BILLET HARVESTING, DRYING AND PROCESSING OF WILLOW SHORT ROTATION COPPICE FOR THE WOOD ENERGY MARKET IN THE UK

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SWS Forestry Services
Shinagh House
Bandon
Co Cork

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EXECUTIVE SUMMARY

One of the key challenges when growing SRC willow for the energy market is to develop an efficient fuel supply chain that is profitable for the grower and processor and that is competitive with traditional fuels such as oil and gas. As with any new venture it is anticipated that costs will be high in the early stages until the processes are demonstrated and become proven at scale. The Renewable Energy Growers Ltd. producer group is a model that could be replicated by farmers in Ireland. Increasing scale by working together will lead to efficiency improvements and cost reductions.

A high standard of site preparation is essential to maximise the yield and produce a uniform, easily managed crop. As willow is a long-term perennial crop, ensuring ideal conditions at establishment (i.e. weed free and deep cultivation) will reap benefits at first and subsequent harvest. Ideally SRC willow should be grown on medium textured soil which is aerated but still holds a good supply of moisture, such as clay or sandy loams. On average SRC willow produces a yield of 10-12 ODT/ha/yr.

End users generally require wood fuel in the form of wood chip. The wood chip needs to be dried to specific moisture content, typically 25-30%. Newly harvested willow has a moisture content of 50-55%.

The billet harvesting system is a low cost option, which enables the billets to be stored indefinitely to dry naturally. The billets can be stored in heaps in the headlands of the plantation, adjacent field or in a covered storage area. By using this system the company incur no drying cost; the air circulates through the spaces in the heap to dry the billets. Over summer drying can reduce the moisture content to 25%.

Renewable Energy Suppliers Ltd. main market is a nearby power plant – Cottam power station. The power station requires a very refined wood chip which is used as an additive to coal dust at the power station. The company have developed a unique large-scale processing unit that produces a very fine wood chip. The processing costs are approximately double the normal chipping costs for energy wood chip. To make the enterprise economic it was essential that there were no drying costs.

The visit shows that growing SRC willow is a viable proposition if the crop has a minimum yield of 8 ODT/ha/yr, there is an establishment grant (Energy Crop Scheme) and an Energy Payment. However, as stated at the beginning of this summary, costs are expected to be high until the operations and processing are developed further and there are greater economies of scale. In the event of a secure wood chip market in Ireland, returns to the farmer could be comparable with returns from traditional arable crops.

AIMS AND OBJECTIVES

The aim of the study visit was to investigate the "billet" harvesting system, natural drying technique and unique processing method developed by Renewable Energy Suppliers Ltd. for willow short rotation coppice (SRC).

If willow is to become a viable alternative for agricultural land in Ireland, it is important to:

1. Increase understanding and awareness relating to the growing of SRC willow;
2. Learn new and innovative husbandry techniques that could reduce the cost of production; and
3. Produce a high quality willow chip to meet market demands.

The profitability of SRC willow as an alternative land use and enterprise is dependent on the efficiency of the harvesting and processing systems. The model in this report was specifically designed to comply with the fuel requirements of market demands.

With the right knowledge and planning SRC willow has the potential to further enhance rural economies by diversifying incomes while at the same time encouraging sustainable development.

INTRODUCTION

Renewable Energy Suppliers Ltd. (RES Ltd.) was established as a result of the failed ARBRE (Arable Biomass Renewable Energy) project. ARBRE project was to be a flagship project in the UK and Europe. It was to be an 8MW gasification plant utilising combine cycle technology situated in Yorkshire on the site of an old power station. Both the DTI (Department of Trade and Industry) and the European Commission put in grant funding of £3M and £10M respectively with the remainder of the financing coming from private companies. The total cost of the project was estimated at £30M.

ARBRE was estimated to use 43,000 odt of wood chip per annum and was planned to utilise biomass fuels from two main sources: forestry residues and SRC. As a result farmers in a 30 miles radius of the plant were encouraged to plant SRC and were given contracts. In total 1500 hectares of SRC was planted. A growers group was established to enable farmers to pool resources and facilitate efficient production of fuel. The first harvest was due in autumn 2003.

In 2002, the final developers (there had been much changing of companies and influences over the years) of project ARBRE pulled out of the programme, beset by technical hiccups and management wrangles and went bust after generating electricity for only eight days. The plant was eventually sold to an American company for £3M and is likely to be dismantled.

When the project failed forty-five growers were left with no market for their willow. The growers decided to form a company – Renewable Energy Growers Ltd. to support each other and to develop markets. A potential market was located in a nearby power station that required a very fine woodchip, which could be used as an additive

to coal dust. A sister company - RES Ltd. was established to take responsibility for processing and delivery of wood chip to end users. The company developed a unique processing technique to produce the refined wood chip with a moisture content of 20-25% and an energy value of 15 GJ. The brand name for its range of wood chip is *Koolfuel*.

SRC WILLOW MANAGEMENT

The Department for Environment, Food and Rural Affairs (DEFRA) in the UK provides grants to assist with the establishment of SRC under the Energy Crops Scheme (ECS). Grants are also available to set up producer groups to facilitate establishment, management harvesting and supply to the energy market.

Site Appraisal

SRC can be planted on a wide range of soil types and similar yields have been achieved in the UK from heavy clay soils to reclaimed sand and gravel sites. Ideally willow should be grown on a medium textured soil which is aerated but still holds a good supply of moisture, such as clay or sandy loams. Water availability is important, but too much has been made of this and in practice SRC is more tolerant of dry sandy sites than any other agricultural crop due to its deep penetrating roots. As with any other crop SRC should not be planted on soils that become waterlogged for any long periods during a year because cuttings planted are unlikely to root successfully and harvesting operations will be hampered on boggy ground. On average SRC produces 10 ODT/ha/yr however on poorer ground or "set aside" land. Renewable Energy Growers Ltd. have experienced yields as low as 4 ODT/ha/yr.

Site Preparation

A high standard of site preparation is essential to maximise yield and produce uniform, easily managed crop. Plough pans need to be broken and care should be taken to avoid compaction. Prepare seedbed to at least a depth of 30 cm. Farmers should prepare the site as if they are getting ready to plant a root crop. Plough heavy ground in the autumn.

Establishment

Optimum yields of SRC are achieved at a planting density of 15,000 plants/ha. The most common planting technique is the "step planter", which is a semi-automated machine that carries 2-3 m whole rods that are manually fed into four planting rows. The machine automatically cuts the rods into 200 mm lengths and pushes them vertically into a pre-formed seedbed.

Picture 1: Willow "Step-Planter" machine

Planting generally takes place from February to May when soil conditions allow. Storing the planting material so that it does not dry out is imperative and the use of cold storage is now commonplace. Cold storage will in theory hold stock so that May and June planting can be possible, however the risk of dry soil conditions and plant cutting desiccation is high. Achieving a fine, deep and soft seedbed structure is essential, the rods are driven vertically into the soil and this cannot be achieved on poorly cultivated or shallow sites.

The "step planter" technique is expensive due to the plant material, speed of operation and labour, with establishment costs of up from £2,000/ha (€2,900/ha). Trials into other planting techniques have been conducted: these include whole rod lay flat planting, billet planting and fully automated step planter.

Crop Cycle

Cycle Year	Description	Notes
Year 1	**Planting (March/April)** Herbicides Fertilisers	15,000 plants/ha Stomp/Flexidor Inorganic – reduced compaction
Year 2	**Cutback (Jan/Feb)** Fertiliser Herbicide	See notes on cutback Organic – CSS Weedazol
Year 3	Monitor Willow beetle/aphids (Harvest 1 where no cutback)	Headland "band" application
Year 4	**Harvest 1** Fertiliser Herbicide	 Organic – CCS Kerb
Year 5	Monitor Willow beetle/aphids	Headland "band" application
Year 6	Monitor Willow beetle/aphids	Headland "band" application
Year 7	**Harvest 2** Fertiliser Herbicide	 Organic – CCS Kerb

Table 1: Crop Cycle for SRC Willow

* All further cycles as above, expect and budget on five harvests (16 years from planting). The crop will last indefinitely but after sixteen years it may be worth planting with new higher yielding varieties.

HARVESTING

Renewable Energy Suppliers Ltd. advocates winter as the best time to harvest willow for the following reasons:

- ***Fuel Quality:*** The cold temperatures in winter create higher temperature within the storage heaps (of billets) which increases the drying process, thus increasing the calorific value (CV) of the fuel.
- ***Impurities:*** The percentage of unwanted elements is high when the crop is growing allowing impurities such as heavy metals, nitrogen, sulphur and alkalies to cause problems in boilers or to the emission quality.
- ***Health & Safety:*** Green leaf material at spring/summer harvest is within the stored product which breaks down creating extra heat that may cause self-

combustion of stored biomass, but the main problem is that it dramatically increases fungal mould within the fuel. This in turn creates problems in the market.

- ***Crop Stress:*** As with any perennial, if the plant is cutback when actively growing it will reduce the yield due to stress.

Billet Harvesting

Picture 2: Case IH (Austoft) sugar cane harvester

The harvesting method used by RES Ltd. is the billet harvesting system. This is harvesting with a self-propelled converted sugar cane harvester, with a converted head to cut the willow. The standard cutter box remains to leave the SRC fuel as billets. The harvester cuts the SRC into 150mm to 200mm lengths (billets) and discharges into trailers. Billets are typically 9mm (diameter) x 200mm (length) with the bark surrounding the inner wood. The billets are stored either on the headland, an adjacent field or a shed. They are left to dry naturally in heaps for at least four months (see Picture 3). The billets typically dry to below 30% moisture content (MC) during summer drying.

Output	1 ha/hour @ 30 oven dried tonnes (ODT)/ha
Cost	£250 per hectare including transport to storage area, but not including any cost for secondary processing
Advantages	– Capable of harvesting very big crops up to 10cm diameter – Speed – Billet storage advantages (see Storage below) – Tracked machines allow for harvest on waterlogged soils
Disadvantages	Billets require secondary processing
Machinery	Case IH (Austoft) sugar cane harvester; John Deere (Cameco) sugar cane harvester

Table 2: Overview of Billet Harvesting System

STORAGE

As with any product, the market is key and storage is necessary to hold the biomass fuel until the market is available at the right price, but also that the biomass dries while being stored. Therefore storage is a valuable holding period for the reduction in MC alone. Bulk storage on the headland or at a storage point provides adequate drying facility.

Picture 3: Heap of billets

One advantage of billet harvesting is that the billets remain enclosed in bark which acts as a barrier and rainwater does not re-enter the material. When the billets are harvested they have a moisture content of over 50%. Since the billets have a large surface area, approximately 200mm, which when stored in heaps retain a large amount of air volume within the heaps. The moisture therefore moves by capillary action out of the billets and into the air. Renewable Energy Growers Ltd. are extremely pleased with the drying and storage capability of billets.

Picture 4 (left to right): Billets stored in piles on field adjacent to plantation and billets stored in covered shed.

The advantages of the billet storage method are:

- The storage heaps dry without creating heat and therefore maximum quality and calorific value is maintained.
- No heat build up allows the stores to dry naturally without decomposition or fungal mould build up, delivering quality fuel meeting health and safety standards.
- Air ducts have been trialled to increase drying timescale but had not impact.
- Crops harvested in November at a 60% MC were below 25% in March. This demonstrates that they dry very quickly even during the winter months.
- The billets are then processed to a very high quality chip when the fuel has dropped below 30% MC and delivered directly to the market.

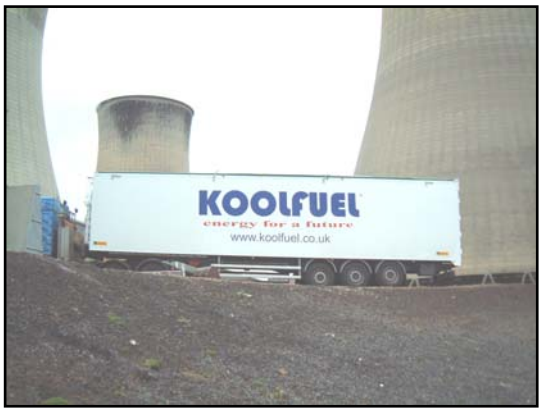
CHIPPING OPERATION

Once the billets have been dried to 20-25% MC they are chipped where they have been stored. Renewable Energy Suppliers Ltd. have developed a unique processing technique that produces a very fine quality chip. RES Ltd. main market requires very small chip, between 2mm and 5mm, very uniform in shape that yet remains 'non-binding and free-flowing'. The company have modified a machine used to chip plastic that produces a chip that is the ideal for co-firing in power stations. The cost to produce this very fine chip is approximately double the cost of typical energy wood chip (i.e. €10-20 per tonne). The billets are feed into the chipper using a front loader and a conveyor belt. The chipped billets are then blown directly into container for transportation to market. Approximately 22 tonnes of high quality chips are produced every four to six hours.

Pictures 5 (Clockwise): Front loader loading billets into chipper, conveyor belt feeds billets into chipper, modified plastics chipping unit, very fine quality wood chip

MARKETS

RES Lt. have a very limited market with one large scale market and two smalls scale markets, all located relatively close (<50 km) from the willow plantations and storage areas.



Picture 6: Cottam Power Plant

Cottam Power Plant: RES Ltd. supply approximately 4,000 tonnes of pulverised chip to Cottam Power Plant per annum. The contract with the power plant is to supply a very fine (pulverised) chip that has a 25% MC. The *KoolFuel* product is the first willow anywhere in the world to be successfully trialled in a PF coal fired power station as 'through the mill'- ideal as co-fire fuel in coal fired power stations. The price of pulverised chip is approximately half the cost of crude oil and cheaper than natural gas.

Durham School & Manor Business Park: RES Ltd. have two local small scale supply contracts. They deliver a front loader bucket load per week to the school. The boiler

was installed in the school over a year ago and the heating cost to the school has been halved.

ECONOMICS OF SRC

In the examination of the economics of growing SRC willow, Renewable Energy Growers Ltd. look at overall Net Farm Income (NFI) associated with growing SRC compared with different crops.

The economic analysis table below breaks down all SRC costs on an annual basis. This enables easy comparison with other farm crops that are annual. The table demonstrates that SRC is a very effective crop at driving up farm profitability in the Single Farm Payment scheme. The yield used is conservative and farmers who are giving SRC a reasonable amount of husbandry input are beating the yield figures. Expected yields could be as high as 12-14 ODT/hectare. It is estimated that by improving the yield from an average of 10-12 ODT/hectare it reduces the cost of producing a tonne by 20%.

The output price of £45/ODT is realistic and the first contracts to the power stations are in this region. At £45/ODT, delivered, the fuel is cheaper than forestry wood chip and as markets develop the price and therefore the budget will become more secure.
SRC is in its infancy in the UK and as the crops becomes more popular and more widely grown the cost of production will quickly fall.

16 Year Rotation	**Willow**		**Grass/Fallow Grass**		**Winter Wheat**
Output (ha/yr)					
Yield	8.75		0.00		8.00
Price/ODT	45.00		0.00		65.00
Yield Income	393.75		0.00		520.00
Energy Crop Payment	1500				
SRC Planting Grant (1000/16 yrs)	62.50				
Output	**471.25**				**520.00**
Variable Costs					
Plants/Seeds	(15000 cuttings 5p x 16 yrs) 46.88				39.00
Fertiliser	Establishment (25.00/16yrs) 1.56				103.00
Chemicals	36.88				127.00
Sundries	10.00				14.00
Total V.C.	**95.32**		**5.00**		**283.00**
Gross Margin	**375.93**		**-5.00**		**237.00**
Operation Costs	**£/ha**	**£/ha/yr**	**£/ha**	**£/ha/yr**	**£/ha/yr**
Cultivation	148.00	9.25	50.00	3.13	50.00
Planting Charge	300.00	18.75	7.00	0.44	18.00
Spraying	104.00	6.50	24.00	1.50	40.00
Fertiliser	40.00	2.50	8.00	0.50	32.00
Harvesting	250.00	83.33			60.00
Transport & handling	(£12/ODT) 105.00				20.00
Primary processing	(£11/ODT) 96.25				32.00
Cut back	33.00	2.06	15.00	15.00	
Compost Application	20.00	6.67			
Operations Total	**330.31**		**20.56**		**252.00**
Fixed Costs (ha/yr)					
Labour & Machinery	5.00		5.00		10.00
Crop Finance	10.00				10.00
Fixed costs	37.00		37.00		37.00
Central Admin	10.00		5.00		35.00
Rent Equivalent	123.55		123.55		123.55
Total Fixed Costs	**185.55**		**170.55**		**215.55**
Net Margin	**- 139.93**		**- 196.11**		**- 230.55**
CAP Payment	**235.00**		**235.00**		**235.00**
Net Farm Income	**95.07**		**38.89**		**4.45**

Table 3: Net Farm Income comparison for three crop types

CONCLUSION

It is hard to make predictions for the future of SRC willow when the wood fuel market is only emerging. However, the future for biomass crops is encouraging, with biomass seen as a key alternative crop for farmers and the SRC willow as the crop with the most potential. As with any new enterprise the initial start up costs are high, and the husbandry and processing operations require modification to adapt to the Irish conditions.

The introduction of the Energy Crop Scheme and the ARBRE project encouraged the initial establishment of 1,500 hectares in Nottinghamshire. The scheme provided guidance on the site selection, site preparation, establishment and management for this new crop, as well as funding its establishment. A high standard of site preparation and planting stock is essential to maximise yield and produce uniform, easily managed crop. On average SRC willow produces 10 ODT/ha/yr however on poorer ground yields can be as low as 4 ODT/ha/yr. SRC willow is generally harvested on a three year cycle, the first harvest being three years after cut-back.

The billet harvesting system used by RES Ltd. is a proven system that has many advantages. The billets are easy to handle and store. They can be stored in piles on the headlands, adjacent field or in storage shed for an indefinite period of time. There is no decomposition and little fungal mould build up; in fact billets that are stored outsides show no signs of fungal mould. The billets remain enclosed in the bark and the large air pockets in the heaps mean that air can circulate through the heap to dry the billets to MC of as low as 25% in just four months. Typically harvested SRC willow has a MC of approximately 50%.

The wood chip produced is over refined for the needs of the small to medium scale wood chip market in Ireland. The fine quality bio fuel produced is used as an additive to coal dust at the power station. The production costs for this wood chip is approximately double the typical chipping costs.

The processing unit developed by the company is a large scale mobile chipping unit that comprises an operator that travels with the unit from site to site, a front loader, a conveyor belt to feed the billets into the chipper and the chipping unit. In my view the processing system is unsustainable as it requires the operator to travel with the unit throughout the region, often on the road for several weeks. Therefore, it is recommended that a central processing unit is established, where the billets are transported to depot for chipping. Although this system would incur double handling costs, the transportation cost of the unit would be removed and the operator’s salary would be reduced.

If SRC willow is to be an attractive land use alternative for farmers in Ireland, establishment and infrastructural support mechanisms are needed. Willow is a new crop that requires high initial investment to establish, manage, harvest, process and deliver to end user. Future developments in the wood energy market will be crucial to the success of this new energy crop. Therefore, the conclusion from the visit was that SRC willow fuel supply chain is a viable alternative farm enterprise if there is local demand for the product at the right price.