THE POTENTIAL CONTRIBUTION
OF ALTERNATIVE SECTORS
TO A SUSTAINABLE
AGRICULTURAL INDUSTRY
AND RURAL ECONOMY
IN WALES

A COMPARATIVE ASSESSMENT

A report for NAWAD and the WDA

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(C) SECTORAL RESEARCH

1. BIOMASS, INCLUDING SHORT ROTATION COPPICE

1.1 NON SHORT-ROTATION-COPPICE BIOMASS

A wide range of previous studies highlight the attractiveness of short rotation coppice (SRC). However, before looking at SRC in more detail we need to quickly review other biomass crop opportunities for farmers.

1.1.1 Miscanthus

1.1.1.1 Background

- Miscanthus is a genus of woody perennial rhizomatous giant grass native to Asia and Africa. It is grown in western Europe as an ornamental in gardens.

- Temperate crops, with the exception of maize, have a C3 photosynthetic pathway. Miscanthus, and maize, have a C4 photosynthetic pathway, which offers greater photosynthetic efficiency in conditions of high temperatures and illumination levels and at normal or reduced CO2 levels. The theoretical potential yield of C4 plants is estimated at 55 t DM/ha/yr compared to 33 t DM/ha/yr for C3 plants.

- Miscanthus has been studied extensively from the late 1980s. This has included a UK MAFF funded trial over 7 sites undertaken by ADAS. The crop has also been studied at an EU level through the Miscanthus productivity network which involved 16 organisations in 9 countries. No significant yield trials appear to have been carried out in Wales, though a small experimental area is now being cultivated.

1.1.1.2 Agronomy

- Early work (Rutherford and Heath,1992) used maize production parameters as a guide for growth of Miscanthus and recent discussions reveal that this remains a suitable guideline. These guidelines use Ontario Heat Units (OHU) of accumulated temperature. Agroclimatic areas where over 2 500 OHU are accumulated in 9 years out of 10 give a good indication that the location is suitable. This would indicate that there are a number of regions in the south of Wales where Miscanthus could be grown at low altitude, although local conditions in other areas may allow some cultivation outwith these confines. At higher elevations, particularly with north facing slopes, with low spring temperatures, and on free draining soils conditions for growth will be less favourable and yields will tend to decline. It is noted that production may be suited to lowland ex-grassland sites.

- As Miscanthus does not produce seed in UK conditions, it is necessary to use vegetative propagation. Rhizomes are planted in May for optimal establishment at a density of 10,000 – 20,000/ha. The plants will grow quickly once daytime temperatures exceed 10°C. Stems may reach 3 - 4 m during the summer months. Senescence will begin during the first frosts of autumn and the standing stems will gradually dry throughout the winter, until the crop is ready for harvest in February/March.

- Herbicides may be required to control weeds during the establishment phase, but once establishment is achieved weed growth is effectively suppressed. Little pesticide input is needed. A nitrogen input of 150 kg N /ha was needed to achieve a full crop canopy in UK trial conditions.

- After establishment, the crops may be cut every year. Harvest is undertaken by forage harvester, during the winter once the moisture content of the material has declined. Moisture content at this time will vary between 35 and 70%. The material can be immediately conditioned to allow easier baling and drying, or swathed to reduce stem moisture content. It can then be baled for transport.

- Yields in the year of establishment are low at 2 - 7 t DM/ha, with yields increasing to a peak of maximum production. The timing of maximum production will depend on location and climatic conditions and yield will tend to decline from 10 years onwards, although Miscanthus plants will survive up to 20 years.

- Yields of up to 44 t DM/ha have been reported in Denmark, however yield estimates from field based mature stands are more usually 11 - 25 t DM/ha. The Miscanthus productivity network, comparing different areas within the EU, indicate a yield of over 24 t DM/ha in Portugal, Greece and Italy, where irrigation was applied. The Irish and British sites in the study gave yields of between 11 and 16 t DM/ha. Results from a MAFF funded study in the UK have indicated variation in yield from 12 - 24 t DM/ha across 7 sites of varying fertilities over different seasons, with a mean annual yield of 18 t DM/ha at the best sites. It was concluded that yields were unlikely to be less than 12 t DM/ha on arable land.

1.1.1.3 Economics/Markets

- The principal market for Miscanthus is for power generation. There are also other uses, for instance in paper production and as a building material, however the crop cannot compete with existing inexpensive feedstocks.

- There are a number of initiatives in the UK which currently offer contracts for Miscanthus cultivation. The BICAL (Biomass Industrial Crops Ltd) initiative is supplying biomass to a renewables power station in Ely. Contracts are on offer for Miscanthus produced within a 50 mile radius. Russell, Baldwin and Bright, Leominster, are offering contracts on a 15 year basis for Miscanthus, based on a payment of £25 /t DM. Cultivation at present is limited to England, but areas are being grown up to the Welsh border.

- The Miscanthus productivity network (EU project) concluded in their final report in 1997 that establishment costs and yield had major effects on the economics of the crop. A selling cost of 33 ECU/ t DM with a yield of 20 t DM/ha and a planting cost of 0.05 ECU/rhizome was necessary to make the crop viable. Currently these are not achievable.

- However, costs of establishment have declined over the past decade, when costs of £0.40 per rhizome were estimated. Recent UK studies anticipate that a unit price of £0.05 per rhizome propagule is feasible with developments in field scale propagation of rhizomes. A planting density of 20 000 plants/ha is used to compensate for any planting system inadequacies.

- Harvesting has been identified as the most expensive annual operation due to the high yield of material to be baled and its high moisture content (Bullard, personal communication, 2000). These changes have led the UK team to conclude that yield and the cost of harvesting are the prime influences on profitability.

- Calculations by Bullard and Nixon (1999) based on the UK data and assuming a harvested yield of 18 t DM/ha give a break-even cost of production of baled Miscanthus of £46/t. When the cost of delivery is added, the break-even cost increases to £53/t and the cost of chopped and dried Miscanthus is estimated at £66/t. If current set-aside support is set against costs, these break even figures decrease to £22, £26 and £44 respectively. For energy generation, it is anticipated that at very best an ex-farm price of £40/t is attainable for Miscanthus, therefore market support is necessary for viability.

- If supported by set-aside payments, Bullard and Nixon (1999) calculate that Miscanthus can achieve a net margin of £286/ha/yr compared to coppice at £255/ha/yr. Cost of establishment, annual production and harvesting are detailed at Appendix 1.

1.1.2 Reed Canary Grass

1.1.2.1 Agronomy

- Studies on reed canary grass have been less comprehensive than Miscanthus. However, an EU project has studied the production of reed canary grass throughout Europe.

- Reed canary grass has the benefit of being produced from seed, so reducing establishment costs.

- Yields have been estimated at 10 t DM/ha in Scandinavia, although a net yield of only 5 - 6 t/ha is noted due to harvest and storage losses. First yields are only obtainable after 2 - 3 years of establishment.

- The crop may be better suited to cooler conditions than Miscanthus, therefore it may offer potential in areas where Miscanthus cultivation and yields are limited. However, with the very limited range of trial sites there is little information to indicate yield potential in Wales.

1.1.2.2 Markets

- As an energy source, it was concluded that reed canary grass could only be competitive where conventional fuels were taxed as fossil fuels.

- Reed canary grass appears to have greater potential as a raw material for the pulp and paper industry, but modifications in current pulping processes, which are designed for wood pulping, would be necessary. Another problem is that the large variation in pulp price influences the economic viability of a new feedstock.

- MAFF has identified a need for further field research in reed canary grass and switchgrass grown at a range of sites across the UK and is currently in the process of commissioning such work.

1.1.3 Switchgrass

- Switchgrass is a C4 grass, which is established from seed with associated cost advantages compared to Miscanthus.

- It is used for biomass production in North America and is claimed to be cold tolerant, with high yield potential and low water and fertiliser input.

- Little information is available on yield in the UK at present.

- A 40 month EU project on switchgrass was commissioned in 1998 to consider the role of this crop in Europe, in addition to the planned MAFF study mentioned above.

- This is another biomass crop which may in time be shown to have potential for Wales, but until further information is available, commercial development will be constrained.

1.1.4 Conclusions

- None of these crops could be grown economically as biomass on a widespread basis in Wales.

- Miscanthus presents the best opportunity at present, but it is heavily reliant on area payments, under the non-Food crop set aside option, for its relatively good margin.

- The best strategy for Miscanthus may be as an additional feedstock to an SRC energy plant in or near arable areas.

1.2 SHORT ROTATION COPPICE (SRC)

An assessment is presented here of the potential for Wales to produce substantial quantities of SRC, farmers' attitudes to SRC, the potential market for SRC as biomass or for other uses, how a large scale SRC venture could be organised, the likely financial returns to growers of SRC and the key strategic issues for successful development of a Welsh SRC industry.

1.2.1 Supply Potential

Welsh supply potential has been based on the identification of the total suitable land area and the likely yield of SRC it could produce.

1.2.1.1 Land Availability Survey

Data obtained from the G.I.S database, FRCA, Aberystwyth were used to estimate the areas of Wales where SRC might be grown. These were:

Potential Area for SRC (Figure 1; Appendix 12);

This is a tighter definition of the area which might grow SRC.

Areas excluded:
- Moorland Map areas
- Statutory conservation designations (SSSI, NNR, LNR, Ramsar, SAC, SPA, RSPB reserves)
- Common Land
- Agricultural Land Capability classification (A.L.C.) areas: Grades 1, 2 & 5
- A.L.C. areas: Urban, Non-Agricultural, Other Land
- Land under Habitat Scheme agreement
- Land under ESA agreements

Likely Area for SRC (Figure 2; Appendix 12):
Areas excluded:
- As above
- A.L.C areas: Grade 3. This has been excluded due to the attractiveness of other crops and enterprises on this land quality.

The Agricultural Land Capability classification (A.L.C), devised in 1988-9 as a result of 20 years experience, is a national scheme covering the whole range of agricultural land types from lowland arable to upland moor. Land areas are graded at a resolution of 80 ha according to the 'most limiting factor', which may be one of climate, soil or topography. Using the G.I.S. database, it was not possible to exclude areas by altitude as such. Instead categories of moorland and A.L.C. Grade 5 land, where yields are likely to be poor, were excluded. Selection of areas by soil classification was not possible due to restrictions on the use of Soil Survey data. Similarly grades 1 and 2 were excluded as this good quality land is relatively scarce and carries arable crops and intensive livestock enterprises against which SRC is unlikely to be able to compete at present. The importance of soil type and, in particular, soil wetness for yields of SRC are recognised (Section 1.2.1.2) but A.L.C. grading is taken as an adequate predictor of average yields. Site-specific predictions would require a different approach based on detailed knowledge of local site factors.

Potential area as defined above equates to A.L.C. Grade 3 and 4 land: widely distributed throughout Wales.
Likely area as defined above equates to A.L.C. Grade 4: mainly in the West/Central and North/East regions of Wales.

Figure 1. Strategic Map of Potential Area for Short Rotation Coppice in Wales

Figure 2. Strategic Map of Likely Area for Short Rotation Coppice in Wales

In total, there is a large area of land available to plant SRC (over 1 million ha, or over 700,000 ha excluding Grade 3 land, See Appendix 1). If only a proportion of this total were to be made available by farmers to grow SRC, substantial quantities of wood fuel could be produced (see below). The areas concerned are distributed throughout Wales, the largest being in **Carmarthenshire, Powys** and **Ceredigion.**

1.2.1.2 Yield Estimates

SRC yields vary considerably with site conditions and with the variety of willow or poplar grown. As with other crops, site location (altitude, local climate, wind exposure), soil type (pH, drainage, structure) and management (fertiliser application, cutting regime) all strongly affect growth rates. The Agricultural Land Capability scheme was not designed for predicting tree growth, other site classification systems with more emphasis on soil conditions being favoured by the Forestry Commission. For this study, A.L.C. grades 3 & 4 (Section 1.2.1.1) have been taken to indicate generally more, and less favourable conditions, respectively for SRC, although within these categories wide variation of yields are likely depending on local soil and site factors such as wetness, and wind exposure. For example, the greater moisture retention of some upland gley soils may be considered an advantage for tree establishment and growth, despite their lower suitability for agricultural crops (A.L.C. grade 4).

Reported yields of different willow and poplar varieties in Wales vary widely. In plot trials, yields ranging from 6 to 15 oven-dry tonnes (odt) /hectare/year for willow occurred on a marginal upland site (Hodson, 1995; Heaton, 2000), similar yields to those obtained at various sites around the U.K. (Mitchell *et al*., 1995). Recent trials in Wales by the Forestry Commission Research Agency (FCRA) yielded up to 12 tonnes for willow and 13 tonnes for poplar but yields for different varieties ranged from 1 to 10 odt/hectare/year. Note that small plot trials may over-estimate the potential of larger plantations in which some land is lost around field edges and for access rides. It is advisable to grow a mixture of varieties to minimise the risk of crop losses from pests and disease. Yields will also vary between years and over the life of the crop. Hence the following yields are assumed to be realistic, with the expectation that local sites may produce substantially more:
On A.L.C. Grade 4 land: 6-8 oven-dry-tonnes/ha/year (12-16 green tonnes/ha/year)
On A.L.C. Grade3 land: 8-10 oven-dry-tonnes/ha/year (16-20 green tonnes/ha/year)

Trials in progress by the Forestry Commission Research Agency at 49 sites in England and 8 in Wales are working towards a site-specific predictive yield model, which may aid in estimating local yields for farmers. These trials gave an average yield over the whole country of 8 odt/hectare/year from a 3-year harvest interval. The above generalised and conservative production figures are considered to be adequate for the current purposes in view of

a) the large total land area available,
b) the unknown extent and quality of available land likely to be released for SRC, and
c) the costs of establishment which are related to area planted, irrespective of yield.

A coppice rotation of 4 years between harvests has been assumed for planning purposes although on many sites at lower elevation a 3-year rotation may be appropriate if the added yield offsets the additional harvest cost. Hence in a 4-year coppice rotation, each harvest might produce 4x6=24 odt/ha, etc every 4 years. Yields are known to rise during the first 2 or 3 rotations as new stools become established.

1.2.1.3 Total Supply Estimate

Over 700,000 ha are considered as likely areas for growing SRC in Wales. If farmers were prepared to release only 10% of that area for SRC, assuming a yield of 8 odt/ha/year, over half a million tonnes of wood fuel could be produced. This amount of fuel would meet the requirements of 5 power stations the size of that proposed for Newbridge-on-Wye. **It is a substantial figure for potential fuel supply compared to the total annual supply of forest waste materials in Wales (72,000 tonnes).** The harvest of wood from farms in Wales can be enhanced with waste wood arising from management of small farm woodlands (Section 5) and from hedgerow trimmings if farmers are encouraged to take a more integrated approach, as proposed by the Forestry Commission.

The total supply potential appears not to be a limitation in promoting SRC production in Wales. Rather, the growth of the SRC supply chain will be dependent on the growth of demand from the energy industry through the promotion and development of bio-energy projects (Section 1.2.7).

1.2.1.4 SRC Establishment and Crop Management

Although producing a wood crop, the establishment and management of SRC is more akin to that of an agricultural crop than traditional single-stem forestry. In Wales, SRC would be grown almost entirely on former pastureland, either permanent grass ley or unimproved rough grazing. For livestock farmers, techniques for growing SRC may be unfamiliar, so that advice and practical assistance may be welcomed. Whereas some farmers may wish to undertake establishment and management of the crop, and obtain access to the required specialist planting and harvesting equipment via machinery-ring co-operatives, others will prefer to hand over responsibility for the crop to a managing agency in return for land lease payments and a share in harvest income.

The details of site selection, ground preparation, variety selection, planting design, protection against pests, weed control, crop management decisions such as cut-back, cutting cycle and choice of harvesting and storage techniques will depend on a variety of factors specific to the site. A Forestry Commission Practice Note "Establishment of Short Rotation Coppice" (Armstrong, 1999), outlines the issues involved with respect to the U.K., but their relative importance in Wales needs to be assessed in relation to local site conditions. For example, in compacted soils or in soils with sub-surface pans such as upland podsols, ripping may be required as part of ground preparation. Where SRC is planted on fertile former ley pastures, there may be problems of poor establishment due to root attack by leatherjackets (Tipulid insect larvae). Liming will be necessary only for some acidic or peaty soils, whereas additions of fertiliser is beneficial on most sites to maintain yields in the long term (Heaton, 2000).

In comparison to willow, poplar is thought to be less suitable in cooler, wetter upland sites. There has been less research in Britain, especially in the uplands, into poplar for SRC (Mitchell *et al*., 1995). Poplar cuttings are more expensive than willow as they require careful preparation, cuttings of some varieties are not readily planted by machine, do not readily coppice after cut-back, and re-growth stems are prone to wind throw, and it is thought that mature poplar stools are harder to remove (Hilton, 2000). On the other hand, the flexibility of poplar to produce either coppice or single stems for round wood logs is perceived as a benefit by farmers who have yet to be convinced of the viability of the market for coppice wood.

This study does not aim to prescribe in detail optimal management practice for SRC in Wales, except in relation to the costs of operations included in a typical grower's scenario for the economic analysis (Section 1.2.5).

1.2.1.5 The Impact of Climate Change

The implications of climate change in Wales for SRC are difficult to predict, given the current state of knowledge of the relationships between site conditions and local climate and their effects on yields. Changes are likely to make the climate on average warmer, wetter and windier, which may have beneficial effects on plant growth at some sites. At others, the need for shelter belts may increase and differences in performance between varieties may change. Potentially of concern is the prospect of a greater prevalence of pests and diseases such as insect defoliators and rusts, underlining the need to plant a diversity of willow and poplar varieties in the foreseeable future.

1.2.2 Farmers' Attitudes to SRC: Interview Survey of Farmers

A small survey of farmers was carried out to simply test attitudes to and knowledge of SRC.

Farmers attending local livestock markets were approached and asked to respond to 8 questions relating to their attitude towards growing SRC. They were asked, "If the price were right, would you be prepared to lease out part of your farm area to grow willow?" A copy of the questionnaire used is shown in Appendix 3.

A majority would be prepared to try SRC (14 "yes", 6 "no", 1 "don't know"). Of those saying "yes" more were aware of SRC as a potential crop (9 to 6). Of those saying "no", most were not aware of SRC (by a ratio of 2 to 1), suggesting that farmers' willingness to take up SRC may depend on a promotion and information campaign. There was little difference between farmers saying "yes" or "no" to SRC with respect to the average size of their holdings (in terms of enclosed land) and to the size of their flocks of sheep (Table 1). This suggests that the larger farmers are not more willing to try introducing SRC as a novel component on their farm despite the loss of a small area to SRC having less impact on the profits of larger farm businesses. Given the relatively small average farm size in many parts of upland Wales this is encouraging in terms of introduction of SRC as a crop.

Table 1. Farmers' attitude to SRC, by farm size.

	"yes" farmers	"no" farmers
Average area for sheep + cows	122 ha	97 ha
Average number of sheep	1080	970

These data give some indication of the willingness of farmers to consider growing SRC at the present time. In our view, current attitudes may change rapidly in response to:

- on-going dissemination of information, e.g. through promotional events, literature and articles in the farming press,
- provision of advice and practical assistance with conversion to SRC, e.g. establishment of agencies to manage the production and marketing of SRC on behalf of farmers.
- provision of subsidy payments towards establishment costs (section 1.2.5.7).
- a clear indication of the likely returns in relation to existing enterprise and an assessment of the risks and how they will be tackled.

1.2.3 Current and Potential Market Outlets for Coppice Willow in Wales

1.2.3.1 Cuttings and Rods for Planting

At present the demand in Wales for these products is small. Until there is a SRC industry, demand for the product will be minimal. Two initiatives in Wales could stimulate the market:

1. An EAGGF Objective 5b / NAW funded "Salix Project" being undertaken by Cardiff University at its Llysdinam Field Centre in mid-Powys, will demonstrate the potential of willow as SRC and for filtration.

2. The current proposals for a wood fired power station at Newbridge-on-Wye and further similar proposals elsewhere in Wales.

The impact of the Newbridge-on-Wye power-plant, if built, on the SRC industry can best be judged at present by the resources required by the ARBRE plant at Eggborough, near Selby in Yorkshire. This plant will require 43,500 oven dry tonnes of wood products per year, 75% to eventually be supplied by 2,000 ha of SRC within a 40 mile radius. To March 1999 agreement for 420 ha. of SRC had been made with farmers.

Initial proposals for the Newbridge-on-Wye plant required 200,000 wet weight tonnes of fuel per year – mainly from forest waste. This approximately equates to 100,000 dry weight tonnes compared with a total production of forestry waste in Wales of 72,000 oven dry tonnes per year. Although not specifically part of the proposals, SRC must be a candidate for meeting this shortfall. This could result in a major demand for cuttings for planting in the near future.

Production of SRC within a 40 mile radius of such plants offers, in the early years of establishment, the opportunity to supply willow cuttings for planting. The value of output from land supplying willow cuttings is:

20,000 established plants per hectare x 5 shoots per plant x 5 cuttings per shoot @ 5p per cutting = £25,000/ha/yr,

Clearly once the crop is generally established the value of cuttings is reduced and most income must come from biomass production.

Long (50cm) rods may have a market for embankment support irrespective of the biomass market. Such rods could have a value of 25-50p. This market is limited only by the extent of future road building and similar projects. Quantities required can be considerable. We are aware of one supplier (Lionel Hill) having a single order for a quarter of a million rods to support the M4/M25 junction embankments.

1.2.3.2 River Bank Support

Although willow has been traditional river bank support for centuries, mainly relying on the roots of, often pollarded, Crack Willow, willow weave for the same purpose is a newer concept. Current practice on eroded river banks is to dig 2m x 10cm diameter Crack Willow posts 1m into the riverbed at approximately 1m intervals along the eroding face of river cliffs. 1-2cm diameter willow branches are then woven between the uprights and the whole structure backfilled.

During 1999 the Environment Agency (E.A.) in Wales undertook several projects using this technology covering in total in excess of 1km of river bank. The length of river potentially requiring this type of treatment is "limited only by available finance" (E.A.) and may be the subject of E.U. funding applications. Currently the E.A. sources its Crack Willow from either English Hurdles or Waterside UK, both based outside Wales. Waterside UK currently quote £42/m and Blocksham £60/m (supply and erect) for this type of work. The asking price for the stakes in 1999 was £7-£9 each and the branches for weaving £1-£2 each.

There is also a demand for bundles of willow to help stabilise river banks and to create deflections within the river to encourage gravel scouring. This is an outlet for surplus material but the demand is localised and sporadic and the price whatever can be negotiated – say £5 per bundle.

1.2.3.3 Wood Chips for Paths and Horticulture

As yet this has not developed into a lucrative market. In rural areas woodchips from woodland and roadside management are generally spread back on their site of production. The potential for a garden centre market exists but has yet to be addressed in Wales. The Landscape industry will pay up to £30 per tonne for chip. Its retail value can be seen from the table below compiled in January 2000.

Table 2: Wood Chip Retail Prices

Supplier	Quantity (Bags Ltrs.)	Price
Wyevale, Hereford	60	£4.99
Percy Thrower, Shrewsbury	70	£4.99 - £5.99
MSF (Countrywide), Worcs.	3 x 80	£11.99
Pengethley Nurs., Ross-on-Wye	80	£5.99
Bayleys, Shrewsbury	90	£4.99
TAFS Gdn. Supp., Telford	120	£4.50

NB: TAFS also offer woodchips loose at £31 per cubic metre.

1.2.3.4 Materials for Basketry, Hurdles and Willow Sculpture

Each of these three uses requires somewhat different materials.

Basketry

Traditionally grown on the Somerset Levels, the fine rods of *Salix triandra* (Almond Leaved Willow) are used for fine craftwork and basketry. The rods of *Salix purpurea* (Purple Willow) range from fine material about 1m long to vigorous forms producing rods 2-3m in length. *Salix viminalis* (Osier) is a hardy variety, currently grown and harvested annually at 380m in mid-Powys, and can be used for coarse basketry and hurdles.

Although growing generally heavier, fast growing varieties for biomass, Cardiff University's (C.U.) experimental site in mid-Powys receives unsolicited annual enquiries for basket willow which it has sold for up to £15 per bundle (c 50 rods). There is clearly an unquantified market for basket type willows in Wales. Indeed it is the type of craft industry which might flourish in such rural areas particularly with E.U. pump primary funds. C.U. have recently (January, 2000) had enquiries about supplying willows for coffins for “green” funerals!

Hurdles

Hurdles are made from several types of timber amongst which willow is widely used. Because it is a coarser product than basketry the fast growing biomass type willows are suitable. Again C.U. experimental site in mid-Wales has frequent enquiries about the availability of material for hurdles, mainly from outside of Wales.

Willow Sculptures

Living willow structures are a relatively new development in the use of this plant. In the period October 1999 to January 2000 gardening programmes on the three major T.V. channels have featured willow structures. T.V. exposure undoubtedly creates demand. Fast growing *Salix viminalis* cultivars are amongst the best types for such work. The demand for this type of work is rapidly increasing to the extent that Steve Pickup of “The Willow Bank” at Machynlleth now spends much of his time constructing willow sculptures throughout Britain. The Cardiff University “Salix.org.uk” website received more enquiries for willows for sculpture in the 3 month period to January 2000, than any other communication. The smallest viable sculpture will require at least £100 worth of tall willow and typically a large sculpture may require ten times that amount. This is a specialist market that currently might be worth £10,000 per year in materials alone.

Sundry Uses

Willow lattice is used to stabilise dangerously unstable open mud as well as steep pond sides and river banks. Promotion of the technique could significantly increase demand.

Because the crop is regularly cut, maintaining a low canopy, SRC is of benefit as cover for game birds at the edge of mature woodlands. Willow is becoming a widely used plant either on its own or with reed in biofiltration systems. In Wales the National Trust have installed a willow bed filtration system at one of their properties in the Conway Valley. The object of this bed is to treat yard washings from the farm, utilising the contained nutrients as fertiliser for the willow which will be harvested as SRC to fuel an on-farm boiler system. Cuttings for such schemes need to be sourced. In conservation terms SRC is very rich in wildlife particularly so for warblers in summer, and therefore has some eco-tourism potential.

1.2.3.5 Energy Markets

The major potential market for SRC in Wales and elsewhere in the E.U. will be energy production. Such installations can be divided, for convenience, into **electricity generation** and **heat production**, although opportunities increasingly exist for co-production using **combined heat and power (CHP)** technology with added benefits of high efficiency (Section 1.3/1.4). New technologies such as CHP, gasification, pyrolysis, fluidised bed combustion and combined cycle gas turbine technology are being employed to provide greater energy conversion efficiency and greater flexibility of application at a range of scales. Such developments will impact upon the economic viability of future SRC enterprises. We have considered as models, energy installations based on conventional wood-chip burning systems which exist or are planned, for which relevant data are available. There is scope for further investigation to predict the market potential in Wales for SRC from new energy conversion technologies. It is assumed that fuel supply for energy production in Wales, as in other countries, will come from a mixture of sources including SRC as well as forestry waste and waste wood material. The potential supply of wood waste from specific sources is great: e.g. a board manufacturing firm in Merthyr Tydfil generates 10,000 tonnes per year; a local landfill operator in West Wales receives about the same amount of waste wood per year – by 2002 regulations will prohibit disposal of wood waste to landfill. Waste wood from on-farm sources, arising from farm woodland management (Section 5) and hedgerow trimmings, rather than being burnt on site could provide a substantial supplement to the supply of woodchips , alongside that from SRC.

It could be said that these waste wood raw materials will undercut SRC and prevent SRC developments. However, the opposite is likely. The legislative need to dispose of waste wood will stimulate energy and heat plant development and as a result create opportunities for SRC chips to bring the facility up to an economic scale and to fill gaps in seasonal waste supplies.

Electricity Generation:
Example 1: ARBRE plant, Eggborough, Nr Selby, Yorkshire:
The U.K's first wood-fuelled power station, using advanced gasification technology is due to start production in March 2000. Its capacity is 10MWe (electricity), of which 8 MW will be exported to the local grid, sufficient for 33,500 people. This plant requires 43,500 odt wood/year, 75% to be eventually supplied by 2000 ha of SRC within a 40 mile radius (to March 1999, 420 ha SRC agreements have been made with farmers). ARBRE pays £20 per tonne to farmers for wood-chips. Some of the waste heat generated by the plant will be used to dry the incoming wood chips down to 10% moisture content.

Details are given later in the financial assessment section of the start up funding for growers and interim payment scheme which are part of the ARBRE project.

In Wales, other power generation schemes currently under consideration involve the co-production of heat for use on site or for other industrial and domestic users. Electricity-only generation plants are large-scale centralised installations, making the transport of SRC between the field and the plant a major issue and raising questions about the loss of co-generated heat energy.

Co-Generation of Electricity and Heat (Combined Heat & Power, CHP, Schemes)
Example 2: B.S.W. Newbridge on Wye Power Plant:
The planned power plant will form part of a new integrated wood processing facility. Employing pyrolysis with modern combined cycle generation technology, the plant will produce 15 MWe for export to the local area grid. Heat from the process will be used on site to dry timber and the wood fuel. The wood fuel consumed will lead to a reduction of about 150,000 tonnes CO_2 emissions per year by substitution of fossil fuels. The new integrated timber processing plant, of which the power plant is an essential part, will preserve 264 local jobs and create a further 255 on site and in associated operations.

The plant is expected to use 200,000 wet weight tonnes mainly from forest waste. This is approximately 100,000 dry weight tonnes compared with a total production of forest waste in Wales of 72,000 oven dry tonnes per year. SRC may be a candidate to fill the gap.

Example 3: Ceredigion County Council, Felin Fach dairy site:
This major dairy processing plant will require 2 MW electricity and heat supply. Locally generated combined heat and power (CHP) is found to be a lower cost solution than to upgrade the Grid distribution line. Free 'waste' heat will supply a local old people's home. It is an example of 'Auto-generation', whereby the local authority is both provider and user. Wood fuel supply from SRC is planned.

- Pembroke County Council will replicate the Ceredigion model as follows:

Example 4: Ynys Mon, Rhos Goch power station, on former Shell tank site:
Plans include horticulture development utilising 'waste' heat for glasshouses. Agreements have been made already for 900 ha of SRC among the EGNI Biomass group, a farmers' cooperative.

Example 5: South Caernarfonshire creameries CHP plant: the HUFENFA Objective 5b Project:
Partners, Dulas Engineering, EGNI Biomass group.

Existing installations outside Wales demonstrate the benefits of energy efficiency gains arising from small CHP schemes.

Example 6: St Pancras Housing CHP Scheme:
Electricity from a small CHP plant currently supplies a dry cleaning firm, the co-generated heat being supplied to local residents in the apartment block (resulting in 25% reduction in their fuel bills). This is an example of small scale CHP providing for local needs, with a net saving of energy and reduction in atmospheric emissions.

Heating Boilers:
Example 7: National Botanic Garden of Wales, Middleton Hall, Carmarthen:
The capacity of this small facility is 160 kW (Nordist boiler) to supply glasshouses at 9^{o}C above ambient temperature, hence loading varies seasonally. As a backup to the main wood-fuelled boiler are two 1000 kW oil burners which can be rapidly deployed in case of emergency or in the summer when there is only a small heat demand. The boiler requires about 270 tonnes per year of wood-chips (equivalent to fuel-oil savings of £4500/yr), sourced from waste wood currently arising on-site and in future to be diverted from landfill. Although the need for SRC is not anticipated in this case due to the ready availability of waste materials, the wood-fuelled boiler provides a useful model system which could be replicated in many small/medium sized installations around the country.

Example 8: Powys Energy Agency:
The agency, a part of Powys County Council, aims to heat at least two schools by woodchip boilers and 50 individual homes within the duration of the E.U funded project (3 years).

Example 9: West Glamorgan, Bridgend County Council:
A pelletising plant is planned for the production of a high quality wood fuel utilising waste heat to dry the wood.

Example 10: Hudnall Park Outdoor Centre (Hertfordshire County Council)
A feasibility study by LRZ Ltd proposed a 60 kW moving grate boiler (can accept up to 50% moisture content wood-chip fuel). This boiler requires 21 odt of wood-chips per year (42 green tonnes/yr), provided by 2 ha SRC at 10,000 shoots/ha density. The estimated saving on oil fuel was £1100/year
Capital costs of the boiler, its installation, and project management were estimated at a modest £12,810.

These examples serve to demonstrate the rapid pace of change in the energy market in Wales and elsewhere in favour of biofuels for electricity and heat generation and the response by local authorities in their commitment to the production of SRC as an energy crop.

Unlike electricity plants, heating installations are small-scale and can utilise a fuel source such as SRC produced in relatively small dispersed production sites, but avoiding extended transport distances. There is considerable potential to replicate such small/medium sized heating installations around Wales for a wide variety of public and private buildings and complexes, such as:

- Swimming pools & leisure centres
- Laundries
- Garden centres & greenhouses
- Schools & Colleges
- Office blocks & County Halls
- Hospitals & nursing homes
- Industrial parks (WDA sites)
- Prisons & Institutions
- Hotels
- Housing complexes (Housing Associations)
- Farm use (grain driers)
- Museums

These small developments would create opportunities for individuals or groups of farmers to diversify their income sources locally.

1.2.4 Short Rotation Coppice Production in Wales – Enterprise, Organisation and Stucture

In common with other agricultural enterprises, SRC production will be highly dispersed on discrete areas of appropriate land, among numerous growers across the country. Unlike traditional agriculture, however, the infrastructure for management and marketing of the crop is not yet in existence, and many of the potential market outlets have yet to develop in Wales. Transport of this bulky wet material over long distances is likely to greatly reduce viability. Also expertise in SRC growing does not exist among farmers. These factors suggest the need for some sort of agency (or agencies) to be established in Wales to act as a facilitator and co-ordinator, for example, in cost effectively linking farmer's product to the market. The agency could be the end user of the wood-chip product, as is the case with ARBRE, the Power Generation company. Alternatively, agencies could act to plant, manage and harvest production of the SRC crop and sell the wood chips under contract to many wood-fuelled boilers in the region. Such agencies could be privately owned, co-operatively owned or associated with public bodies such as the recently formed Powys Energy Agency. An alternative model is that the farmer takes responsibility for planting, managing, harvesting and marketing the crop. It is anticipated that few farmers would be prepared to embark on such a major commitment, mainly because they do not have the energy market expertise. At least in the early years they may prefer to lease land to an agency.

In each of these models for the SRC enterprise, opportunities for new employment will arise in the context of direct labour requirements and associated industries, as follows:

- Machinery contractors for novel operations such as planting, harvesting
- Manufacturers and repairers of machinery
- Willow/poplar planting material suppliers
- Haulage contractors
- Labour associated with planting, site maintenance, harvesting, transport
- End users (Electricity generation, Heating, Other Novel uses)
- Machinery and Plant manufacturers/suppliers/installer/repairers (heating units and power plants)
- Labour in heat and power plants.

Estimates of the amount of labour required directly for SRC production appear in the following section. Labour requirements for the associated industries and other “multiplier” benefits to the wider economy are not considered in detail here, but could amount to an important contribution to local or regional economies.

1.2.5 Economic Analysis of SRC as an energy crop in Wales.

This analysis examines the economics of growing willow SRC in the uplands, assuming the biomass would be sold to a wood-fuelled electricity plant. Additional production of woodchips from on-farm woodland and hedgerow management are not included in this analysis (Section 5).

1.2.5.1 Method of analysis and economic assumptions.

Analytical methods and assumptions.
A spreadsheet model was prepared in Microsoft Excel (further details can be found in Heaton *et al*., 1999). The model represents standard cash-flows for different silvicultural regimes and allows other factors to be varied such as chip price and government subsidy level. Output from the model is in three forms: discounted cash flows (DCF), equivalent annual values (EAV) and gross margins (GM).

Discounted cash flow analysis was chosen to reflect the long term nature of forest enterprises and the unevenness of the cash-flow in establishment years. It is a common tool used to study the economics of SRC (Mitchell *et al.,* 1993, Thurhollow, 1994), and to compare agricultural returns with single-stem poplar and agroforestry systems (Willis *et al*., 1993). DCFs are suitable for long term projects where it is necessary to even out irregular cash flows over several years and to allow for the progressive reduction in the value of future cash flows.

EAVs are annuitised NPVs, whereby an annual average of the NPV is derived. This measure has the advantage of allowing for variable cash flows, as in NPV, but is more readily comparable with an annual GM figure for competing enterprises. For comparison, values of NPV and EAV for sheep production over 25 years have also been calculated.

Gross margins for SRC were determined for comparison with figures for other agricultural enterprises such as sheep and cattle production. GMs are commonly used in livestock farming to reflect the farmer’s margin over variable costs for a specific enterprise in a typical year, and are based on average annual income and expenditure (variable cost) figures. Variable costs are those which can most readily be allocated to a single enterprise and which vary directly with the scale of that enterprise. In the context of SRC with its irregular cash flows over several years, once-only expenditure items such as establishment costs are annuitised over the life of the crop (25 years) to reflect the total investment as an annual cost item, so that a GM can be prepared.

Assumptions.
For comparability all figures in the model are calculated for one hectare although when determining economies of scale it was assumed that 10% of the mean size of hill farm, 15 ha, would be planted (Welsh Office, 1997).

If only 10% of the farm were put over to SRC, fixed costs of the current farming enterprises such as sheep production would not change to any great extent. All costs relating to the SRC enterprise are considered variable, including contract labour, which was charged at a rate of £4.47 hr^{-1} (Nix, 1999).

The duration of the analysis was chosen as 25 years as that is the expected life of the SRC stools (Britt *et al*., 1995). No allowance has been included for removal of the coppice stools at the end of the 25 year rotation. Complete mechanical removal can be costly (£800/ha) but the plants can be killed cheaply with herbicide, after which they quickly rot, enabling the site to be re-used after ploughing.

For gross margin calculations, establishment costs were annuitised at rates of both 6% and 8%, the latter being comparable to the 7.9% rate which the Agricultural Mortgage Company charges on a 25 year fixed rate loan. For the DCFs and EAVs a discount rate of 6% was used, being that used by the main forestry investment companies in Britain (Tilhill Economic Forestry Group).

Although the chips would be sold as fresh weight, all figures are quoted in oven dry tonnes (odt), this being the standard in the industry. Generally willow has a moisture content of approximately 50%.

Production Scenarios.
Two production scenarios were considered, the independent farmer and an ‘agency’. It has been suggested that rather than a farmer independently growing SRC and selling it to a power company, an agency would have responsibility for growing and harvesting the crop. A successful system is currently running in Yorkshire as part of the ARBRE project (see Section 1.2.3.5), with the agency owning and operating the power plant. The farmer is responsible for ground preparation and ARBRE for rabbit fencing (if needed), planting, post planting weed control, cut-back and harvest. The farmer is paid £20 odt$^{-1.}$ However to provide an annual income he receives an annual fee of £110 ha^{-1}, and this is deducted from the harvest payment (Hilton, 2000).

The analysis is presented in two forms, a farmer growing SRC independently and also via an ‘agency’. The role of the agency would be similar to that presented by the ARBRE project (Table 3). The agency’s income is not considered as it was assumed to be derived from the sale of electricity by the power plant.

For the independent farmer scenario, in order to provide the farmer with annual incomes, the model assumes planting will be on a sustained yield system, that is to have as many areas of coppice as there are years in the rotation. Each year the oldest stools are harvested. The analysis used a four year rotation which is likely to maximise yields on upland sites in Wales (Heaton, 2000), so the model is designed with a quarter of a hectare planted each year for four years. In years one, two and three the farmer will still have sheep on the areas yet to be planted, and the income from this has been included in the DCF.

Table 3 The roles of the agency and the farmer in the SRC ‘agency’ scenario.

Farmer	**Agency**
Costs: Pre-planting herbicide and labour Power harrowing Lime Pre-emergent herbicide and labour	**Costs:** Planting material and labour Post-planting herbicide and labour Harvesting costs and delivery to power plant Annual interim payment (£110 ha^{-1}) Harvest payment (£20 odt^{-1} less interim payments)
Benefits: Annual interim payment (£110 ha^{-1}) Harvest payment (£20 odt^{-1} less interim payments)	**Benefits:** Control over supply of chips for power generation

Subsidy
The only grant applicable to SRC in the uplands is the Woodland Grant Scheme (WGS), currently set at £600 ha^{-1}, payable in establishment year only, and this is due to end in 2000. As no alternative scheme has been announced to replace WGS after this year the analysis

has been carried out using no subsidies, and also with an initial grant of £1000 ha^{-1} which approximates to 40% of establishment costs. Note that ARBRE plantings are subject to a locational supplement under the Woodland Grant Scheme and thus receive £1000 ha^{-1} in establishment year. Of this, the farmer receives £367 and ARBRE the remaining two-thirds.

1.2.5.2 SRC cash-flow data (table 4).

Site Preparation
No fencing costs have been included as it has been our experience that the farmer will use one of his existing fields. Rabbit fencing may be needed, on some sites, and cost is dependant on the number and size of field boundaries protected. Current costs of rabbit fencing are approximately £1.50 - £2.50 m^{-1} (Nix, 1999).

Complete weed control before and during the establishment year is essential (Mitchell *et al*., 1995; Armstrong, 1999), but the extent of weed competition varies between sites and is likely to be less severe in upland sites (Heaton, 2000). In this study we have included the costs of full weed control and ground preparation, including initial weed clearance using herbicide (glyphosate), power harrowing and treatment of re-growth of weeds. A pre-emergent herbicide (e.g. propyzimide) should be applied prior to planting.

Planting and cut-back.
Planting cuttings at a relatively high density of 20 000 ha^{-1} is assumed here. A Nelder spacing trial in upland Wales showed best establishment to be at a density of 22 000 ha^{-1} (Hodson, 1995), and other upland trials have used 20 000 ha^{-1} (Heaton, 2000). Earlier trials in the U.K. for ETSU (Mitchell *et al*., 1995) and by the FCRA (Forestry Commission, 1995) used 10 000 ha^{-1}. Higher densities are now recommended, as recent research has shown higher yields to be obtained at 15 000 and 17 777 ha^{-1} (Armstrong & Johns, 1997; Armstrong, 1999). Planting under the ARBRE scheme is at 17 777 ha^{-1}. Despite the higher costs of the cuttings, planting at higher densities results in site capture being achieved earlier in the rotation. Planting material is bought from a reputable supplier: a cost of 8p per cutting is typical for older varieties of willow and poplar. New varieties recently available from Sweden attract plant breeder's royalties, resulting in higher prices and are currently in limited supply, although this situation is likely to change in the future. Trials are in progress in mid Wales to assess the yields from these new varieties in the upland context.

Planting was assumed to be by a contractor using the tractor-mounted Catkin planter which works well in wet conditions (ETSU, 1997). An alternative 'lay-flat' planting system now under trial involves setting whole stems horizontally into the soil at a depth of a few cm along a continuous row. A double row spacing of 0.75m and 1.8m between the paired rows results in 7600m length of planting per ha. The resultant shoot density from this linear system is not yet known, but establishment success appears to be good. The costs of purchasing whole-stems for planting should be similar per hectare as for the short cuttings.

The model assumes that the stems are cut back to ground level at the end of the first year to produce the stool, using manual brush-cutters and stacking the produce at ride-side. It is unlikely that after one year the 'cut-back' shoots will be of a large enough diameter for use in cuttings, and recent studies have shown that cutting back does not always result in more shoots per stool, casting doubt on the whole procedure (Heaton, 2000).

Fertilisation and liming.
Fertilisation with organic fertiliser, such as sewage sludge and cattle slurry has been shown to more than double yield (Heaton, 2000; Hodson, 1995). An application cost for this has been included, and it is assumed that the agency will pay for this as is the case for ARBRE.

Willow grows best in soils with a pH in the range of 5.5 - 6.5 (Britt *et al.,* 1995), and many sites in upland Wales on acidic soils will benefit from liming. As this is carried out before planting the cost has been allocated to the farmer in the agency scenario.

Management

A cost is included to apply herbicide after the first rotation harvest so the new shoots are not competing for moisture or nutrients. By the second rotation the stools should be well established and the new shoots outgrow any weeds.

Harvesting
Harvesting is assumed to be by the Claas modified forage harvester, which harvests the coppice stems through a head developed from a sugar cane version. The cut stems are chipped directly into a hitched tractor trailer unit. Transporting chips is less bulky than bundled wood and so more economical to handle. Storage of wet chips can be a problem but it is assumed that the power plant will have these facilities and use waste heat to dry the chips. The harvesting cost is that which a contractor is likely to charge (LRZ, 1993).

Table 4 SRC cash-flow data.

Operation	Unit Cost (£)	Source
Establishment		
Pre-planting herbicide	18 ha^{-1}	Nix, 1999
Labour	6.70 ha^{-1}	Nix, 1999
Disc harrowing	19 ha^{-1}	Nix, 1999
Lime	169 ha^{-1}	Jones, *pers. comm*.
Manure application	40 ha^{-1}	Nix, 1999
Planting material	0.08 cutting	Hill, *pers. comm.*
Labour	182 ha^{-1}	ETSU, 1997
Post-planting herbicide	15 ha^{-1}	Nix, 1999
Labour	6.70 ha^{-1}	Nix, 1999
Pre-emergence herbicide	35 ha^{-1}	Nix, 1999
Labour	6.70 ha^{-1}	Nix, 1999
Cut-back	70 ha^{-1}	ETSU, 1996
Management		
Pre-emergence herbicide	35 ha^{-1}	Nix, 1999
Labour	6.70 ha^{-1}	Nix, 1999
Harvesting		
Cut and chip	6.79 odt^{-1}	LRZ, 1995

1.2.5.3 Variables used in sensitivity analysis (Table 5).

Predicted yield.
The analysis includes yields for SRC between 6 and 12 odt ha^{-1} yr^{-1} to reflect the range of yields expected under the wide range of site conditions in Wales (Section 1.2.1.2).

The maximum mean annual increment has been shown to be achieved on a four- to five-year rotation. There is also an increase in annual increment in the second and third rotations and this was reflected in the DCFs and EAVs by increasing the output by 10% for the second rotation, and a further 10% for the third and successive rotations. It is not known if the stools die back and produce less yield towards the end of their lives, so such a parameter could not be included. This increment was excluded from the GM calculation to prevent over-complication.

Delivery
Delivery costs vary according to the distance the chips are being transported. Four distances were considered, 10, 20, 30 and 40 miles, 40 being the maximum distance ARBRE consider to be economic. Figures were obtained from BSW Sawmills (Balfour, *pers. comm*.).

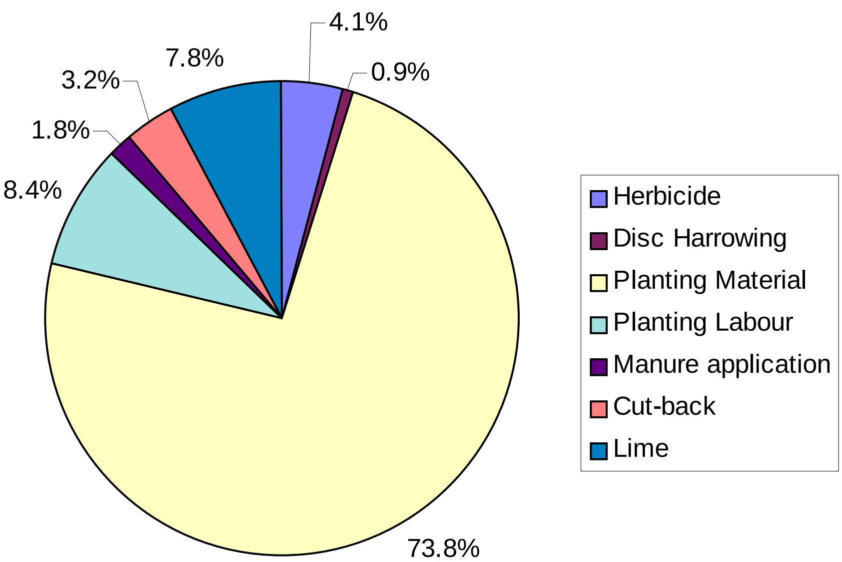
Chip price
Estimates of potential chip price range from £24 to £40 odt^{-1} (McPherson, 1995; LRZ, 1993; Billings, *pers. comm.*) and so three chip prices were chosen for this study, £30, £35 and £40 odt^{-1} (low, medium and high). Although the chips are sold green all figures are based on oven dry tonnes (odt).

Table 5 SRC Sensitivity Analysis Variables

Variable	**Rate**		**Source**
Yield	6, 8, 10, 12 odt ha^{-1} yr^{-1}.		Heaton, 2000; Hodson, 1995.
Delivery	0-10 miles	£3.87/tonne	Balfour, *pers. comm*. (BSW)
	11-20 miles	£4.44/tonne	
	21-30 miles	£5.23/tonne	
	31-40 miles	£5.96/tonne	
Chip Price	£30, £35, £40 odt^{-1}		LRZ, 1993; McPherson, 1995.

1.2.5.4 Establishment Costs

Figure 3 Breakdown of establishment costs for SRC.



Independent Farmer scenario:

Total establishment costs, presented in table 4 and figure 3, come to £2168.16 a hectare. This would be spread over four years if the farmer planted on a sustained yield system. When annuitised over 25 years (the expected life of the crop), for GM calculation this results in an annual figure of £169.12 at 6% or £203.80 at 8%.

The greatest cost, £1600, is plant material. This cost is likely to increase if modern varieties are planted which incur plant breeders' royalties. A farmer may be able to use the 'cut-back' shoots from the first year as cutting material, but on poorer sites these may not be of sufficient diameter, and again royalties would have to be paid.

Agency scenario:
Under the agency scenario, the farmer would pay for pre-planting and pre-emergent herbicide application, power harrowing, and liming, totalling £254.40. When annuitised over 25 years (the expected life of the crop), for GM calculation this results in an annual figure of £19.84 at 6% or £23.91 at 8%.

1.2.5.5 Results from Discounted Cash Flow and Equivalent Annual Value analysis.

Independent Farmer scenario.

A sensitivity analysis was carried out on the influence of transport distance, chip price and yield on the NPV (£ ha^{-1}) of SRC over 25 years (Table 6) and these figures are converted into EAV (Table 7). The model assumes that sheep subsidies (HLCA, SAPS) will be paid on the area unplanted and under sheep production in the 3 start up years.

Table 6 NPV (£ ha^{-1}) of SRC over 25 years.

(a) Chip Price: £30 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	Transport distance (miles)

	10	20	30	40
6	-85.71	-124.59	-178.48	-228.27
8	361.49	309.42	237.27	170.59
10	793.80	729.00	639.19	556.19
12	1233.60	1155.80	1048.00	948.42

(b) Chip Price: £35 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	255.37	216.48	162.59	112.80
8	818.17	766.11	693.95	627.28
10	1362.30	1297.50	1207.60	1124.60
12	1915.70	1837.90	1730.20	1630.60

(c) Chip Price: £40 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	596.44	557.56	503.67	453.87
8	1274.90	1222.80	1150.60	1084.00
10	1930.70	1865.90	1776.10	1693.10
12	2597.80	2520.10	2412.30	2312.70

Table 7 EAV (£ ha^{-1}) of SRC over 25 years.

(a) Chip Price: £30 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	-6.71	-9.75	-13.96	-17.86
8	28.28	24.20	18.56	13.34
10	62.10	57.03	50.00	43.51
12	96.50	90.41	81.98	74.19

(b) Chip Price: £35 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	19.98	16.94	12.72	8.82
8	64.00	59.93	54.29	49.07
10	106.57	101.50	94.47	87.97
12	149.86	143.77	135.35	127.56

(c) Chip Price: £40 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	46.66	43.62	39.40	35.51
8	99.73	95.66	90.01	84.80
10	151.03	145.96	138.94	132.45
12	203.22	197.14	188.71	180.92

Agency scenario.

Selected output from the analysis model is presented in figures 4 and 5 and table 8. The model assumes an interim payment of £110 ha^{-1} and harvest payments in years 4 (*i.e*. after four years of interim payments) and then every 4 years (with three years of interim payments in between). Four harvest yields are considered, ranging from 6- 12 odt ha^{-1} yr^{-1}.

Figure 4 Discounted cumulative cash-flow of farmers SRC income under 'agency' scenario, assuming an interim payment of £110 ha^{-1} and yields ranging from 6- 12 odt ha^{-1} yr^{-1}.

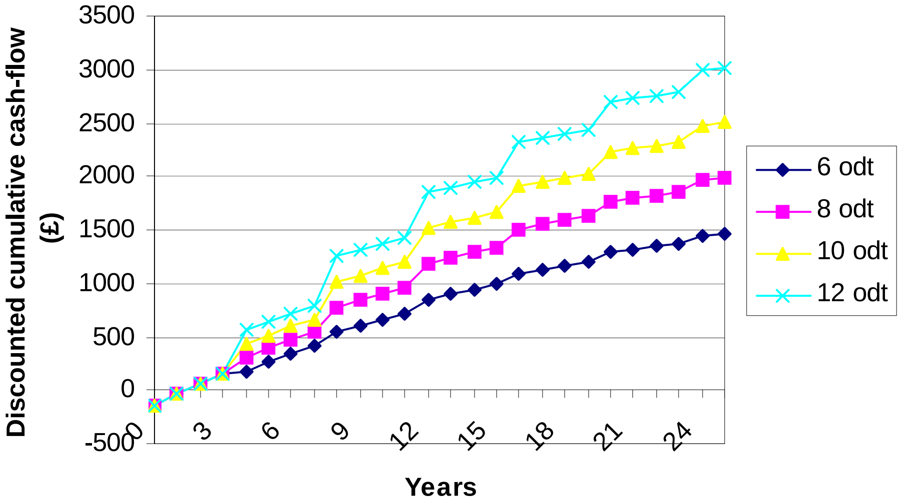
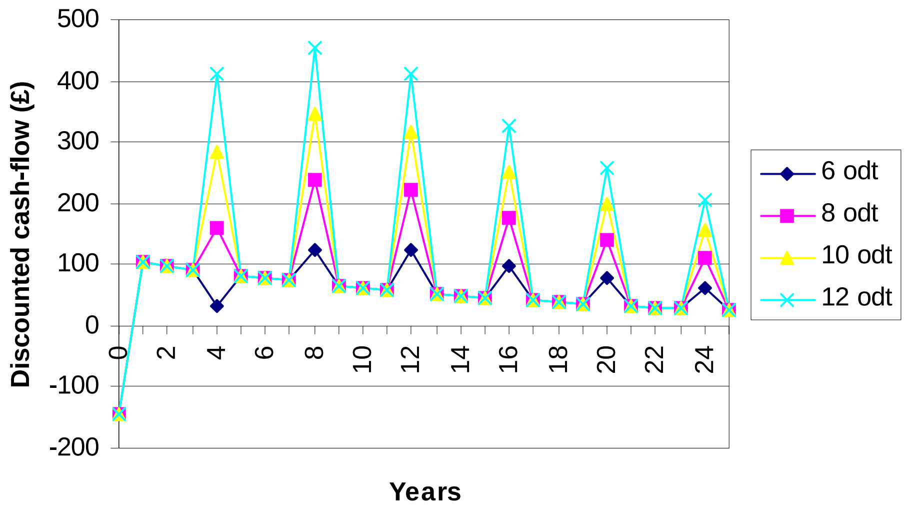


Figure 5 Discounted cash-flow to farmer with an agency paying £110 ha^{-1} interim payment.

Figure 5 shows that the payment of £110 ha^{-1} per annum provides a positive cash flow in the



years between the harvest peaks. It also shows the extreme variation in cash flow depending on yield. These graphed results are summarised in figures below

Table 8 Net Present Values (NPV) and Equivalent Annual Values (EAV) of the farmer's income in conjunction with an agency.

Production (odt ha^{-1} yr^{-1})	NPV (£)	EAV (£ yr^{-1})
6	1289.36	100.86
8	1748.38	136.77
10	2207.41	172.68
12	2666.43	208.59

Discussion.
For comparison with these figures, sheep production over 25 years gave a NPV of £3238.95 (EAV of £253.37). Even with an agency contributing towards establishment costs the NPVs and EAVs for SRC are considerably lower (Tables 6, 7 & 8). However, the values for sheep production drop to NPV £247.69 (EAV £19.38) if sheep subsidies are removed.

For both scenarios yield has a large influence on discounted income. This is evident from the first harvest onward (Figure 4). There is a clear need to optimise yield, through the choice of suitable sites, planting material and fertilisation. Farmers with poorer ground will find SRC less profitable. For the independent farmer, transport costs also have an impact on income, although this is less evident at higher production rates (Table 6 & 7).

Figure 5 highlights the unevenness of the cash-flow under an agency scenario. If a farmer produces only 6 odt ha^{-1} yr^{-1} then in year 4 he will receive a smaller income than in previous years, indicating that in areas of low production a lower interim payment may be needed (the agency could not afford to smooth cash flow in this way and to this extent if output in harvest years was low). For productions of 8 odt ha^{-1} yr^{-1} and more the cash-flow is also uneven. To even out the cash-flow an interim payment indexed to yield could be paid, but predicting yield in future rotations is prone to error (Heaton, 2000). Additionally, if high yields are predicted and a farmer received higher interim payments and then the crop were to fail due to unforeseen circumstances such as rabbit/hare damage, rust/insect attack then problems could arise with the farmer owing the agency money. Interim payments from an agency must therefore be modest in relation to expected crop output.

1.2.5.6 Results for Gross Margin approach.

Independent Farmer scenario:
In the first rotation there will be an income from the sheep on the unplanted land, although this will decrease each year until zero in year 4. Thus for simplicity a GM for the second and subsequent rotations only has been determined. These figures represent annual GMs for the farmer, assuming a rotational harvest of one quarter of the planted area each year. Calculation of the components of a GM is illustrated for the case of a yield of 8 odt ha^{-1} yr^{-1} over a four year rotation, a chip price of £35 odt^{-1} and a transport distance of 20 miles, with establishment costs annuitised at 6% and 8%:-

	Annuitisation rate	6%	8 %
Outputs:	Sale of wood chips (8 odt ha^{-1} yr^{-1} @ £35) odt^{-1})	£280	£280
Variable Costs:	Annuitised establishment costs	£169.12	£203.80
	Harvesting (8 odt @ £6.96 odt^{-1})	£54.32	£54.32
	Delivery (8 odt @ £4.44 odt^{-1})	£35.52	£35.52
Total Variable Costs:		£258.96	£293.64
Total Gross Margin:		**£21.04**	**-£13.64**

The GM figures for the independent farmer are sensitive to the rate of annuitisation used but are close to break-even without subsidy. For SRC, GMs are thought to be less reliable than EAVs (Section 1.2.5.1), the relevant EAV (8 odt ha^{-1} yr^{-1}, £35 odt^{-1}, and 20 miles) being larger, at £59.93 (Table 7).

Sensitivity Analysis:
A sensitivity analysis for the influence of transport distance, chip price and yield on GM ha^{-1} is shown in Tables 9 & 10 with establishment costs annuitised at 6% and 8% respectively.

Table 9 Independent Farmer Scenario: Gross Margin (£ ha^{-1}) for the second and subsequent SRC rotations, with establishment costs annuitised at 6%

(a) Chip Price: £30 odt ha^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	-53.07	-56.49	-61.23	-65.61
8	-14.39	-18.95	-25.27	-31.11
10	24.29	18.59	10.69	3.39
12	62.97	56.13	46.65	37.89

(b) Chip Price: £35 odt ha^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	-23.07	-26.49	-31.23	-35.61
8	25.61	21.05	14.73	8.89
10	74.29	68.59	60.69	53.39
12	122.97	116.13	106.65	97.89

(c) Chip Price: £40 odt ha^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	6.93	3.51	-1.23	-5.61
8	65.61	61.05	54.73	48.89
10	124.29	118.59	110.69	103.39
12	182.97	176.13	166.65	157.89

Table 10 Independent Farmer Scenario: Gross Margin (£ ha^{-1}) for the second and subsequent SRC rotations, with establishment costs annuitised at 8%

(a) Chip Price: £30 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	-87.76	-91.18	-95.92	-100.30
8	-49.08	-53.64	-59.96	-65.80
10	-10.40	-16.10	-24.00	-31.30
12	-28.28	-21.44	-11.96	-3.20

(b) Chip Price: £35 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	-57.76	-61.18	-65.92	-70.30
8	-9.08	-13.64	-19.96	-25.80
10	39.60	33.90	26.00	18.70
12	88.28	81.44	71.96	63.20

(c) Chip Price: £40 odt^{-1}

Yield (odt ha^{-1} yr^{-1})	**Transport distance (miles)**			
	10	**20**	**30**	**40**
6	-27.76	-31.18	-35.92	-40.30
8	30.92	26.36	20.04	14.20
10	89.60	83.90	76.00	68.70
12	148.28	141.44	131.96	123.20

Agency scenario:
Assuming a yield of 8 odt ha^{-1} yr^{-1} over a four year rotation, the GM to the farmer in the harvest year (every 4th year) would be, with establishment costs annuitised at either 6% or 8%:

	Annuitisation rate	6%	8%
Outputs:	Sale of wood chips (9 odt @ £35 odt^{-1})	£310	£310
Variable Costs:	Annuitised establishment costs	£19.84	£23.91
Total Gross Margin:		**£290.16**	**£286.09**

And between harvests (each of 3 preceeding years):

	Annuitisation rate	6%	8%
Outputs:	Interim annual payment	£110	£110
Variable Costs:	Annuitised establishment costs	£19.84	£23.91
Total Gross Margin:		**£90.16**	**£86.09**

A weighted average GM over the 4 years of the rotation at 8 odt ha^{-1} yr^{-1} is £140 (at 6%) or £136 (at 8%). In this case the influence of annuitisation rate is negligible, as the farmer incurs little of the establishment costs.

Sensitivity Analysis:

Table 11 Influence of yield on GM to the farmer (agency approach), with establishment costs annuitised at either 6% or 8%:

Yield (odt ha^{-1} yr^{-1})	**Gross Margin (£) per hectare in harvest year**	
	6%	8%
6	130.16	126.09
8	290.16	286.09
10	450.16	446.09
12	610.16	606.09

Gross Margins for sheep production:

For comparison with these figures obtained for SRC, a GM ha^{-1} for sheep production in Wales on partially improved, enclosed pasture at a stocking density of 7 sheep ha^{-1} is shown (source: Farming & Rural Conservation Agency). GM figures are normally quoted per head (Nix, 1999). For comparison with SRC production to an area basis, it is necessary to convert them to an area basis, which requires an assumption of stocking density. We have assumed 7 ewes ha^{-1} to be typical of the areas of land likely to become available for growing SRC. GMs for livestock farming are based on annual average income and expenditure figures per hectare.

		£ per Ha
Outputs:	Lamb sales	£106.19
	Draft and cull ewe sales	£14.00
	Wool	£4.55
	SAPS (7 @ £22.5/head)	£157.50
	HLCA (£8.5/head)	£59.50
Variable Costs:	Total feed and forage	£42
	Other costs	£56
	Flock replacements	£8.75
Total Gross Margin:		**£234.99**
Without subsidy:		**£17.99**

Scottish Agricultural College figures for Upland Breeding Ewes are similar with GM ha^{-1} of £215 with subsidies and -£15 ha^{-1} without subsidies in 1999. GM figures for sheep depend strongly on the stocking density, itself related to the A.L.C. grade, or other designation. For upland hill sheep on semi-natural rough grazing, a lower value of GM of £115 is given, reflecting lower stocking rates under the ESA scheme (1.5 sheep ha^{-1}), despite additional income from ESA payments. (source: ADAS Pwllpeiran).

For comparison, EAVs for sheep production were £253.37 with, and £19.38 without subsidy.

Gross Margins for Upland Suckler Cows:

Assumptions:

- Spring calving cows, selling weaned calves at October sales.
- Upland situation: 0.34 Ha grazing and 0.21 Ha silage per cow and calf, silage based winter ration for cows, small quantity creep feed to calves in month prior to sale.
- Outwintered or cubicle housing. Minimal straw purchases.
- 94% calf weaning rate.
- Approximately 2000 subsidy rates. No agri-monetary compensation added

			£/cow
Outputs:	Calf Sales Steers 259 kg @ 113p		
	Heifers 241 kg @ 96p		**271**
	Suckler Cow Premium		**110**
	Hill Livestock Compensatory Allowance (SDA rate)		**73**

			454
Less:	Replacement Animal Share	Cow	**40**
		Bull	**9**

			405
Variable Costs:			
	Barley and minerals 100 kg @ £90/t		**9**
	Calf Concentrate 30 kg @ £165/t		**5**
	Vet & Medicines		**17**
	Sundry Stock Expenses (marketing, haulage		**13**

			44
	Forage Variable Costs (share of establishment, ferts, contract)		
	Silage 0.2 ha @ £142/ha		**30**
	Grazing 0.3 ha @ £90/ha		**31**

			61
Total Variable Costs			**105**

GROSS MARGIN			**300**
Gross Margin per Forage Hectare			**545**
Gross Margin without subsidy			**213**

Note: No costs included for labour, buildings, machinery and finance. These will all tend to be higher than for a sheep enterprise utilising the same forage area.

Discussion:

In the **independent farmer scenario** the GMs obtained from SRC without subsidy (Table 9 & 10, maximum value £182.97), even under the best scenario considered, are considerably less than currently available from sheep or cattle production. The effect of including a subsidy towards establishment costs is considered below (Section 1.2.5.7).

In the **agency scenario**, at yields of 8 odt ha^{-1} yr^{-1} or more, the GM in the harvest year exceeds that obtainable from sheep production, whereas the GM in interim years is much less, being 38% (or 36%) of that for sheep. This uneven-ness in cash-flow was highlighted in the discounted cash-flow figures previously discussed (Section 1.2.5.5). The 4-year weighted average GM (£140) is 60% of that available from sheep production.

Assessment:
Independent Farmer scenario:
The GM arising from SRC is highly dependent upon the yield obtained and on the chip price paid by the market (electricity generator, heating plant, etc), but less sensitive to the location (transport distance). The modelled results suggest that, unless subsidy is provided or unless there is a further reduction in levels of sheep support, SRC is likely to be attractive only on the most suitable growing sites (Section 1.2.1.2), where yields of 10-12 odt ha^{-1} yr^{-1} can be achieved.

Agency scenario:
The GM arising from SRC is, again, highly dependent upon the yield obtained. A weighted average GM over 4 years at 8 odt ha^{-1} yr^{-1} is £140 ha^{-1} (60% of the GM obtained from sheep at current levels of subsidy). If the current level of sheep subsidy (£217 ha^{-1}) is added to the GM for SRC, this gives a subsidised GM of £357 (over 150% of subsidised sheep GM). Hence the future of SRC will depend on relative levels of subsidies applied to the two competing sectors. As noted above, sheep subsidies are, in general, declining: SAPS rate has dropped by £4.50 per head in the past two months. Less than half the level of the quoted sheep subsidy (£95 ha^{-1}) would need to be paid to farmers (on the agency model) to equate the GMs of the two sectors, assuming a yield of only 8 odt ha^{-1} yr^{-1}. Hence SRC may be feasible also on the poorer growing land, where lower yields (6-8 odt ha^{-1} yr^{-1}) are assumed.

1.2.5.7 Subsidy Payment for SRC

The influence of a £1000 ha^{-1} establishment grant, paid to the independent farmer in the establishment year is analysed. This level of subsidy equates to approximately 40-45% of the establishment costs. The independent farmer approach only has been used to show the economic impact of subsidy. If the agency scenario were modelled, the subsidy would most likely be split between the agency and the farmer. In the case of ARBRE, approximately one-third of the establishment grant is paid to the farmer (£367 ha^{-1}).

(i) Discounted cash-flow and EAV– Independent Farmer Scenario:
As before, this assumes that a quarter of a hectare would be planted each year for four years, and thus a grant of £250 paid each year.

Sensitivity Analysis:
The influence of yield and chip price with a £1000 establishment grant:

Table 12 NPV (£ ha^{-1}) of SRC over 25 years, 20 miles transport distance. (Compare with Table 6:a,b,c; 20 mile column)

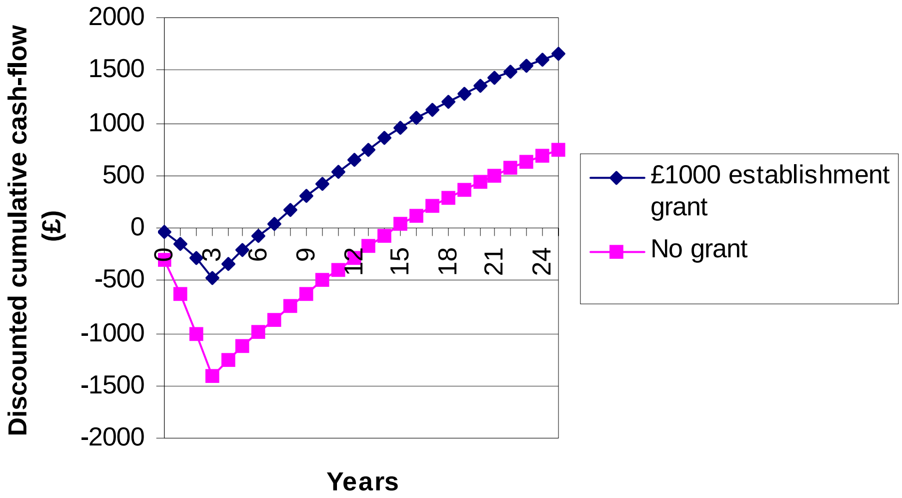
Yield (odt ha^{-1} yr^{-1})	Chip price (£ odt^{-1})		
	30	**35**	**40**
6	767.68	1108.80	1449.80
8	1201.70	1658.40	2115.10
10	1621.30	2189.70	2758.20
12	2048.10	2730.10	3412.40

Table 13 **EAV (£ ha^{-1}) of SRC over 25 years, 20 miles transport distance. (Compare with Table 7:a,b,c; 20 mile column)**

Yield (odt ha^{-1} yr^{-1})	Chip price (£ odt^{-1})		
	30	35	40
6	60.053	86.738	113.413
8	94.005	129.731	165.457
10	126.829	171.293	215.765
12	160.216	213.567	266.941

For the independent farmer receiving establishment subsidy, NPVs and EAVs at the highest yield and chip price exceed those for subsidised sheep production (£235 ha-^{1}). Cash flows for SRC with and without subsidy are compared in Figure 6. With subsidy, break-even occurs after half the number of years required for the non-subsidised case.

Figure 6: Impact of £1000 establishment grant on cumulative DCF break-even.



(ii) Gross Margins – Independent Farmer Scenario:

Sensitivity Analysis:
GMs shows the farmer's annual margin, assuming a quarter of a hectare is harvested each year.

Table 14 Gorss Margin with £1000 establishment grant

Yield (odt ha^{-1} yr^{-1})	Chip price (£ odt^{-1})		
	30	35	40
6	21.50	51.50	81.50
8	81.50	121.50	161.50
10	141.50	191.50	241.50
12	201.50	261.50	321.50

For the independent farmer receiving establishment subsidy, GMs at higher yields and chip prices are closer to, or exceed GMs for subsidised sheep production (£235 ha^{-1}).

(iii) Conclusion

We can conclude that the economic viability of SRC is strongly influenced by the start-up costs and hence the availability of grant assistance for planting costs.

1.2.5.8 Machinery Costs

The two major pieces of specialist equipment used in SRC production are planting and harvesting machines. The prices used in this model come from extensive studies of machine purchase prices and depreciation and are the likely contractor rate.

Studies of the operating and capital costs of recently developed planting and harvesting machines are not available, but the following data were taken from a study carried out by the Forestry Commission (Anon, 1995a; Anon, 1995b):

Table 15 SRC Machinery Costs

Harvesting Machine	**Capital Cost**	**Operating cost hour^{-1}**
Claas 965	£151500	£60.92
Claas header to fit forage harvester	£30000	£60.92
John Deere	£148595	£48.99
Salix Maskiner	£40000	£15.00
Empire 2000	£90000	£47.75

Planting Machine	**Capital Cost**	**Operating cost hour^{-1}**
Austoft	£9600	£22.87
Salix Maskiner Step Planter	£25000	£37.07
Super Prefer UT	£2620	£26.06
Catkin	£3000	£26.21

1.2.6 Impact of SRC on the environment of Wales.

The introduction of SRC to former pasture areas in Wales, both upland and lowland, will change both the conservation value and landscape of the environment. Good practice guidelines have been produced by the DTI, regarding plantation situation, design and planning issues for SRC in the lowland landscape (DTI, 1996). Many of those guidelines will also apply in the uplands. Extensive work on the impact of SRC on the wildlife habitat has been carried out (Hodson, 1995; Sage, 1998; Slater *et al*., 1998).

1.2.6.1 Conservation value.

The presence of SRC is generally considered to lead to an increase in the diversity of plants and insects (Sage, 1998; Slater *et al*., 1998). Areas of special conservation interest should be avoided in any SRC planting plan. If SRC is to become grant-aided in future, conditions for granting of subsidy should include an assessment of the conservation status of proposed sites. Vegetation communities on partially improved upland pastures suitable for SRC, typically have low floristic diversity and of little conservation interest. Although herbicide use is vital during the establishment phase of SRC the original ground flora has been found to return at only a slightly lower diversity in subsequent years (Hodson, 1995). Planting SRC results in a wide diversity of invertebrate fauna in the willow canopy, providing a rich food source for passerine birds. Additionally SRC is always at or near the peak age for coppice to support maximum bird diversity (Sage, 1998; Slater *et al*., 1998). SRC can also provide valuable cover for game birds, which themselves may provide an important additional source of income in some areas of Wales.

The influence of SRC on the ecology of the site will depend on what it has replaced, but generally if former sheep grazing land is planted, as Slater *et. al*, (1998) conclude “SRC could be a monoculture that actually adds to the ecological diversity of the uplands rather than detracting from it.”

1.2.6.2 Landscape.

It is important that future SRC plantations should not be visually intrusive. In the large-scale landscape of the uplands small plantings (up to 5ha) seem insignificant. If a farmer were to plant 10% of his land this would be, for the average upland farm, 15ha (Welsh Office, 1997). If planting is staggered over three or four years, in adjacent blocks, the visual impact is not likely to be great. In any grant-aid scheme, consideration could be given to the visual impact of proposed in the same way as, under the Woodland Grant Scheme, the Forestry Authority authorise planting in accordance with strict design guidelines, only supporting proposals which are sympathetic to the surrounding landscape (Forestry Commission, 1989). Further details on limiting the impact on the landscape are discussed in the Good Practice Guidelines for SRC (DTI, 1996).

1.2.7 Developing Energy Markets for SRC in Wales

Attempts to promote the production of SRC in rural Wales as an alternative enterprise for farmers cannot succeed unless parallel efforts are made to develop markets for the crop. Although markets currently exist for SRC products, the main potential for future expansion is seen to be in energy generation (Section 1.2.3). Energy markets in Wales are not restricted to particular locations and the land requirement for coppice wood production is potentially large. Hence, the impact of a novel bio-energy industry would be widespread throughout the country, with consequent benefits to widespread local economies. Parallel development of the supply and demand sides of the biomass-to-energy industry is vital in order to avoid creating a woodchip mountain, with consequent loss of confidence on the part of both supplier and consumer.

1.2.7.1 Energy policy and the statutory framework

The European dimension:
In response to international obligations, the European Commission (Anon, 1999a) has set a target to double the current level of energy generation from renewable sources to 12% by the year 2010. The Commission's White Paper "Campaign for Take-Off" gives a clear indication of the importance attached to promoting "renewable" energy in view of its contribution towards reduction in emissions of CO_2 and to greater efficiency of fuel-to-energy conversion through the use of new technology. Proposals include fiscal and financial measures applied *via* regional policy, structural funds, the Common Agricultural Policy and the Rural Development Policy. Each Member State and their devolved regions are expected to apply these measures to their own circumstances, and they will be required to draw up implementation plans for each energy sector. A target for biomass of 10,000 MW(thermal) capacity throughout the E.U. is given, comprising bio-power installations varying in scale from a few hundred kW to multi-MW.

The U.K.'s response:
In response to the Kyoto Protocol, the U.K. government is committed to a 20% reduction on 1990 levels in CO_2 emissions by 2010 (DETR, 2000). Energy from SRC is favoured as it is CO_2-neutral, that is, the growing crop sequesters the same amount of CO_2 as is released when it is burnt. The government's target of 10% of the U.K.'s electricity supplies from renewable sources would reduce carbon emissions by around 2.5 MtC in 2010. It is estimated that 125,000 ha of short rotation willow coppice could provide about a quarter of this target (DETR, 2000). In December 1999, the government announced its intention to comit £30 million of funding, in the form of establishment grants and other support, over the life of the Rural Development Regulation. The government recognises the importance of developing renewable souces of energy as part of a drive towards sustainable development and, in turn, The National Assembly of Wales has a duty under Section 121 of the Government of Wales Act 1999 to promote sustainable development. Renewable energy is already recognised as part of the national planning policy in Wales (Anon, 1999b; Anon, 1999c). Planning authorities must have regard to these documents in drawing up development plans and in exercising their development control responsibilities.

1.2.7.2 The changing energy industry in the U.K

New Electricity Trading Arrangements (NETA, Oct '1999) and the New Utilities Bill:
Electricity supply is undergoing reform, replacing the traditional wholesale market (the Pool), with competitive energy trading markets. One effect of these changes will be to favour "**Despatchable**" renewables (*e.g.* bio-energy, where production is under voluntary control and generation can be linked to demand), over "**Intermittent**" renewables (*e.g*. wind power, where timing/duration cannot be controlled). This difference will be reflected in a premium price for bio-energy relative to other renewables. Another effect is to favour "**embedded generation**" where the producer is closely linked to the consumer, in contrast to the traditional centralised generation and "long wire" distribution, with its consequent losses of power and higher costs. It is expected that local authorities will assume the role of both energy provider and consumer in local communities. Bio-energy plants are well suited for distributed generation with small locally-fuelled installations in rural areas, making use of new technologies such as gasification and CHP. A new bidding process between the suppliers (generating companies) and the distributors (the Grid network) will affect the relative prices paid for electricity from different renewable sources, to the disadvantage of wind power. This will act to close the gap between the current costs of generation; 5.5p per KWh from biomass; 2p per KWh from wind (Billings, *pers.comm*.).

The Climate Change Levy:
A 15% tax on all industrial and commercial users of energy (heat and electricity), with exemption for wood fuels will apply from April 2001. Local authorities, faced with a 15% increase in fuel bills, are now planning alternative supply strategies.

Market stimulation measures:
In a reformed electricity market the need for stimulation of renewables is recognised (DTI 1999). Options include:
- Economic instruments; taxes or emissions trading permits,
- Schemes to stimulate the market for renewable-sourced energy – obligation to provide funding for particular technologies,
- Direct grants – includes European Structural Fund, 5th Framework – support for demonstration projects.

In addition to government initiatives, consumer-led schemes such as Midlands Electricity Board's "Ever-Green" can provide funds for the development of "green" electricity capacity through a £5 voluntary annual donation added to the electricity bill. This mirrors a successful voluntary contributory scheme to fund green electricity projects in Hamburg (Beek, *pers. comm*.). Such "green" fund schemes could bring additional investment into Wales to be used as match funding to lever in E.U. funds.

Biomass-to-energy projects:

The economic viability of energy production from biomass is affected by the nature of the project and the source of fuel (Billings, *pers. comm.*):

- **Joint production of heat and power (CHP):** In conventional electricity production, heat is wasted (conversion efficiencies are typically only 40%). It is recognised that heat should be utilised on site by cooperating industries, *e.g*. glasshouses, institution heating, food processing. The U.K. government has set a target to double the capacity of CHP plants by 2010.
- **Integrated production of electricity:** Biomass jointly with gas production provides greater flexibility, with cost savings – *e.g*. BAGIT project - E.U. funded demonstration scheme.
- **Energy crops – a more reliable supply**: Energy crops are dedicated for long term production, whereas supplies of waste materials *e.g*. forest residuals and waste wood, typically fluctuate in quantity and are less dependable in quality.

Energy projects based on woodchip fuel differ in scale:

1. Large individual projects, *e.g.* the proposed power station at Newbridge on Wye, Powys.
2. Projects where individual investment is too small to be commercially attractive to investing/financing bodies on a project-by-project basis. A regional package of such projects providing economies of scale, *e.g.* a group of schools or a mixture of projects, could generate financial interest from, for example, investment companies seeking green investment opportunities.
3. Individual projects which cannot be grouped, requiring one-off grant support, *e.g.* WDA schemes currently proceeding (examples in Section 1.2.3.5).

1.2.7.3 SRC for energy production – key issues for Wales

Recent changes in the economic and policy climate in the UK (Section 1.2.7.2) will have profound impact on the developing energy market for renewables, in particular energy crops. Similar measures in the USA, such as a package of tax credits for using electricity from biomass, have been announced. Their effect will be to make energy markets more transparent and militate in favour of energy crops by making them more competitive and, by changing the long term business climate, to create real opportunities irrespective of NFFO.

The issues arising from these new policies and statutory instruments which will favour electricity and heat production from SRC in Wales may be summarised as:-

- CO_2 neutral (U.K. government's commitment to fossil fuel substitution).
- Exempt from the new Climate Change Levy.
- Consistent with U.K. government's stated aims on energy generation.
- Can contribute to targets for electricity generation from renewable sources (10% by 2010; 5% by 2003) and CO_2 reduction (20% by 2010).
- Consistent with European Commission's policy on use of bio-energy.
- Can contribute to regional targets required by U.K. government (devolved to N.A.W.).
- Biomass-to-energy schemes are consistent with local Agenda 21 – sustainable development strategies embody aspirations to improve the local environment and local industry.
- Local authorities and other public bodies are owners of public assets, *e.g.* schools, leisure centres, hospitals – their ongoing needs for refurbishment generate enhanced opportunities for conversion to biomass heating systems.
- Can contribute to diversification of farm enterprise, helping to maintain farmers on the land and long-term viability of rural life (such goals cannot be met solely by B & B and golf courses).
- Continuity and reliability of supply places woodfuel from SRC at a premium relative to wood wastes, which are typically variable in quality and supply. Pelleting of wood waste may overcome this, but at an increased cost.

These national targets pose a challenge for Wales and, at the same time, an opportunity to develop a new rural energy industry involving producers and consumers around the whole country.

1.2.7.4 Facilitating the bio-energy market – the role of ESCOs (Energy Supply Companies)

As electricity and gas become commodities, so Energy Supply Companies (Anon 1999d) are becoming increasingly interested in providing value-added energy services. This is a "win-win" situation, adding value to the product and improving service to the customer. For example, a school may wish to improve its thermal insulation and modernise its boiler. The ESCO would provide capital investment and service to the client, paid for by the local authority (*i.e.* 3rd party financing of energy efficiency). DETR is currently investing in ESCOs in England: Wales has yet to benefit from such initiatives. Such a consortium setting up biomass heating projects is South West Heat ltd, providing small scale heating packages for schools in the south west of England. Another such biomass ESCO group comprises ETP Ltd, Midlands electricity, LRZ Ltd and the Marches Energy Agency.

ESCOs can provide a mechanism to realise biomass heat-and–power projects. However, most of such schemes cannot offer currently more than £30 odt for woodchip, even with the climate change levy. Can woodchip production be commercially viable at a maximum price of £30 odt? From the preceeding discussion of economic models for woodchip supply (Section 1.2.5), it seems unlikely that individual farmers can supply at £30 because of the high investment costs incurred unless grant support is provided to cover such startup costs on an individual basis. An alternative scenario is to create commercial structures, which can act as local or regional investment channels to facilitate startup of local enterprises (see above Energy Agency Model).

IMPLICATIONS FOR GRANT AID OF THE ENERGY AGENCY MODEL

A commercial Energy Agency, in receipt of grant aid, would bear all the risks (crop failure, farmer relations, lack of market), but enters a long-term contract with farmers. Such a long term security of income would be a strong incentive to farmers to join the scheme, in view of the uncertain future for traditional livestock support payments. The Energy Agency model has the following advantages:

- The corporate business is insurable, unlike the individual farmer scale
- It can attract financial backers and partners
- It is based locally (creates local jobs and uses local skills)
- A variety of scales of production can contribute – small, distributed projects become big enough by grouping. At the same time it does not preclude an individual farmer contracting directly with a large project such as a regional power station.
- It enables a modular approach to SRC production.

1.2.7.5 Towards an implementation strategy

In order to make progress towards the promotion of biomass-energy projects there is an urgent need to:

- Assess the potential heat market in Wales – identify sites for feasible conversion to biomass and where individual projects could be packaged.
- Assess the economic viability of such projects and packages.
- Develop an Implementation Strategy.

We would argue that the supply side of SRC-biomass is potentially viable, especially if farmers' establishment costs are subsidised (Section 1.2.5.7). Equally, the market side needs to developed, otherwise the taxpayer may be providing subsidies to create a woodchip mountain. To avoid this it is essential to identify and exploit potential biomass heat markets in Wales. The priority mechanism to achieve this is likely to be grouping of projects using the ESCO model.

1.2.7.6 Employment opportunities in SRC/woodfuel supply

It is likely that, at best, the industry will sustain employment numbers in the region rather than creating new jobs. New employment opportunities will be created, however, for high quality skilled jobs. Hence, this would not create an employment boom, but counteract the current loss of jobs in rural areas, and some stimulation of indirect employment could occur. Some nationally quoted figures for job creation should be treated with caution in the context of Wales.

1.2.7.7 A model for developing a biomass heating market – Austria

Led by government decision, consistent with its declared environmental obligations, Austria (population 8 million) has been successful in creating a biomass heating market including promoting its own boiler-making and servicing industry and support services. As a result of this ambitious policy, Austria has become an exemplar in Europe in the commercial exploitation of biomass for heat and CHP, leading to:

- Environmental benefits.
- Increased balance of payments through reduced imports.
- Increased security and diversity of supply of energy.

1.2.7.8 The future for biomass-to-energy schemes in Wales

In view of the developing local energy projects in various areas of Wales (Section 1.2.3.5), many of which plan to use SRC crops, there is an apparent demand for "green" energy production. Such projects are likely to be replicated in the future as the cost of brown energy rises and the advantages of a more distributed system of electricity and heat production are felt. Rising market demands for biofuel must be matched by supply provision – farmers will need to be encouraged into SRC production by appropriate financial support, either directly or via purchasing contracts with energy supply agencies.

The potential “fit” of biomass-to-energy in Wales appears good in the context of a rural, decentralised and dispersed (low density) population. Small centres of population are well suitable for embedded generation of CHP from biomass rather than large-scale multi-MWe power stations, with local users of power and heat (in accord with regional planning targets). Such integrated developments avoid the wastage of heat arising as a by-product of large electricity-only stations, which are no longer acccepted on the continent. Planning controls, together with direct financial support from regional funds such as Objective 1 and Rural Development funds can contribute to promoting appropriate energy projects to the benefit of local industry and local communities. In the same way, rural communities in Wales would benefit through support to farmers targetted at a new industry producing short rotation energy coppice.

1.2.8 Strengths, Weaknesses, Opportunities & Threats (SWOT) for SRC

(Numbers in parentheses refer to report sections).

A SWOT analysis is presented here to bring together the key conclusions of this sectoral study.

Strengths

- Comparisons of annual Gross Margins between SRC with, and sheep without, subsidy where an agency is carrying the establishment costs shows that, at higher yields, Gross Margins for SRC exceed those for sheep (1.2.5.7).
- With an annual subsidy of £1000/ha towards the costs of establishment to an individual farmer, at the highest yields and chip prices, values of Net Present Value, Equivalent Annual Value and Gross Margin all exceed those for sheep with subsidy (1.2.5.7).
- SRC can be grown in upland, nutrient-poor soils considered to be agriculturally poor (A.L.C. grade 4), benefiting from greater water retention capacity and higher rainfall than on drier sites to the east of Wales (1.2.1.2).
- Organic fertiliser, *e.g*. sewage sludge, cattle slurry, can be used to increase yield and as a disposal route for the waste material (1.2.1.4).
- Ground preparation prior to planting can utilise farmers’ existing expertise and farm equipment (1.2.5.1).
- Problems arising from weed competition in the establishment phase of SRC are likely to be less severe in the uplands of Wales, leading to the need for less herbicide than in lowland sites, especially if planting at high shoot density (1.2.5.2).
- SRC plantations , in the context of former sheep grazing land, can increase biodiversity and provide a novel habitat for wildlife and game birds, as well as increasing landscape diversity (1.2.6).
- Production of woodfuel from SRC can contribute to U.K. targets for reduction of CO2, increased use of renewable energy and introduction of sustainable development (1.2.7.1).
- Locally produced energy from woodfuel in the form of heat and power is in keeping with the requirements of NETA and the New Utilities Bill and will be exempt from the impending climate change levy (1.2.7.2).
- Employment opportunities of SRC and bio-energy generation are predicted to sustain employment numbers and create high quality skilled jobs (1.2.7.6).

Weaknesses

- It is unlikely that average yields of SRC greater than 10 odt/ha/yr will occur in upland Wales, although some sites may produce considerably more (1.2.1.2).
- Poor demand, due to the currently poor state of development of the bio-energy industry, and the need for encouragement of new projects (1.2.1.3; 1.2.7).
- Lack of infrastructure to support management and marketing of the SRC crop (1.2.1.4).
- Lack of a subsidy scheme available to offset the high establishment costs of SRC (Woodland Grant Scheme ends in 2000), and arable set aside payments mostly do not apply in Wales (1.2.5.1).

- Site access by machinery in upland sites for planting and harvesting can be limited by wet weather, creating problems for scheduling of shared equipment (1.2.5.2).
- Comparison of cash flows between SRC and sheep production based on Net Present Values and Equivalent Annual Values shows SRC without subsidy to give considerably lower returns than sheep with subsidy, in both the individual farmer and agency scenarios (1.2.5.5).
- Comparison of annual Gross Margins between SRC without, and sheep with, subsidy shows SRC at a strong disadvantage for the independent farmer (1.2.5.6).

Opportunities

- Large land area potentially available to grow SRC in Wales, well distributed around the country (1.2.1.1).
- In Wales, a total of over half a million tonnes of wood fuel could be produced, if only 10% of the likely area were made available for SRC (1.2.1.2).
- Farmers, suffering reduced incomes from the depressed livestock industry, show some willingness to consider putting some of their land over to SRC as an opportunity to diversify into a non-food crop (1.2.2).
- Existing markets for willow products include planting material, river bank supports, wood chips and material for willow crafts, for which local sources of supply are, at present, limited (1.2.3).
- SRC, together with other wood sources, waste from forestry, farm woodlands and industry, could provide the feedstock for a new energy industry in Wales, comprising locally based heat and power projects (1.2.3.5; 1.2.7).
- Examples of planned projects for combined heat and power and local heating schemes indicate the pressure for change in the energy market in Wales (1.2.3.5).
- Management of SRC-to-energy projects may be most efficiently achieved by agencies, coordinating resources of the producers and exploiting economies of scale (1.2.4).
- Development of a new decentralised energy market, in line with government policy, depends on encouragement of local schemes, identifying local energy users through the facilitating role of Energy Service Companies, and given favourable bio-energy prices and favourable investment terms for such projects (1.2.7.4).
- The emerging bio-energy industry can develop alongside the rural production of SRC as a "green" fuel, to the benefit of farmers, local communities and industry in Wales (1,2,7.8).

Threats

- Poor establishment of the planted cuttings/stems could occur due to inadequate ground preparation, poor weed control or drought after planting, with severe financial consequences (1.2.1.4).
- Pest/disease (*e.g*. rust) attack may result in yield losses, but its impact is less likely to be severe if several varieties of willow and poplar are planted (1.2.1.4).
- Increasing farmers' willingness to plant SRC may require a promotion campaign and a scheme to offer financial assistance with startup costs (1.2.2; 1.2.5.7).
- Development of the supply (SRC production) and demand (energy consumption) sides should be in parallel to avoid imbalances and market instability (1.2.7.8).

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