Forestry and Biomass Production.
Lessons from the Temperate Regions and the Tropics

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Executive summary

The role of biomass energy within Europe varies extensively throughout the continent and has been mostly directed to heating applications. However trials of willow and poplar supported by commercial planting of short rotation coppice crops (SRC) are becoming increasingly important and biomass is seen by most European governments to have a role in meeting Kyoto commitments. European targets for 2010 include the need to reach 12% of power production from renewable resources; from a present level of about 6%. The target for biomass-derived energy is to reach 135 Mtoe by 2010. Expanded planting is being promoted through the provision of both planting grants and imposed financial restrictions on the power producers.

Both planting and harvesting is highly mechanised in Europe, generally using suitably adapted agricultural equipment. To ensure high productivity, emphasis is given to the intensive use of improved hybrids and clones from an active tree breeding and selection programme. Willow (*Salix spp.*) and Poplar (*Populus* spp.) predominate in the SRC programme in Europe. There have been some trials with GM trees, but current restrictions are limiting the wider use of this technology. Planting of SRC in the USA has been concentrated more on the use of poplar and particularly within the Pacific Northwest; planting of SRC in New Zealand and Australia has been relatively conservative as both countries have extensive timber/pulp plantations to utilise. Biomass planting in the tropics is using a wide range of fast growing species used both in SRC and in agroforestry combinations with agricultural crops and more use is made of non-mechanical management.

SRC are generally planted at dense stockings in the range of 10-20,000 stems per ha (sph) and on rotations of 2-4 years. Production figures vary widely with 8-20oven dry tonnes/ha (odt/ha) being the normal range within a temperate environment and rising to 15-30 odt/ha in the tropics. Use is also being made of woody grasses and waste agricultural material such as *Miscanthus,* cereal straw and bagasse from the sugar industry. Future development will require greater cooperation between the farmers/foresters as a means of spreading capital costs and also with the energy producers; in addition there will need to be better integration of a range of technologies to maximise the efficiency of energy conversion. In the tropics more attention will need to be given to the use of improved planting material developed through both national and international breeding programmes. The level of tariff paid to growers of SRC tends to be low and does not always represent the considerable investments required. Access to finance and the general weak position that dendro-power has in national energy programmes is also noted to be a constraint to the development of this source of energy.

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Introduction

The role of wood and forestry residues in terms of energy production is as old as fire itself and in many societies wood is still the major source of energy. Even here in Sri Lanka, the use of wood-derived fuel represents 50% of total energy consumed and similar high percentages are common for many countries in both Africa and parts of Asia. Taking simple fuelwood and charcoal applications out of the equation, however changes the situation dramatically and the role that forest based material has with respect to electricity production or combined heat power applications is still relatively small. However the picture is changing and in this paper I want to explore what work has been done in the use of forest-based energy plantations as an economic use of land. The paper will cover an examination of some of the species that have been used, the manner in which they have been grown, their yield and the way in which material is harvested and the overall economics of the various systems. From this I want to draw out the lessons that have been learnt to date and present these for a more co-ordinated process for the future.

The Policy Framework for the encouragement of biomass- energy

As a signatory to the Kyoto, the EU has been collectively moving towards the target of ensuring that an increasing proportion of its electricity production will come from renewable sources and that a reduction in carbon dioxide emissions of 8% of 1990 levels are achieved. By 2001 the proportion of primary power coming from renewable sources was around 6%, the target is 12% by 2010. As part of this overall target a Directive on the Promotion of Electricity from Renewable Energy Sources in the Internal Electricity Market (2001/77/EC), also called the Renewables Directive, has set a target of 22% of electricity from renewables by 2010. For the same year, the target for biomass-derived energy has been set as being equal to 135 million tonnes of oil (Mtoe). A directive on the Promotion of Use of Biofuels for Transport proposes a target of 5.75% for the share of biofuels to be used in the transport sector by 2010 and an intermediate target of 2% by the end of 2005; though the indications are that this latter target will not be met.

Targets for the level of renewable energy being used for individual countries vary widely depending on the starting position and the current energy structure. For Austria, the target is 78% from a base of 70%, whereas for Belgium it is just 6% from a baseline of 1.1%. For Italy and the UK, both represented in this meeting, the respective figures are:

Italy	16% to increase to 25%
UK	1.7% to increase to 10%

In the case of Italy, a Green Certificate system is in operation with binding targets. Certificates are issued to plants which commenced operation after April 1999 and have a capacity greater than 50MWh. Hydro represents 90% of Italy's renewable electricity production, solid biomass providing less than 1%, equal to about 400 GWh out of a total of 46,300 GWh

In the case of the UK a system of Renewable Obligation Certificates (ROCs) has been introduced. Power producers are required to meet a rising annual commitment to the production of electricity from renewable sources (set at 10.4% by 2010 and continuing to 15.4% for 2015).

Produces have three options:-

(i) Obtain ROCs by meeting their requirement
(ii) Paying a buyout price set at £30/MWh
(iii) Combination of ROCs and buy out

In addition, a Climate Change Levy is payable by energy producers not using renewable fuel sources and various grants are available to promote the establishment of energy crops and the establishment of biomass power units. The level of Renewable electricity was 11TWh in 2002 of which hydro and land fill biogas were important components. Solid biomass represented around 8% of the renewable energy production = 870 GWh, out of a total of 10,950 GWh.

Under a statement on proposed energy cooperation from the EC to developing countries[1] various suggestions have been put forward including the need for attention to both the improvement of energy efficiency and the development of renewables. Attention has been drawn to the fact that the growth in demand for energy from Asia is now 3-4 times that of the OECD area and in the medium to long term, Asia's demands for energy are expected to outstrip that of the OECD. There is seen to be a danger of the energy intensity (i.e. ratio of energy consumption to the GDP) being allowed to rise, as not enough attention is paid to the adoption of systems that are energy efficient. Overall the EU has confirmed its commitment to facilitating the achievement of the Millennium Development Goal of halving the number of people in extreme poverty by 2014 through the provision of affordable sustainable energy sources.

As part of the research and development programme under the new framework programme (FP7) aimed at the needs of Europe itself rather than the wider aid programme; increased expenditure is to be directed to the energy sector. Under the bio-energy component attention is to be directed in three directions:-

(i) <u>Feedstock Production</u> – aim to maximise the supply chain of a wide range of biomass feedstock based on forestry, agriculture and food industries and improvement of the standardisation and trade of solid fuels.
(ii) <u>Conversion Processes</u> – optimise reliable processes (combustion, gasification, pyrolysis), looking at ways to maximise conversion rates and energy efficiency and the development of new biochemical processes.
(iii) <u>End Use Integration</u> – to enhance the integration of technological development with end users needs; looking at such issues as life cycle assessment and chain optimisation; impacts of grid integration of decentralised power; accounting methods for Kyoto-related benefits; and the socio-economic aspects of biomass energy production.

[1] Communication from the Commission to the Council and the European Parliament: Energy Cooperation with the Developing Countries, July 2002

Current locations of interest
An examination of the literature indicates that within Europe those countries where there has been marked development in the growth of biomass energy and particularly short rotation coppice crops (SRC) is Sweden, Finland, Austria, Denmark, and to some extent Spain, Italy and the UK. Interesting work has been carried out in Brazil, Southern USA, Australia and New Zealand., India, the Philippines, Indonesia and here in Sri Lanka. I do not claim to attempt to cover all areas where such work has been undertaken, but these do seem to the main countries where substantial effort has been given to the development of biomass renewable energy.

But when looking at the development of this type of forestry, it is important to first examine what are the driving forces behind the interest in this type of land use, and to question whether it be dictated by national concerns to adhere to Kyoto Protocol obligations or whether there is a genuine desire from both the state and the private sector to be involved in what is perceived to be an economic viable method of using land. Certainly in Europe, there has been some degree of financial support to the forest- energy sector on one hand coupled with financial arm twisting of the power producers on the other.

In the UK the Government has set a target of 10% of the national energy requirement should be coming from renewable resources by 2010; currently the figure is closer to 3%. To meet the 10 per cent target, approximately 10,000 megawatts of renewable energy will need to be generated. This equates to between 3,000 and 5,000 wind turbines, or two hundred 50-megawatt biomass power stations. In 2003, biomass used for both heat and electricity generation accounted for 87 per cent of renewable energy sources in the UK. The majority of this came from landfill gas (33 per cent) and waste combustion (14 per cent).[2] Smaller amounts also came from sewage gas, domestic wood and industrial wood. Electricity produced from biomass accounted for 1.55% of total electricity supply in the year. The Carbon Trust and the Department for Trade and Industry in the UK considered that a reasonable target was for 6% of the country’s electricity supply to come from biomass. They estimated that this would require an area of 350,000 ha of energy crops. Further, the National Farmers Union suggests that up to 20% of the crops grown in the UK could be for non-food uses by 2020.[3]

Forest cover in the UK is amongst the lowest in Europe. Currently 2.8 million ha or around 11% of the land area is classified as under forest, to be compared to an average of 30% for EU-15 and as high as 46% for the whole of the European continent. Current annual planting by both state and private resources in the country is around 26,000 ha of which half is replanting and half is new afforestation. In March 1999 the EU leaders, as part of the Agenda 2000 strategy, decided to drastically reform the Common Agricultural Policy (CAP), reinforcing rural development policy in several ways and to encourage alternative sources of income in rural areas, while supporting agro-environment measures. Member States can choose those measures that respond best to the needs in their own rural areas. In England this has been supported by the England Rural Development Programme amongst which is included

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[2] Source: Department of Trade and Industry (DTI), *‘UK Energy in Brief’*, July 2004).
[3] NFU Response to the Royal Commission Study on Environmental Pollution (2003).Quoted in the Paper on Biomass as a Renewable Energy Source, Royal Commission, 2004.

the Energy Crops Scheme. This provides financial support to those wishing to establish short rotation crops (SRC). Currently this support is set at £1,600 ($2,800 approx) for forest converted from former livestock land and £1,000 ($1,800 aprox.) for other types of land. This grant is supposed to equate to roughly half the total cost of establishment. Restrictions that apply include that the area established must be a minimum of 3 ha in extent and the produce must be for the production of heat or energy and not for consumption by the grower. A further grant provision of around £30/ha is payable under the Single Payment Scheme of the CAP for land which is converted to the use of energy crops for the first time.

The Forestry Commission has been carrying out trials with willow and poplar species over the last 20 years and more recently the woody grass *Miscanthus*. Production levels are in the range of 5-20 oven dried tonnes per ha per annum (odt/ha/an) [4]; with respect to willow. The average yield obtained for Jorunn variety which acts as bench mark due to its wide scale planting was 8.8 odt/ha/an. With current levels of funding and fuel wood prices, growers consider that yields need to be around 10 odt/ha/an to provide an acceptable income. More recent results using dense planting and improved varieties have seen yields closer to 20 odt/ha/an. Trials with poplar have been more restricted to date. The variety Trichobel has proved to be popular and results are often markedly better than willow with yields in excess of 20 odt/ha/an, though yields can vary widely[5].

The total area under SRC in the UK is around 1,800 ha of which willow is by far the dominant genus. The land dedicated to energy crops is less than 0.01% of the total arable land so there is plenty of room for expansion especially when it is realised that the average area of land under set aside[6] has been around 640,000 ha.

One of more high profile attempts to establish a commercial network of SRC growers linked to a large scale gasification unit – the Arable Biomass Renewable Energy (ARBRE) Power Station settled on the piloting of a plant operating on the Biomass Integrated Gasification/Combined Cycle (BIG/CC) technology. The ARBRE project unfortunately failed shortly after the commencement of its trial operation – due in part to technical problems, namely deposits fouled the heat exchangers; but also in a large part due to inadequate investment at the start up period[7]

Although the ARBRE project came to an abrupt end, a partial market replacement for the willow growers in the area has emerged in the form of the Drax power station. This is the largest coal powered power station in the UK with the claim of being the most efficient. Its power rating is 4,000 megawatts and its annual coal requirement is some 10 million tonnes. It has been adopted a policy of utilising wood as a co-fuel for its furnaces. Those farmers that were unfortunately left high and dry with the collapse of the ARBRE project have since been given supply contracts with Drax. The station is aiming to reach a biomass input of 0.5 million odt/annum. Although the theoretical

[4] Yield Models for Energy Crops of Poplar and Willow. UK Forestry Commission , Forest Research 2003

[5] I. Tubby, A. Armstrong (2002). Establishment and Management of Short Rotation Crops. Forestry Commission.

[6] Set aside refers to land which is temporarily taken out of production in order to reduce over-production within the EU.

[7] Royal Commission of Environmental Pollution (200?) Biomass as a Renewable Energy Source.

limit for replacement of coal by wood is considered to be 20%, a more realistic long-term goal has been set at 10%.

Farmers are currently being paid at a rate of £45/tonne for oven dried wood, which should provide a profit of around £20/tonne to the farmer. At an average of 10 odt/ha in the area, the net returns of £200/ha are considered to be reasonable.

At present, in much of Europe, short rotation forestry is still at the experimental stage or early pilot stage. In Sweden, however, developments are more advanced and the area under this type of management is in excess of 15,000 ha, moreover there are plans to increase this to 30,000 ha by 2010 and in the medium-long term to see this increased to 200,000 ha plus. Planting of SRC crops initially took-off in the mid 1990s in Sweden when the income from growing cereals was low and there were good financial incentives from the EU to grow willow. Later however, some of the incentives were removed as a reaction to there being too great an area under the Set Aside programme and consequently many farmers pulled out of the industry.[8]

Austria claims several thousands of hectares of energy poplar; and many experimental plantations have been established in Germany. *Robinia* is being planted in Italy by Regional Management Agencies, who are keeping an eye on poplar and eucalyptus as potential species groups.[9] Austria in particular has been extremely successful in its approach to efficient use of biomass and indeed in its overall use of renewable energy. In 2002, the share of renewable energy was 23%, of which half is from biomass and the other half from hydro power. A large market for wood pellets and an effective distribution system has developed using waste wood and sawdust products as the resource for the pellets. Many householders are now regularly using wood pellets for home heating. In Salzburg, 50% of all new-build projects now incorporate biomass heating, 70% of which use pellets as fuel.[10]

All these crops are very similar to each other in terms of rotation, density and yield. One may even say that they are regional versions of the same concept, each version being adapted to the local climate and terrain. Geography and climate, however, do not account for all differences. Some of them can simply be explained by the growers' preferences. This is especially true for the planting system.

One of the promising species now being tried in Europe is *Miscanthus*. This is a genus made up of 20 species. It is a large, tough tropical grass sometimes confusingly called elephant grass, though the true elephant grass belongs to a different genus.[11] . There are a number of species but the one receiving the most attention is a sterile hybrid called *Miscanthus x giganteus* which is still productive at lower temperatures. It is

[8] Full scale implementation of short rotation willow coppice in Sweden. S. Larsen and K. Lindegaard, Ogrobransle

[9] R. Spinelli, P. Kofman (1996)A Review of Short-Rotation Forestry Harvesting in Europe. Paper presented to first conference of the SR Woody Crops Working Group. September 1996.

[10] Quoted in the report of the Royal Commission on Environmental Pollution – Biomass as a Renewable Energy Source.

[11] *Pennisetum purpureum* is the true elephant grass

still only being planted on an experimental stage in the UK and most of Europe. In the UK yields have been variable with production in some sites in excess of 20 odt/ha /an but in others hardly reaching 12 tonnes/ha/an. One of its advantages is the ease of handling. It can be cut and baled like straw and stored in that manner. There are some losses associated with storage, but spring harvested *Miscanthus* may be handled and stored like dry straw, though losses must be expected with winter harvested crops.[12] The crop can be used directly as a fuel or the material can be converted into ethanol. It has several advantages along with its ease of harvesting and relatively high yields. It seems to be relatively non-demanding with respect for fertiliser and can be managed to provide an annual harvest. There are indications that nitrogen-fixing bacteria can associate with this crop which adds to its positive effect on soil organic status. Also it appears to have a good energy balance and output/input ratio compared with other biomass options.

Some work has been done on the productive use of agricultural waste. In Eastern England a straw-burning power station has been established at Ely, Cambridgeshire. This is the first modern, and the world's largest, straw-fired power station. It became fully operational in September 2000. The 36-megawatt facility consumes around 200,000 tonnes of straw and generates sufficient electricity every year to satisfy the needs of 80,000 dwellings. The plant is also capable of burning a range of other baled energy crops, including *Miscanthus*, and can use mixtures of up to 10 per cent natural gas.

It is not necessary to plant exclusively for bio-energy. There are some 125 million ha of industrial plantations in the world. Although this area only represents 3.5% of the total forest area, it provides around one third of the industrial roundwood supply. Plantation forestry has existed in Europe for 300 years and until the 1950s forestry industry was concentrated on the northern hemisphere. Experimental planting of exotics started about 100 years ago in the southern hemisphere and over the last 40 years production forestry took off as the benefits of the better growing conditions were realised. This shift has been caused by the adaptability of the exotics particularly the pine species native to Southern USA and Central America and the *Acacia* species of Australia. This has led to every large scale pulp and paper company investing heavily in the tropics and sub tropics.

New Zealand has over 1.7 million ha of industrial plantations with a dependence on *Pinus radiata*. Although there has not been any planting specifically for energy production; small diameter material from the sawlog working circle and low quality material from the pulp/chip board working circles can provide large amounts of material. Fossil fuels represent 71% of the country's sources of energy, with hydro some 19%. Biomass and waste currently provide about 7% of the energy needs. There is a policy now to meet the demands of future additional future demand from renewables supported by the imposition of a carbon tax of 25 NZ$ from 2007.

Australia has introduced a mandatory renewable energy target which requires that an additional 9,500 GWh of electricity (about 2% of total output) will be produced by

[12] Harvesting and Handling of Miscanthus. Danish experiences. E.F.Kristensen, Danish Institute of Agricultural Sciences.

renewable energy resources by 2010; to increase the total contribution to 12%.[13] Australia is obtaining waste wood from its native forests as a bi-product and from the conversion of its plantations. One of the peculiarities of the Australian legislation controlling the production of renewable energy[14] is that Renewable Energy Certificates are not eligible for crops specifically grown for energy; it should be from waste material that would be deemed unacceptable for other uses. Nevertheless, there has been work carried out on energy crops in the hope that the current legislation will be amended. The oil mallee eucalypts (for example *E. kochii*) has been extensively planted as an alley crop and harvested on a 2-4 coppice cycle. In one project the wood is converted to activated charcoal and oils are extracted from the leaves. Heat from theses processes is used for power production. Borough (2002)[13] above reports that from an intake of 20,000 tonnes of biomass the project is producing 7.5.GW/annum from a 1 MW steam turbine, 690 tonnes of activated carbon and 210 tonnes of eucalyptus oil.

A total of 23 million trees have been planted in Western Australia on low rainfall (400 mm) sites. Although rainfall is low, there is has been a problem developing from the growing of annual crops and pasture on cleared wheat land which surprisingly leads to an under-use of water resources and a consequent increase in the water table and a deposition of salts in the upper soil levels. Crops such as eucalypts are therefore being promoted to try to stabilise the water balance and provide an alternative income. Work on the silviculture and water use of the mallee in these areas[15] has indicated that production rates of around 7 odt/ha/an was possible if managed on an initial period of 7 years before coppicing followed by a coppicing cycle of 3 years.

Casuarina is also gaining some interest in Australia. One proposal is to grow the *Casuarina* in strips as an SRC, interspersed with strips of high quality timber trees grown on a full rotation and subject to thinning and high pruning. Bagasse, a waste product from the sugar industry is an important component of the bio-energy equation in Australia and this can be supplemented by the addition of waste thinnings from industrial plantations.

In the USA, between 1983 and 1998, around 50,000 ha of SRC were established, the major proportion being some 30,000 ha of poplar in the Pacific Northwest as commercial SRC. Other short-rotation crops include eucalyptus, sweetgum (*Liquidambar styraciflua*) and sycamore *(Platanus occidentalis*). There has also been some interest in grasses, including switchgrass (*Panicum virgatum)* and this has been used for co-firing two biomass power units. Even as far back as the 1960's there was intensive research in eastern USA to develop coppice systems with a short coppice cycle of less than 4 years as a pulpwood resource. Much of the attention was directed to sycamore. But overall, it would seem that in recent years more attention has been given to the development of bio-energy technology from Europe rather than from the USA. However there has been particular interest in the role of biomass for future power production in the extreme south of the USA. The reasons for this are not hard to find. Florida has the unenviable record of being one of the states producing the

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[13] Prospects for bio-energy from SRC in Australia. C. Borough, Australia National SRC Bioenergy Team, 2002

[14] Renewable Energy (Electricity) Act 2000 and the associated Renewable (Electricity) Regulations.

[15] Silviculture and Water Use of Short-rotation mallee eucalypts. D.Wildy, J.Pate and J.Bartle, Rural Industries Research and Development Corporation, 2003.

highest proportion of its electricity from oil – roughly around one fifth - and it has been calculated that the South-eastern states of America produce carbon emissions at a level that equals 70% of the total carbon emissions for the whole of China or at a level that is equivalent to the figure for the whole of Russia. A research and development strategy has been devised by the US Climate Change Technology Programme that aims to see an automated harvest/processing/transport system for biomass and for energy crops to be a substantial part of the raw material for power production by 2020. Price will be a determining factor for development of the industry and there will be a need for some sort of intervention in terms of a green premium. The Southern Company, the largest electricity utility in the Southern states has recently calculated that the price of the cost of power production using coal was 3.5 cents/kWh, for natural gas the comparable figure was 2.6 cents and for power derived from biomass the figures varied widely between 4-11 cents.

It is the tropics, the role of biomass in energy production is high, due both to potential growth rates, low cost land, lower employment costs and often a high reliance on imported oil; a situation that we find here in Sri Lanka. One country that has been active in plantation development and the use of biomass in the tropics is Brazil. It has a recorded area of almost 5 million ha of plantations[16] and has been active in pushing growth rates to the highest level through intensive selection programmes using cloning, controlled hybridization and micro-propagation fired by the huge investment made into the pulp and paper industry.

Much of the planting has been geared to the use of Eucalyptus – particularly *E.grandis* and *E.saligna*, which can be highly productive providing that the period of drought is not excessive. Much of the early planting was made on inappropriate sites and extensive replanting has been necessary. The soils and climate in Brazil coupled with intensive breeding and silviculture has led to very high production rates for Eucalypts with production up to 80 m^3/ha/an. In the 1980s attention was given to the development of agroforestry systems based on Eucalypts. As part of the accompanying research that has been undertaken, such combinations as *E.torelliana* intercropped with maize, *E. grandis* intercropped with beans, *E.citriodora* with grasses (*Panicum maximum*) in a silvopastoral system with cattle and sheep; *E.cloeziana* with legumes and grasses for cattle production and *E.grandis* intercropped with legumes for soil protection. The native tree, Bracatinga (*Mimosa scabrella)* has also proved to be popular in the cold high lands of southern Brazil. The species is leguminous and therefore has beneficial effects on the site and although not as productive as Eucalyptus, it can achieve growth rates of around 13 m^3/ha/an.

One country that did start early on to develop dendro power on a commercial scale was the Philippines. Even as long ago as 1979, the Government embarked on a major programme of substituting importing imported fuel by wood. Some 60,000 ha were planted. The Dendro Programme had the intention to establish 60-70 wood-fired power plants, each served by a plantation of 1,100 ha or more, which in turn would be managed by farmer associations[17]. The overall programme failed largely because, too much reliance was placed on a single species – the giant ipil-ipil or *Leucaena leucocephala,* which although a very productive species is not suited to all sites,

[16] FAO State of the Forests, 2003

[17] Biomass Fuel from Woody Crops for Electric Power Generation. R.D Perlack, L.L. Wright, M.A. Huston and W.F. Schramm. Report for the Environmental Sciences Division, USA 1995.

particularly those at higher altitudes. It is also seriously affected by a psyllid leaf defoliator. But the other serious mistake was to assume that fast growing plantations could be grown on rugged steep land. There was little attention to the problems of getting wood from the plantations to the power plants and even expensive skylines were attempted before the various schemes collapsed.

In Asia and Africa there has been a strong focus on the development of farm forestry and agroforestry systems, energy crops are grown alongside food crops or livestock production areas. Species used for this type of management are often multi-purpose, coppice easily and often nitrogen-fixing. A few examples that can be given also include *Leucaena leucocephalla* along with *Prosopis species, Calliandra calothyrsus, Azadirachta indica, Cassia siamea, Sesbania sesban. Glyricidia sepium, Albizia lebbeck, Acacia spp, Tamarindus indica.* Here in Sri Lanka particular success has been demonstrated with *Gliricidia sepium.* This species has demonstrated superb growth and provides a secondary crop to an overstorey of coconut. Both *Acacia auriculformis* and *Glyricidia sepium* performed well on a wide range of sites. Generally continuous harvesting seemed to be the most productive method coupled with a spacing of 1x2 m or 1x1 m. One hectare of short-rotation plantation could produce well in excess of 25 tonnes of dry matter per ha and a more conservative figure of 20 tonnes/ha was considered suitable for planning purposes. Recommendations have promoted the use of *A. auriculiformis*, *G. sepium C. siamea* and *L. leucocephala* planted at 1 x 2 m with harvesting commencing around 15 months removing branches above a height of 1.5 m as they develop and reach a usable diameter of 25mm. The results of the trials and pilot investigations that have been carried out within Sri Lanka are described separately.

What has perhaps been missing is the same intensity that has been given to provenance and clonal selection that has been the case with willow in Europe. Clearly a programme of intensive tree breeding and selection within established populations of Gliricidia could have dramatic effects on overall performance.

Gartland *et al* (2002)[18] have argued strongly for Europe to invest in biotechnology and in particular the use of genetically modified (GM) trees in plantation forestry including SRC. Experimentation with GM tree crops is continuing through such initiatives as the European Forest Genomics Network allied to national programmes. Cooperation is also being made with the $28 million US Poplar Genomics Initiative. The authors were able to list 43 GM tree field trials within Europe many of which are linked to the improvement of SRC. There are however strict controls in place governing the trial and release of GM trees in the same way as there for agricultural crops. Since 1990 the deliberate release of genetically modified trees has been governed by Directive 90/220/EEC and a revised directive came in to operation in 2002 which establishes compulsory and harmonised rules for environmental risk assessment.

The Forest Stewardship Council (FSC) forest certification scheme, which is one of the more important certification schemes, currently will not allow GM crops to be part of

[18] Forest Biotechnology and Europe's Forests of the Future, K.Gartland, R.C. Kellison and T.M. Fenning, University of Abertay, Dundee, UM.

a certified forest. However, the Pan European Certification Scheme takes a more tolerant position in this respect.

As an aside to the dendro-power issue, it is worth mentioning the growing importance of the bio-ethanol industry. In the long term the potential world wide production is considered to be at least 2 billion tonnes per year, with 0.5 tonnes coming from sugar/starch crops and 1.5 billion tonnes from ligno-cellulosic biomass. Brazil is the largest producer of bioethanol and has been making use of the product as automobile fuel since 1975[19].

Establishment and Harvesting

Labour costs in Europe and the developed world dictate the need for maximum use of machinery for both planting and harvesting. In Europe all new willow plantations involve newly bred varieties which are more productive and have greater resistance to pests and diseases – the rust *Melampsora* is of particular concern with both willow and poplar. It is worth noting however, that the levels of pest or pathogen damage that are considered as unacceptable in food crops can be tolerated in plants destined to be burned. Consequently established SRC can be managed with few pesticide applications without suffering significant economic penalties[20]. In practice, within the European context rabbits are the main cause of damage to newly established SRC.

Willow is established from vegetative material –either rods, which are cut stems of 1.5-3.0 m long or cuttings which are taken from the rods and measure just 20 cm. Current recommendations are to use a mix of varieties with diverse rust tolerance. Because of the legal protection offered by the European Plant Breeders Rights, it might not be possible for farmers to use material that is harvested on their own farms as planting material for the next cycle and only licensed producers are able to propagate willow propagation.

Sites are cleared and prepared to agricultural standards and from a tractor the rods are either laid flat into opened slits or cuttings are inserted vertically in lines at a total density close to 15,000 stems per ha (sph). Willow-growers generally adopt the twin-row system, with a spacing of 0.75 m in the twin-row and 1.50 m between the twin rows. On the other hand, farmers growing Poplar and *Robinia* seem to prefer single rows 1 m apart. The distance along the row is subject to large variation, and it is generally between 0.5 and 1.0 m. Of course, these "details" have a strong impact on harvesting technology and performance. Planting densities have been in the region of 15,000-20,000 sph. Recently there has been a more attention to reduced planting densities - closer to 10,000 sph. This is in part due to the development of improved clonal material which provides better growth and hence a faster rate of site capture. Poplar is generally planted at these lower densities in the form of cuttings of 20-25 cm long, to be successful it has been noted that the stem must have an apical bud within 1 cm of the top of the cutting and hence more careful preparation is needed of the planting material.

In the case of *Miscanthus,* the timing of harvesting is found to have a critical effect on the quality of the product. In the autumn when harvesting might be expected to take

[19] A Global Network on Bioenergy – Objectives, strategies and first results. R.Janssen, P.Heim, P.Grimm, G.Grassi, B.Coda, A.Grassi, A Agterburg. International Sugar Journal Vol 104, 2002.

[20] UK Royal Commission on Environmental Pollution – Biomass as a Renewable Source

place, the crops moisture content is still high – up to 70%. By delaying harvesting to the spring (March-April) it has dropped to 20%. However, this has to be balanced by a loss in biomass dry matter. After cutting the material is baled, using standard agricultural equipment though operating speeds are lower because of the structure of the material (long and stiff)[21], Storage of spring-baled material should give no problems, however with the winter-harvested material more problems could be expected and careful out-door storage is used, protected from rain. Some investigations are being carried out into the feasibility of pelleting the crop for ease of storage and transportation.

Since in Europe weed control and harvesting will by necessity need to be more or less fully mechanised, the planting design needs to reflect the demands for tractor access. A common silvicultural technique especially with willow, but with many crops destined to be managed on a coppice system, it to carry out an early cut back in the first year of establishment. This is done to encourage multi-stem production which is considered to be overall more productive and lead to better sized material. However recent experimentation in the UK is questioning this practice. Also in the case of Poplar cultivation this early cutback is not normal practice. Subsequent harvesting would normally be carried out on about a 2-4 year cycle, with replacement of the stool at around 20 years. In the case of Poplar, which tends to produce fewer but heavier stems a longer cycle of at least 4 years seems to be ideal.

As part of the recent studies carried out here in Sri Lanka trials were carried out using a range of espacements giving stockings from 5,000-20,000 sph. Although the differences were not great the consensus was that an espacement of 1 x 2 metre (5,000 sph) and 1 x 1 m (10,000 sph) worked well. At these espacements, the crop could be expected to produce small diameter material within 18 months and could be harvested on a continuous basis, following pollarding at 1.5 metre above the ground. Resulting regrowth could then be harvested throughout the year as they reached a suitable diameter.

The need for fertilisers obviously varies from site to site, but it is interesting to note that one of the driving forces for adoption of SRC as an agricultural crop has been the need to make use of sewage sludge. This sort of waste material is not permitted on food crops and disposal can often be a headache for water companies or municipalities. It is worth noting that the driving force for the ARBRE project in northern England, already referred to, stemmed from a need to make use of use of sewage sludge as a fertiliser. The owners of the plant – Kelda, formerly Yorkshire Water - saw the improved need to handle this waste as a prime reason for encouraging SRC; although the sludge can not be used for crops in the human food chain it is permitted for forest crops. Similarly in Sweden, sewage sludge has been used to fertilise crops of willow. Larsson and Lindegaard (2003) [22] report that half of the harvested plantations in 2002 had been so treated.

The application of sludge does not always provide a response in growth but it can act as a mulch and reduce weed growth and improve moisture retention. Application of

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[21] Harvesting and Handling Miscanthus: Danish Experiences. E.F. Kristensen, Danish Institute of Agricultural Sciences.

[22] Full scale implementation of short rotation willow coppice in Sweden. S.Larsson and K.Lindegaard, Agrobransle AB, Orebro Sweden.

inorganic fertiliser would always be resisted due to cost. But in addition the production of inorganic fertilisers relies heavily in the use of fossil fuels. When these products are used on SRC the carbon and energy budgets of the crop are altered and might be defeating one of the objectives of the development[23] . It is worth noting that one of the benefits of growing willow is its ability to take up heavy metals – particularly cadmium and to concentrate them in the wood. The crop can therefore be used for the remediation of contaminated land.

The emphasis in the tropics has been towards the use of leguminous species in order to improve the soil fertility at the same time as producing a useful biomass product. The extended pilot trials here in Sri Lanka carried out be the Coconut Research Institute have clearly demonstrated the positive value of *Gliricida sepium* to maintain soil nitrogen levels. The foliage is incorporated into the upper layers following harvesting of the fuelwood. They have found that when established under coconut at around 1,300 stems/ha that some 5.5 m.t. of wood can be produced each year along with 4.5 m.t of foliage. The foliage can either be used as an additional soil supplement or used for animal fodder. *Gliricidia* close planted as a fuelwood/fodder block can provide annually over some 15-30 m.t./ha of wood

Harvesting in Europe is carried out generally using modified forage or maize harvesters. There are two harvesting systems. The crop can be cut and chipped in one operation or the stems can be cut and left in situ to dry with chipping carried out as a separate operation. The Claas Jaguar harvesters are currently in use in Sweden fitted with suitable SRC headers. These machines will cut the stems, complete chipping and blow the material into adjacent trailers. The pellets are then dried and stored as necessary. Long term storage is a problem as the material quickly heats and is subject to decomposition.

In many parts of the world, hand harvesting would be the norm, the stems being cut into smaller billets either in the field or closer to the storage where simple machines can speed up this element of the process.

Future Developments for Establishment, Management and Harvesting of SRC
Major strides have been made in the promotion of SRC for biomass production over the last 20 years but much more needs to be done if this type of renewable energy is going to have an appreciable affect on the overall energy balance. We can expect biotechnology to play its role in the improvement of yields, better site adaptability and in pest control. At the current time there are no commercial applications of GM trees within Europe though as indicated above, research field trials have been established some of which have relevance to SRC and inevitably this technology will have a role along side the more traditional approaches of large-scale micro-propagation and improved rooting of selected clonal material.

The agro-forestry approaches that have been adopted in part here in Sri Lanka will prove a useful model for others, where there is an opportunity to incorporate SRC with other land use activities and as such will fit in with small-scale farming systems. In Europe, where the emphasis is in part on making use of land taken out of food

[23] Establishment and Management of Short Rotation Coppice. I.Tubby and A. Armstrong . UK Forestry Commission 2002.

production through the implementation of the Set Aside policy, this will be of more limited scope. Biomass energy crops cover the whole gamut of forest thinnings, coppice production, use of straw and woody grasses, production of bio-diesel and bio-fuels. In order to maximise benefits on a national level, full integration of both the growing and the processing of these materials is required and a greater integration of all the various conversion technologies that can be grouped under the general term of biomass energy production is needed. Therefore along with co-generation through CHP there should be consideration of bio-ethanol and bio-diesel production.

In addition, better integration of sawmills with energy production is needed especially linked to the use of CHP technologies in order to maximise conversion efficiency. Such techniques as the production of fuel pellets and briquettes from small dimension waste and sawdust is an obvious step, taking due note of the success that Austria has had in this respect.

It has been noted that in the context of Europe, there will be benefits all round if more encouragement can be given to the formation of co-operatives between the wood producers and the energy producers in order to spread capital costs and at the same time, extend current planting support grants to groups rather than to individual independent farmers/foresters. This type of refocusing of support to farmers groups will be highly relevant to S.E. Asia.

Clearly linkage with the CDM and other carbon trading initiatives for a more favourable financing package for the bio-energy suppliers is an important catalyst to greater inputs into SRC development. The establishment of working systems for feeding back fines or penalties paid by the power producers who show an over-dependence on fossil fuel, to those engaged in the growing of renewable energy crops would clearly provide a stimulus to future investment in forestry.

Yield and the economics of SRC

Some indication of yields has been referred to in the previous section, but here I want to bring the information together and summarise how competitive this type of forestry production can be.

Looking first at a plantation established for a combination of saw timber and small roundwood production at an espacement in the range of 1-2,000 sph and managed in accordance to a defined thinning regime to encourage diameter development: in Europe we would be happy with production of the order of 10 m3/ha/an. In the tropics a fast growing plantation species such as *Pinus radiata, Pinus kesiya, and Pinus caribaea* one might expect 15-20 m^3/ha/an. In the case of Eucalypts (*E.grandis, E.cloeziana*, *E.camalulensis*) or the Australian *Acacia spp*. growth rates would be expected to be of the order to 30m^3/ha/an on a good site but perhaps closer to 15m^3/ha/an on a poor site with limited rainfall. However at the other extreme, by using selected clonal planting material on a highly fertile site one could obtain production figures well in excess of 60m^3/ha/an and even as high as 80m^3/ha/an

For SRC grown on close espacements with stockings of the order of 15,000 sph: the benchmark yield for willow in Europe seems to of the order of 10odt/ha/an though on good sites this figure can double to 20odt/ha - a similar figure for poplar can also apply. This would equate to standing production of around 18-35 m^3/ha/an i.e. equivalent to a stand of tropical pine/eucalypt being grown on a sawn timber regime. A recent assessment of the economic returns of growing SRC in southern Britain has calculated the IRR on a willow-based crop to be of the order of 46%[24] This is based on a the receipt of a planting grant of £1,000 per ha ($1,800/ha) and an annual energy crop payment of £30/ha (= €45/ha, or $55/ha). . The first harvest is made at 4 years and subsequent harvests are made at 3 yearly intervals. Sales revenue is based on a yield of 10odt/ha and a minimum price of £36 per tonne. However additional costs for fencing against rabbit damage and possible first year weeding would considerably reduce the IRR to a figure closer to 12.5% .The table is appended (Table 1).

SRC grown within a tropical environment should be capable of 20-30 tonnes/ha or around 35-45 m^3/ha/an when grown as a dedicated SRC rather than combined with an agricultural crop in some form of agro-forestry regime. However where it is grown as an agro-forestry crop then a wide range of benefits can accrue in terms of improved soil fertility and the production of animal fodder; the total economic benefits of the agricultural system need to be costed. Reference was made above to some of the production figures that have been obtained by the Coconut Research Institute in Sri Lanka from an integrated farming system based on the use of *Gliricidia* as a fuel for the over-storey of coconut. In supporting trials of SRC of *Gliricidia* grown as a pure crop adjacent to stands of coconut/grass, 30 tonnes of fuelwood valued at $450 plus 26 tonnes of fresh foliage were produced which can be used both as a fodder for cattle and hence support milk production as well as act as a replacement for expensive inorganic nitrogen fertiliser. The total income directly attributable to the growing of *Gliricidia* (excluding coconut production) is estimated at some $2,200/ha/annum.

The low density of fuel chips is a problem. Energy density is affected by the basic density of the wood and the moisture content. The amount of space needed for the transport and storage of chips is 11-15 times that needed for oil and 3-4 times that needed for coal. Consequently, in terms of simple economics it is important that the distance from the plantations to the power unit is not allowed to get too excessive[25].

The role of dendro power in Sri Lanka

We will hear from other contributors about the special nature of Sri Lanka with respect to the urgency to invest in renewable energy sources and in particular the potential high profile that dendro power could play in the country. Text Box 1 summarises some of the key facts, taken in part from the Energy Master Plan of 2004[26]

The Master Plan suggests that a good target to aim for in terms of renewables would be 10% of total energy production by 2015, divided by the following categories:-

Small-scale hydro	= 250 MW	= 875 Gwh	(40% availability)
Wind	= 170 MW	= 357 GWh	(25% availability)
Dendro	= 80 MW	= 489 GWh	(70% availability)
Total	500 MW	1,722 GWh	

[24] Thames Valley Energy - personal communication from G.Alker
[25] Bio-energy from Sustainable Forestry. J.Richardson *et al.* Kluwer Academic Publishers
[26] Interim Energy Sector Master Plan prepared for the Ministry of Energy and Power by Nexant 2004.

The availability percentages relate to the proportions of time that the different production systems can be expected to provide power over the course of a year. Biomass should be available for a major proportion of the time and hence the conversion from the power rating to the estimated output in GWh reflects that fact. Whereas, hydro is likely to be of limited value during the drier parts of the year and wind energy is subject to daily variations.

Currently the contribution from small scale hydro and the other renewables is less than 0.2% so even with the relatively modest target of 10% there is a long way to go. Some suggestions have been made that the potential for dendro power could almost equal the present total level of electricity production. Land availability for dendro plantation development is unlikely to be a limitation.

In order to reach the suggested Master Plan target of 80 MW this would require a plantation source of around 40,000 ha, although on the basis of the results of the Walapane plant a more conservative figure would be closer to 60,000 ha.[27]. Ridgway and Silva [28] have indicated that the area of degraded forest or sparsely covered forest land is of the order of 800,000 ha which would be theoretically available for plantation development, however the complete picture will not be clear until the Land Use Policy Planning Division has finished the task of assembling a comprehensive Land Data Bank of land use and planning data for the whole country, but it is considered unlikely that a lack of adequate plantable land would be a major constraint.

[27] The 1MW unit at Walapane in Central Sri Lanka has a daily requirement of 40 tones a day of *Gliricidia* at 20% moisture content, this would equate to around 1.5-2.0 ha of plantation.
[28] Land Availability and Land Tenure in Sri Lanka. Paper presented to this conference.

Text Box 1 - The Energy Situation in Sri Lanka

1. Biomass dominates the total energy equation providing 50% of the country's energy needs, but in terms of electricity production it has no significance as indicated below

2. Current Grid connected power sources comprise:
    a. CEB Large-scale hydro units = 1205
    b. CEB Thermal units (oil-based) = 560
    c. CEB Wind = 3
    d. IPP Thermal units = 338
    e. SPP (Hydro and others) = 35

(Where CEB = Ceylon Electricity Board, IPP = Independent Power Producers and SPP = Small Power Producers. Total grid connected dendro power comprises 1MW)

2. 48% of the electricity production currently from hydro, fallen from 99% in 1990 and 52% from oil as the plateau for large scale hydro-production has already been reached.
3. Current projections are for the power mix to switch to Hydro 24%, Oil 9%, Coal 67% by 2017
4. Currently 65% of the total population are connected to the grid but in terms of the rural population only this proportion reduces to just 47% . The target is to increase the overall figure to 75% by 2007. It is considered economically unviable for this proportion to be pushed above 80% due to high connection fees for the more remote communities, leaving around 1.8 million with out access to electricity.
5. Majority of rural households use less than 50 kWh per month.

Recent studies by the National Renewable Energy Laboratory (NREL) of the USA indicated that the potential for wind energy could be as much as 24,000 MW, so again the current Master Plan suggested targets for 2015 would be technically feasible.

It is clear that with the high cost of grid connections for the more remote communities ($400 per household) that there will be a significant core of the rural population that will need to get its future power from free-standing power sources. Some interesting comparisons have been made for the cost of providing different types of renewables[29]. The development of the 1 MW dendro power unit at Walapane is leading to a cost of $800 per kW. For micro hydro development in the range of 0.5-50kW, the cost is working out at $275 per household installation, but this is equivalent to $1,500 per

[29] Economic Growth and Energy Integration Strategy in Sri Lanka, Nexant 2003. Study funded by USAID.

installed kW. In the case of solar photo voltaics, some 25,000 individual home systems have been provided over the last 10 years at a very variable cost of $300-700 per household. This is equating to $10,000 per installed kW. This does tend to suggest that dendro-power is a very cost effective alternative energy source for off-grid situations.

The development of the use of renewable energy has in recent years been given a boost as the world wakes up to the dangers of continuing to push huge quantities of carbon dioxide in to the atmosphere and as the cost of oil pushes up over $60 per barrel and we look back with envy to the times when oil was a mere $30 or less. But why has the spread of small scale renewable energy been so slow? Certainly here in Sri Lanka, the country has been cushioned by its huge large-scale hydro resources, which have only in the last 15 years been seen to be inadequate for future energy needs. The Energy Master Plan carried out an analysis of what are the issues that are limiting the spread of small-scale renewable energy in Sri Lanka.

Institutional Aspects – constraints relating to obtaining necessary approval from authorities to establish plants and a general lack of support from the Ceylon Electricity Board. (CEB)

Inadequate tariffs: most would-be power producers complain at the low tariff that is offered to the Small Power Producers (SPP), where they are interested in selling to the grid. Where the plant is rated at less than 10 MW, then the SPPs must make use of renewable power and required to enter into standardised agreements that tend to be non-negotiable 15 year contracts. The price offered does not adequately reflect the invested capital cost, since the CEB calculate the tariff on the basis of "avoided cost" and this is calculated on the basis of energy only. Dendro-power producers have argued that their power has an advantage over mini-hydro or wind power since production can be more or less guaranteed and would not be seasonable or subject to daily variation.

Technical Aspects: There is a limited absorptive capacity of take up by the grid and a general lack of local technical expertise relating to this type of technology.

Financial Aspects: inadequate available equity and limited interest by the financing institutions for dendro-power made worse by a general high commercial interest rates for borrowing on the open market. General lack of knowledge by the banking sector

Policy Issues: In terms of the tariff structure, renewable energy is not given adequate economic credit for the hidden benefits that the energy provides compared to the use of fossil fuels i.e. the carbon saving, saving in foreign exchange, creation of local employment etc. In addition there is scant recognition of the importance of dendro-power in terms of the national energy strategy.

To some extent, although these issues have been highlighted for Sri Lanka, they would apply to many countries both in SE Asia and indeed Europe.

Table 1   Illustrative Cash Flow

A single SRC plantation has an expected lifespan of at least 20 years. The table below shows an example cash flow for a 10 hectare plantation over the 10 year contract period.

		Year -1	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Establishment inflows		£	£	£	£	£	£	£	£	£	£	£	£
	Planting grant		10000										
Revenue inflows													
	Energy Crops Payment		300	300	300	300	300	300	300	300	300	300	300
	Wood chip sales (minimum)[1]						10800			10800			10800
Total Inflows			**10300**	**300**	**300**	**300**	**11100**	**300**	**300**	**11100**	**300**	**300**	**11100**
Establishment outflows		£	£	£	£	£	£	£	£	£	£	£	£
	Site preparation	789	397										
	Cuttings and planting		[2]10254										
	Fencing[3]		0										
	Weed/pest control[4]		0										
Revenue outflows													
	Cut-back harvest			[2]620									
	Weed/pest control			218			0			0			0
	Harvesting						[2]4615			[2]4615			[2]4615
	Haulage						[2]1200			[2]1200			[2]1200
	TVBC Membership Fee		50	50	50	50	50	50	50	50	50	50	50
Total outflows		**789**	**10701**	**888**	**50**	**50**	**5865**	**50**	**50**	**5865**	**50**	**50**	**5865**
Net Cash Flow		**-789**	**-401**	**-588**	**250**	**250**	**5235**	**250**	**250**	**5235**	**250**	**250**	**5235**
Accumulated Cash Flow		**-789**	**-1190**	**-1777**	**-1527**	**-1277**	**3958**	**4208**	**4458**	**9693**	**9943**	**10193**	**15428**

Costs shown are based on the experiences of TVBC or are taken from the Farm Management Pocketbook, Nix (2004)
All activities would be carried out according to Defra Best Practice Guidelines
Assumes 10 hectares of former arable land.
The crop can be repeatedly harvested for over 20 years, but it is likely that newer varieties will supercede current varieties, making replanting after 20 years more economical.
Farmer carries out all site preparation and weed control activities
Planting and harvesting is carried out by a contractor located in Northern England
The Energy Crop Payment is €45/ha/yr maximum and is not available for set-aside
The farmer would also receive his single farm payment, but this has not been included in the economic assessment.
Assumes a haulage distance of 20 miles

Notes

[1]**Assumes yields of 10 tonnes of dry matter per hectare per year and a minimum price of £36 per tonne of dry matter**
This is to be a split pricing deal, under the terms of which there is to be an additional premium paid per tonne dependant on prices achieved in the market.

[2] **Activities which TVBC would ordinarily organise on the growers behalf**

[3] **Fencing for rabbits may be required at some locations, this would amount to £5,500 for the 10 ha block**

[4] **Weed-prone sites may benefit from an increased level of pre-planting herbicide in Year 0. If applied this would cost about £80**

All values are given in real 2004 money