks 17 and 18.

It was suggested that internet site linking could be a means of network building, and may serve to enhance cooperation.

Item 6 The role of education

It was generally recognised that education is an important tool to support several of our task objectives. No consensus could be reached, however, about the forms of education that could be run within the framework and expertise of our task force.

Item 7 Next meeting and press conference

The next meeting was proposed to take place in the Netherlands. Within the weeks to come, Leen Kuiper will investigate and report on the possibilities to hold the next meeting there. This meeting is intended to take place during 11-13 December 2000 and may be co-organised with an EU-project meeting, including a joint press-conference. Furthermore, a post-conference excursion to Sweden is planned to study harvest and transport logistics of SRC.

Item 8 Final report

The final report will be a collection of our proceedings. Lars Christersson will report our current state of progress to the Executive Committee during their next meeting in Utrecht, the Netherlands.

Lars Christersson finished the meeting by thanking the Australian hosts, esp. John Bartle and Tom Baker, for the well organised and splendid meetings and field tours (see below) that greatly contributed to our perspectives on Short Rotation Forestry.

Uppsala,
Department of Short Rotation Forestry
March 20, 2000

Theo Verwijst	Lars Christersson
Secretary	Chairman

Field tours:

On the way from Perth to Albany (Monday 6 March 2000) John Bartle introduced the geology, geo-hydrology, native vegetation and cultural land use practices in south western Australia. Discussing the background of salinity problems and control, visits were made to an oil mallee planting in an alley configuration and to a farm with integrated land-care practice to control salinity. Biodiversity issues were discussed while visiting the native vegetation in the Dongolocking Reserve. A prototype harvester for oil mallee was shown in Dumbleyung and the effects of rising saline groundwater on a rural town (Katanning) were illustrated.

On Wednesday 8 March we studied the integration of production functions and environmental functions, implemented in Albany as a renewable energy 'model town'. We visited a Bluegum (*Eucalyptus globulus*) plantation and the town effluent disposal, now used as a resource for bluegum growing. Finally we visited a wind-exposed coastal site that will serve as a wind farm in the near future.

On the way from Albany to Pemberton (Thursday afternoon 9 March), a visit was made to an old growth native Eucalypt stand.

On Friday 10 March, we visited a factory for wood chip production for export to Japan. We discussed the possibilities to use residues from native and plantation forestry (in the Manjimup region) for bioenergy purposes, and had a look at logging practices in the surroundings of the factory.