
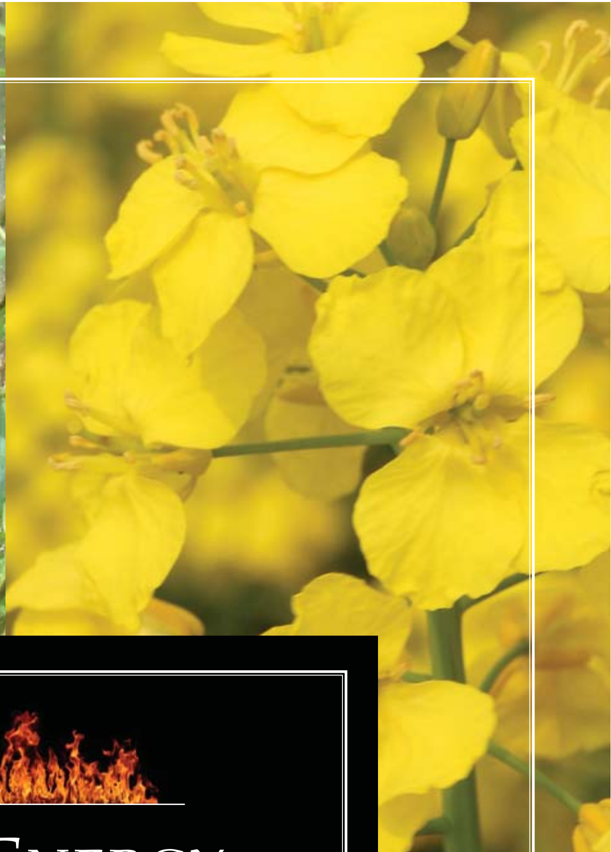

Farm Energy

Farm Diversification Manual


This project has been co-financed by Meath, Barrow Nore Suir, Cavan-Monaghan and Louth Leader groups through the National Rural Development and LEADER+ Programmes under the NDP 2000-2006.

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Farm Energy

Farm Diversification Manual

National Development Plan 2007 - 2013

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Teagasc
Agriculture and Food Development Authority

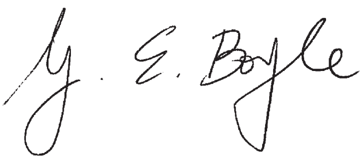
FOREWORD

Welcome to the first edition of *Farm Energy*, a joint publication by Leader, Teagasc and the IFA. This collaborative book is perfectly timed, as the renewable energy industry is developing rapidly, not just in Ireland, but also around the world. The farming industry is in a unique position to drive the development and adoption of much of this new technology. Farmers have the land resource required to produce energy crops, or for locating anaerobic digestion units, which have the potential to convert many of our waste products into energy sources. The adoption of these technologies has the potential to provide alternative income streams for farmers.

In today's world of rising oil prices, escalating effects of climate change and erosion of energy security, there is an urgent imperative to implement solutions. Bioenergy represents a real and practical way forward in helping to solve the evident energy, environmental and security challenges that we face today. The ascendance of bioenergy is attracting ever-greater attention from politicians, multi-lateral institutions, agriculture, business, forestry, finance and, of course, populations the world over.

These are exciting times in agriculture. Bioenergy is experiencing a surge of interest stemming from a combination of factors. These include a greater recognition of the current role for biomass and its future potential contribution as a modern fuel: its availability, versatility and sustainability; its local and global environmental benefits; and, the development of entrepreneurial opportunities. Bioenergy is viewed today as the future energy source for development and industry.

This book provides an introduction to bioenergy and an overview of the possibilities. It is a useful reference for farmers, and a starting point from which to identify the potential role for individual farmers in meeting our challenging national bioenergy targets in the heat, transport and electricity sectors. I hope you find this publication not just interesting but, more importantly, useful and practical. I would like to commend our partners in this publication, Leader and the IFA, and indeed my colleagues in Teagasc, on producing an excellent publication.



Professor Gerry Boyle
Director of Teagasc

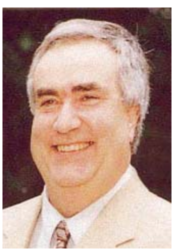
Leader

This publication centres on land use and the possibilities it offers through the production of farm energy. Many crops, some relatively new to Ireland, can be cultivated in order to meet energy demand. From a farming perspective we need to know: can this be done profitably?; is there an existing market for these products?; and, does Ireland have the capacity to assemble and process these products? In short, has this industry advanced to the point where these crops can be grown with confidence and in the expectation that they can compete with traditional alternatives?

From both a sustainability and economic imperative, diversification in agriculture is now considered to be a desirable and necessary objective. In exploring opportunities for the development of on-farm alternative enterprises offering a real and sustainable return on investment, the Leader programme continues to engage with farmers and their families, with farm organisations and with development and advisory bodies, including Teagasc.

Many such diversification opportunities can be exploited through the utilisation of resources to be found on the farm and within the farm family. In this context, Leader has invested in rural tourism enterprises, manufacturing facilities for the production of artisan food products, light engineering, community services, and so on. These new income-earning opportunities have largely been very successful. However, for many farmers these are not realisable opportunities, perhaps due to location, farm type, structure, or family circumstances.

For these farmers, making the best possible use of the lands they farm is the most obvious action to be taken in improving family farm income levels. This may require step-change research and investment, and while farmers demonstrate great interest in diversification, given the capital and other resources required they are, during the decision-making process, entitled to the best possible advice and information available.



This publication sets out to provide some answers and also to ask those questions that need to be addressed. We believe Leader will have a future role in building elements of this industry, and in seeking to do so we are pleased to be associated with Teagasc and the Irish Farmers Association in the production of this farm energy manual.

Michael Ludlow
CEO, Meath Leader

Irish Farmers Association

This is a timely publication, aimed at providing relevant information for farmers who believe there is a future in bioenergy.

In recognising the potential of bioenergy, I established a project team, led by JJ Kavanagh, to pursue profitable alternative land use opportunities for farmers. The team quickly identified a number of areas hindering the development of a bioenergy-based industry, the main one being profitability.

Good progress has been made to-date in securing establishment aid for biomass crops; the €80/ha energy crop top-up payment; and, eligibility for REPS payments. The team is currently pursuing additional issues and has devoted a considerable amount of time and effort to exploring the possibilities that could be pursued by tillage and grassland farmers.

It is noteworthy that Government is now recognising that potential and realises that farmers can play an innovative role in assisting the growth of bioenergy.

A cornerstone of our policy is that an indigenous sector should be nurtured and developed by Government policy, and that incentives should be aimed at producers in this country who are committed to developing the sector. Our over reliance on imported fossil fuels should not be replaced by a dependence on another form of imported energy.

I am delighted that IFA has, in conjunction with Teagasc and Leader, produced this informative and practical guide.

Padraig Walshe
IFA President

From left: Tom Shortt, IFA Biofuels Committee; Padraig Walshe, IFA President; and JJ Kavanagh, IFA Project Team Leader

This manual is a comprehensive guide to the pivotal role that Irish agriculture can play in providing bioenergy solutions for Ireland's energy needs: from anaerobic digestion through to the cultivation of bioenergy crops for combined heat and power, or transport biofuel production.

The whole bioenergy area represents a real opportunity for increased confidence and investment in agriculture and the rural economy, while simultaneously addressing environmental and sustainability issues.

Producing energy crops, however, will only have a viable future if they can provide an economic return on investment and labour for farmers. While research and the provision of husbandry management guidelines are a critical component in achieving optimum yields, the industry will only achieve viability if Government puts in place a proper framework policy that supports an indigenous bioenergy sector.

This excellent publication gives a practical overview of the emerging opportunities that are developing for farmers in the production of bioenergy from crops through to anaerobic digestion.

JJ Kavanagh,
Project Team Leader, IFA Alternative Land Use

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This publication has been produced by Teagasc in association with Meath Leader, Cavan-Monaghan Rural Development Co-op, Barrow Nore Suir Rural Development, Louth Leader and the Irish Farmers Association.

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The authors also acknowledge the help and co-operation of Michael Ludlow, Meath Leader, for helping to bring the project to fruition.

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Introduction

The question of food versus fuel is increasingly being asked. For Ireland, this will narrow down to whether we need to ask: will it be politically more acceptable to import energy instead of producing and exporting food in the future? This is a difficult question with environmental, economic and social considerations which will be debated over the coming years. This manual is an introduction to bioenergy to allow farmers to identify the opportunities available in meeting our challenging national bioenergy targets in the heat, transport and electricity sectors.

Irish farmers have the potential to supply energy. Currently, we import energy at over 90% of our annual energy requirement, while we export 90% of our beef, often at very low margins for the farmer. The general public is beginning to see how dependent we are on oil, coal and gas imports. A marketplace is now developing for local home-grown energy. Irish farmers are becoming more aware of environmental issues through REPS and are also becoming more aware of the opportunity to produce energy from the land, which is environmentally clean and which can supplement declining farm incomes. The main benefits of bioenergy are: the mitigation against the climate change caused by greenhouse gas emissions; energy security; and, the increased employment opportunities for rural communities.

Global energy demands are continually increasing. Countries like China and India, which between them are home to one-third of the world's population, are becoming more and more affluent and are looking for a better standard of living. The new EU accession countries will also be striving for a better standard of living, and this will, consequently, result in higher energy demands in these countries. According to the US Energy Information Administration, world oil use is forecast to grow from 80 million barrels per day in 2003 to 98 million barrels per day in 2015 and 118 million barrels per day in 2030.

This increased demand for energy will result in increased oil, coal and gas prices for us, as we are import dependent for our energy needs. Across the developing world, cheap diesel generators from China and elsewhere have become a practised way to make electricity. They power literally everything from irrigation pumps to television sets, allowing growing numbers of rural villages in many poor countries to grow more crops and connect with the wider world.

As the demand increases for the electricity that makes these advances possible, it is often being met through the dirtiest, least efficient means, creating pollution problems in many remote areas, which previously had pristine air and negligible emissions of carbon dioxide (CO_2), the main global warming gas.

Coupled with scarcity of energy supply, we also face what has been described as the world's greatest challenge – global warming – caused by man-made greenhouse gas emissions. CO_2 represents 75% of all greenhouse gases. Energy crops are generally high yielding and carbon neutral. During photosynthesis the plant takes or captures CO_2 from the atmosphere to build its bodyroots, shoots, leaves and seeds. The plant makes its structure from CO_2 and in essence locks up that CO_2 within its structure. Unlike fossil fuels such as coal, oil or gas, which have been stored in the earth for millions of years and release billions of tonnes of CO_2 into the atmosphere on an annual basis, energy crops have sequestered the CO_2 in more recent times so are effectively using the energy from modern sunlight as opposed to ancient sunlight. Crops like willow, miscanthus, hemp, reed canary grass and oilseed rape all have a role to play in reducing greenhouse gas emissions.

The future will lead to a more diverse cropping regime around the world. Currently, we are focused on food production. However, the plastics and chemicals we use could come from plants such as hemp and the grass our cattle graze could be used to produce electricity or heat through gasification or anaerobic digestion. Farmers will embrace new opportunities in the bioenergy sector. Second generation biofuels will open up new opportunities such as the conversion of cellulose in raw biomass to ethanol; we will also see the development of biomass to liquid BTL with the conversion of biomass through gasification to a gas that can be converted further into a diesel substitute. While bioenergy will not solve all our energy needs, it will solve a piece of the energy challenge puzzle. However, with present technologies, we need to get the markets and supply chains in place and the industry developed. Agriculture is facing a whole new and exciting world of opportunity.

This publication discusses the various energy crops, their end product and potential market, and hopefully goes in some way to addressing the question: 'Should we invest or is now the right time to invest'?

BIOENERGY TARGETS

In this chapter we look at: summarising the key Government targets relating to energy crops; giving a sense of the possible scale of energy crop production in Ireland; and, examining the perspectives on some broader issues including energy efficiency, other renewable energy sources and sustainability issues.

Key targets

Two important policy documents were published in March 2007: The Bioenergy Action Plan for Ireland and the White Paper ('Delivering a Sustainable Energy Future for Ireland'). Among others, the following targets have been set:

- **5% share of renewable energy in the heating sector by 2010 and 12% by 2020;**
- **co-firing in the peat-fired power stations of 30% by 2015; and,**
- **a biofuel target of 5.75% for road transport fuel by 2010 and 10% by 2020.**

Potential heat and electricity markets for energy crops

The heating and co-firing targets provide a significant market opportunity for energy crops such as willow and miscanthus; **Figure 1** shows this graphically. For every 100ktoe (kilo tonnes of oil equivalent) supplied from energy crops, about 23,000 hectares of crop would be required. (Taking the yield of energy crop at 10 oven-dry tonnes per hectare per year, and the net calorific value at 18Gj per oven-dry tonne, 1,000 hectares of energy crop would therefore yield 0.18Pj per year, equivalent to 4.3ktoe.) The first round of the BioEnergy Scheme of the Department of Agriculture, Fisheries & Food resulted in the planting of 900 hectares of miscanthus and 80 hectares of willow in 2007. For the second round of the Scheme, it is envisaged that up to 1,600 hectares of willow and miscanthus will be grant aided.

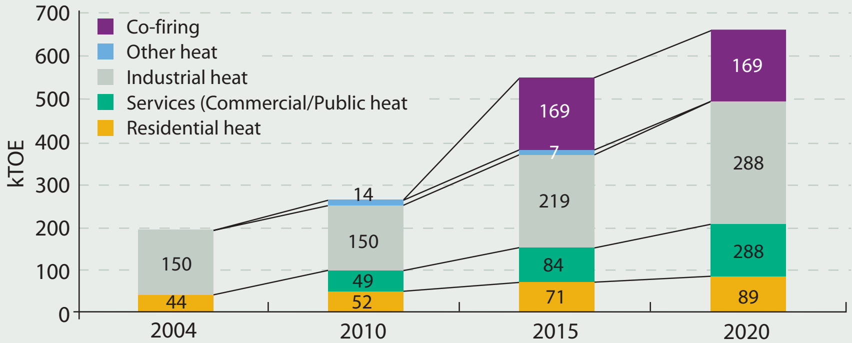


FIGURE 1: Renewable heat and co-firing targets.

Notes on Figure 1

- **The totals for the years shown are 194, 265, 550 and 666ktoe. To put these figures in context, the total primary energy requirement (heat, electricity and transport) of Ireland in 2006 was almost 16,000ktoe (Howley, O'Leary and Ó Gallachóir, 2007, p12);**
- **2004 figures from DCMNR, 2007, p22;**
- **2010 figures from DCMNR, 2007, p23;**
- **2020 figures for heat from Howley, O'Leary and Ó Gallachóir, 2007, p31. The figures take account of the energy efficiency measures in the White Paper, which would reduce Ireland's heat demand by 27% from about 5,500ktoe in 2005 to about 4,000ktoe in 2020;**
- **2015 figures for heat calculated as midpoint between 2010 and 2020 figures;**
- **2015 and 2020 figures for co-firing calculated from DCMNR, 2007, p27: "The three peat-burning stations burn a total of three million tonnes of peat per annum," and taking the energy content of milled peat as received at 7.87GJ per tonne. 30% co-firing therefore equates to an energy input from other fuels of 7,083,000GJ, or 169ktoe; and,**
- **biomass-fired combined heat and power (CHP) is likely to be an additional market, and the Bioenergy Action Plan states that the SEI CHP Grant Scheme aims to deliver 10-15MWe (megawatts electrical) of biomass CHP.**

The Bioenergy Action Plan also discusses many action points, including:

- **bioenergy heating systems to become the norm in new OPW buildings;**
- **the existing programme of biomass heating in schools to be expanded;**
- **a total of 20 of the State's large existing buildings to be converted to bioenergy heating systems within one year;**
- **biomass CHP to be used in future major site developments by the OPW;**
- **CIE to move towards a 5% blend in all their existing diesel fleet;**

- **CIE to ensure that new fossil fleet purchases are capable of using biofuels at blends of at least 30%; and,**
- **the use of biofuels at up to 5% blends in local authority fleets to be promoted, and new fossil fuel vehicles to be capable of taking biofuel blends of 30% and more.**

Other energy sources

Energy crops will not meet the heat and co-firing targets on their own – other bioenergy sources and other technologies (e.g., solar, heat pump) will also contribute. Most of the existing renewable heat in Ireland is supplied by wood residues used in the timber processing industry, and firewood for home heating. Teagasc estimates that wood fuel from private forests (based on 50% of stands being thinned) could provide 50ktoe per year by 2015 (302,000 green tonnes at 6.9Gj per green tonne gives 2.1Pj or 50ktoe [Farrelly, 2008]), but the Bioenergy Action Plan emphasises the importance of continued afforestation to maintain future supply from this source. Wood pellets are increasingly used in the residential and services sectors. The current production capacity on the island of Ireland is 100,000 tonnes of pellets per year, equivalent to about 40ktoe (there are also imports from other parts of Europe and from North America). Other sources that could contribute to meeting the targets include: quality firewood used in efficient stoves and boilers; straw; forest residues; by-products from the meat processing industry, including tallow; and, suitable post-consumer wood waste.

Liquid biofuels

Energy consumption in the transport sector increased by 167% from 1990 to 2006, when it reached 5,400ktoe (Howley, O'Leary and Ó Gallachóir, 2007, pp. 2, 10). The White Paper lists actions to reduce transport demand, improve efficiency, and promote biofuels. The Bioenergy Action Plan gives more details, and quotes Teagasc estimates that 2% substitution of road transport fuel would require 75,000 hectares of tillage land (about 20% of the country's total tilled area). Using recovered vegetable oil and some beef tallow could reduce this requirement by 20,000 hectares or more. Looking to 2010, the Plan states: "It will be an acknowledged challenge for Ireland to achieve the 5.75% target purely from indigenous feedstock in the medium-term future, as liquid biofuels can only be produced from annual arable crops using current (first generation biofuel) technologies", but that: "In the medium to long-term, the possibilities include 180,000ha of rapeseed for biodiesel and pure plant oil, and 75,000ha of cereals for ethanol" (DCMNR, 2007, p18).

Knock-on effects of this possibility are recognised (rotational requirements, new markets for additional cereals and limit on reduction in permanent pasture). The Plan supports the development of new 'second-generation' biofuel technologies, which allow ligno-cellulosic materials to be converted into liquid biofuels. Such technologies would open up more possible markets for wood, energy crops and agricultural residues. Ligno-cellulosic crops (including willow and miscanthus) are better suited to Ireland's climate than starch, sugar or oil crops for 'first-generation' biofuels.

Looking further into the future, the Plan (p19) concludes that: "A target of at least 10% by 2020 will almost certainly involve importing biofuel feedstock or ready blended biofuel, as the land implication of achieving this target from indigenous sources would be in the region of 400,000 to 500,000 hectares". (To put these figures in context, the Bioenergy Action Plan [p.13] states that: "The land area of Ireland is some seven million hectares [ha], of which 4.3 million hectares is used for agriculture and approximately 710,000ha for forestry, or about 10% of total land. 79% of agricultural area is devoted to grass [3.4 million ha], 11% to rough grazing [0.5 million ha] and 10% to crop production [0.4 million ha].") The Plan points out that under EU state aid rules, Ireland cannot discriminate in favour of indigenous production in our biofuels programmes such as the existing Biofuels Mineral Oil Tax Relief Scheme and the proposed Biofuel Obligation Scheme. People assessing opportunities in liquid biofuels should therefore be aware of the sector's global context.

Sustainability issues

It has become clear that the production of liquid biofuels is having negative environmental and social impact in some parts of the world. The greenhouse gas emissions resulting from the conversion of forest and grassland to energy crops are also being investigated (e.g., Fargione *et al.*, 2008). Sustainability criteria and certification systems for bioenergy are being developed at EU level in an effort to deal with these impacts.

References

1. **Caslin, B.** Bioenergy Scheme and Land Required to Achieve our Policy Targets. Presentation at the Teagasc and IrBEA Bioenergy Conference 2008. Teagasc Oak Park, Co. Carlow, 2008.
2. **DCMNR.** Bioenergy Action Plan for Ireland – Report of the Ministerial Task Force on Bioenergy. (Then) Department of Communications, Marine and Natural Resources, Dublin, 2007.
3. **Fargione, J., Hill, J., Tilman, D., Polasky, S., Hawthorne, P.** Land clearing and the biofuel carbon debt. *Science* 2008; 319 (5867): 1235-1238. Abstract accessed at www.sciencemag.org on March 5, 2008.
4. **Howley, M., O'Leary, F., Ó Gallachóir, B.** Energy in Ireland 1990-2006. 2007 Report. Energy Policy Statistical Support Unit (EPSSU) of Sustainable Energy Ireland, Cork, 2007.

Additional Information

Bioenergy International – www.bioenergyinternational.com. Magazine with information on global production and trade in wood fuel.

Sustainable Energy Ireland – www.sei.ie. The information on the Greener Homes Scheme and the Renewable Heat Deployment Programme is particularly relevant to energy crop growers and heat sellers.

Anaerobic digestion

Anaerobic digestion (AD) uses bacteria to convert organic matter into methane and nitrous oxide in the absence of oxygen. Farm wastes can be used in an AD facility to produce methane for use as heat and power, or as a transport fuel.

On combustion, methane is converted to the less damaging carbon dioxide (CO_2) and releases energy, which can be used in place of fossil fuels for both heat and power. While there are currently no realistic plans to harness the gaseous emissions from farm animal waste systems, the use of AD is now a well-established technology used increasingly in Europe and elsewhere. When cleaned, the gas produced (often called biogas) can also be passed through an internal combustion engine used either for the generation of electricity or as a fuel for vehicles. The power it generates is increasingly valuable, as it will assist towards the achievement of targets for renewable energy production.

Energy potential of agricultural slurries

Some 132 million tonnes of agricultural slurries, wastewaters, effluent and sludge are generated in Ireland annually.[1] The energy potential of agricultural slurries from AD are presented in **Table 1**. Poultry waste has the highest per tonne energy potential at 0.131MWh of electricity per tonne. The energy potential of cattle, pig and poultry manure is estimated at 2.759 million MWh, over 10% of the total electricity supplied in the Irish economy in 2006.

Table 1: Indicative energy potential from livestock slurries.

Livestock	Population June 2003 '000	Wet tonnes/year (millions)	Potential biogas m^3/year (millions)	Potential electricity MWh/year	Electricity MWh/tonne feedstock
Cattle	6,967	84.763	1,441.0	2,641,772	0.031
Pigs	1,713	2.274	35.2	64,493	0.028
Poultry	12,738	0.404	28.8	52,810	0.131
Total		87.441	1,505.0	2,759,075	

Table 2: Biogas from agriculture and abattoir wastes.

	Biogas (m^3) per tonne organic waste	Energy equivalence in heating oil (litres)
Cattle slurry	22	13
Pig slurry	22	14
Poultry manure	50-100	33-65
Abattoir gastro-intestinal waste	40-60	26-39
Abattoir fatty waste	>100	>65

Drivers

There is now renewed interest in AD. The rise in the cost of fossil fuel-derived energy has concentrated minds on the alternatives. The growing awareness of climate change has lead to directives from Europe, forcing the Irish Government to control greenhouse gas emissions. Specifically, the Landfill Directive 1999/31/EC has set targets for the reduction of the amount of biodegradable matter that is sent to landfill. The majority of this material must be either composted, digested, rendered or incinerated. The process for material of animal origin is tightly controlled by the animal by-products regulations. The increasing cost of landfilling is focussing the minds of landfilling and food processing companies to alternative disposal options. The control of nutrient run-off from farmland may also help the development of digestion, as strict standards for water quality and control of nitrates and phosphates may mean that in some areas digestion is favoured over inorganic fertilisers.

Benefits of AD

AD of animal slurry and other feedstocks could have several potential national benefits. It could allow the methane to be harnessed for energy use, while at the same time reducing greenhouse gas emissions normally emitted during manure and waste storage, artificial fertiliser use and emissions from soils after spreading fertiliser. It could also alleviate smells, reduce artificial fertiliser use and

potentially reduce nutrient loss to the environment. To date, only a handful of farm digesters have been erected, largely due to the difficulties in achieving economic viability. AD of pig slurry has the potential to reduce emissions by the equivalent of 144kg of CO_2 per tonne of pig meat produced. On this basis, 75% adoption by the pig sector in Ireland would reduce emissions by 16,000 tonnes of CO_2 per year. If digestion were economically viable, a high adoption rate should be achievable in this sector, as the technology would fit in easily on the large centralised units that now make up most of the industry. These units are having increasing difficulty finding land nearby for spreading, and the smells from slurry spreading are becoming an increasing problem. Digestate does not have an offensive odour, and the nutrient availability is improved and more reliable; therefore, it is more likely that farmers would be willing to use digested slurry as a fertiliser. It would also make it easier to find land for spreading. AD could provide a solution to the management of manure from intensive agriculture, if economic viability can be achieved.

Digestion would also apply to the dairy industry, but is likely to have a much slower uptake in this sector. Cattle slurry is only produced during part of the year, when the animals are housed. Many dairy units are too small to justify an on-farm digester and too geographically dispersed to supply a centralised unit. Smells are less of a problem than with pig slurry and, to date, on most dairy farms, the land bank is adequate to take all of the slurry. However, there are situations where the farm is suited to having a digester. This is particularly so where there is a high heat demand. In the beef sector it is difficult to envisage significant investment in digesters in the near future.

If digestion could be introduced at the levels projected above in the pig and dairy sectors, a total of about 80,000t/year of CO_2 could be abated, and methane with an energy content of about 80TJ (22GWh)[2] produced. Some of this energy could be used for on-site heating, although it is more likely that it would be used in electricity production for export to the national grid. The main reason for lack of investment in digesters to date is that the financial payback is longer (>5 years) than that currently acceptable to financing institutions. If digesters were rewarded for the benefits they could provide to the national interest – for which the farmer cannot currently gain value – economic viability could be reached.

Viability of AD

Looking to the future, there are a number of scenarios in which biogas production could become viable. The first is a substantial increase in the price available for renewable electricity. The present price paid to on-farm digester operators in Germany ranges from €0.15-0.17/kWh, and is consequently stimulating rapid development in the sector. The Department of Communications, Energy and Natural Resources has recently announced that capital funding of €8 million will provide up to 30% investment grant support from Sustainable Energy Ireland (SEI) for eligible projects, with an increased guaranteed price under REFIT (Renewable Energy Feed in Tariff) of €0.12/kWh for the production of electricity from biogas. The second scenario that might stimulate development is the

Anaerobic digestion operation in Denmark.

Digester tank.

co-digestion of animal manure along with organic wastes, with an attached gate fee. Disposal of food waste is an increasing problem and several digestion options could be considered. On-farm digestion of a combination of animal manure and local food and catering wastes would be one possibility. Processing these wastes in a digester prior to spreading would significantly benefit both agriculture and the environment. The digester could levy a gate fee per tonne for taking these wastes; however, much of this value is required to pay for additional costs resulting at the digester. These wastes generally have higher energy content. Current management (landfill) produces significant greenhouse gas emissions; therefore, it would be very attractive to process them in a digester. However, because they generally contain animal by-products, there are added processing requirements and restrictions on where and when the digestate can be utilised. These requirements increase capital and processing costs, and restrict the number of locations where such plants can be located.

A third scenario to improve financial return from digesters is to develop a method of rewarding the digester owner for the resulting environmental benefits. Both a Danish research report in 2002[2] and a report from the EPA in 2005,[1] state that over 50% of the value of anaerobic digesters is in national benefit, for which digester owners in Ireland are currently not rewarded. These benefits include: reduction in greenhouse gas emissions; avoided costs related to other waste management solutions; improved water and air quality; and, rural development benefits.

AD in Austria and Germany

In Austria, approximately 10% of new plants digest energy crops only, 65% digest energy crops with animal manures, and the remainder also include other organic wastes (less financially supported by the Austrian government). Only a small proportion of plants digest only one feedstock (3.1%). The remainder use two to seven different materials with over half using four or five feedstocks. Pig manure is used in 61% of the plants and cow manure in 39%. Energy crops used are listed in **Table 3**. Maize is clearly very important. Grass, specifically ryegrass, may be an alternative in areas where maize underperforms. In the future, further crops such as switchgrass, reed canary grass or other giant grasses may be considered as feedstocks for digesters.

Table 3: Use of energy crops in German AD plants (Hopfner-Sixt *et al*, 2005).

Crop	Frequency of use
Maize	92%
Cereals	50%
Whole crop silage	48%
Grass silage	37%
Grass	8%
Corn cob mix	5%
Maize grains	4%
Sunflowers	2%

Siting of plants

In Ireland, plants will need to be sited in areas where there is a supply of animal manures, potential for growing energy crops and, ideally, a source of other organic wastes. To increase the options for including organic wastes such as municipal green wastes or food processing wastes, the successful plants will either be near a centre of population, or allied to a food processing plant in a rural location.

Constraints

A number of factors dictate against investment in an AD system on farm scale. These include:

- **insufficient access to a suitable feedstock;**
- **process costs associated with animal by-product regulations and the cost of permit to apply digestate to land;**
- **guaranteed continuity of supply of feedstock (could be addressed by storage facilities);**
- **insufficient need for power on site and a prohibitively expensive grid connection;**
- **demand for 'waste' heat produced;**
- **lack of land that can utilise the digestate usefully;**
- **lack of reliable, competent and motivated staff; and,**
- **periodic shut downs when no staff will be available.**

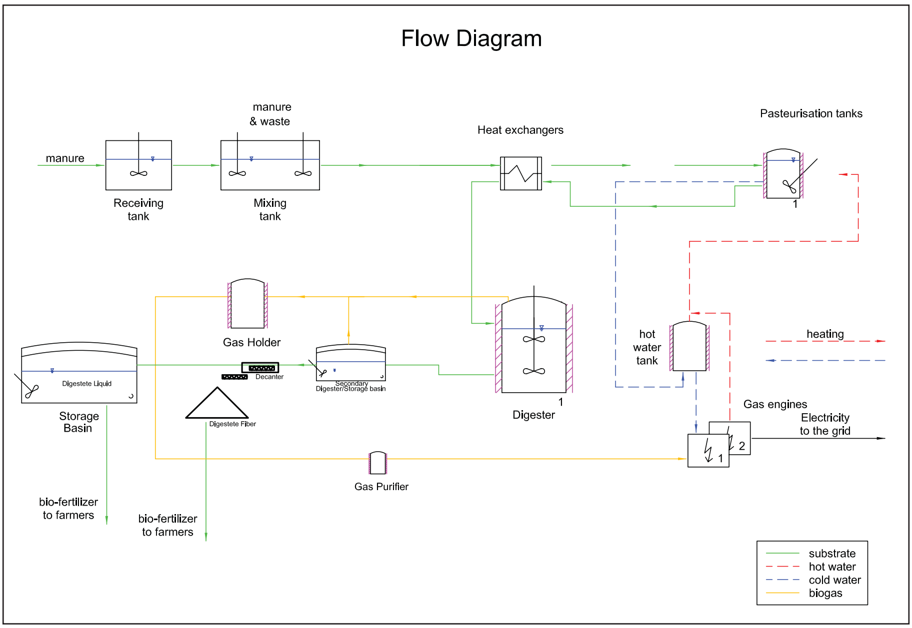
Is it worth investing in a farm-scale anaerobic digester?

- **The economics of operating an AD plant are improving, making this technology worth considering. It is clear that a plant fed only with animal manure will need to be very large to produce enough gas to pay back its costs. This is more likely to be appropriate as a central plant taking material from a number of farms;**
- **approval to apply digestate to land should be investigated at an early stage;**

- other sources of organic matter will produce considerably more gas than manures so adding these in the digester will give more gas and boost energy production;
- if the farm can produce crops specifically to feed the digester, at a cost less than the value of the extra gas output, then it may be possible to reduce the payback period;
- if the digester is able to dispose of organic waste then the extra income received could cover the extra cost of pasteurisation equipment and also reduce the payback period; and,
- the treatment of farm wastes to reduce pathogen load, increase the value as a fertiliser, and reduce odour emissions may also help to justify the system installation.

References

1. **EPA.** Anaerobic digestion benefits for waste management, agriculture, energy and the environment, 2005.
2. **Danish Food & Economics Institute.** Socio-economic effects of centralised anaerobic digestion.



Cereal grain as a fuel

Many tillage farmers are looking seriously at the possibility of heating their homes with grain. This interest was stimulated initially by an over-supplied grain market, the Greener Homes and Bioheat Boiler (now ReHeat) grant schemes, and by the upward move in oil and gas prices. A group of Athy farmers are working to develop the production and supply of fuel grain into a business opportunity. There are four grain boilers on the market at present.

An Oak Park grain burning trial on oats, wheat, barley and triticale, burned at two moistures – dried (14-15%) and undried (19-20%) – gives the following general assessment of the feasibility of grain burning and set out to answer two questions:

- **How do the grain species compare as fuels?; and,**
- **Is it necessary to dry the grain before burning?**

Grain heating value and energy density

Heating value is the most important property of any fuel. All the cereal grains had roughly similar gross heat values (i.e., the heat recovered per kilogram of fuel with all the moisture removed). Oats came out on top and close to wood pellets because of its high oil content; the other grains were slightly lower and all similar (**Table 1**).

Net heat value is a better measure of the heat that is actually recoverable from the fuel as burnt. At 14-15% moisture the grain net heat values were 14-15MJ/kg, about 85% of the value for wood pellets and one-third that of diesel fuel. At 19-20% moisture, the grain heat values fell to 13-14MJ/kg (**Table 1**).

The net energy density of the cereal grains, an indicator of storage space requirement, was approximately three-quarters of that for wood pellets. All the cereals were very easy to convey into the boiler storage bin and to meter from there onto the boiler grate.

Ash handling

The cereal grains had ash contents from 1.7 to 2.9%, as compared with 1% for wood pellets (**Table 1**), resulting in two to three times as much ash for disposal with grain as with wood pellets. Ash disposal would be of little concern to most farmers, but might be seen as a drawback by non-farmers.

Grain ash is reputed to be more inclined to form clinker than wood ash. In these trials, some clinker was formed when wheat and barley were burned at the higher moisture. If this was perceived to be a problem, it could be overcome by adding lime to the grain. No problems were encountered with any grain at the lower moisture or with oats or triticale at the higher moisture.

Table 1. Heat and ash contents of cereal grains compared with wood pellets.

Fuel	Ash content (%)	Gross heat value	Net heat value @ 14-15% m.c MJ/kg	Net heat value @ 19-20% m.c.
Wheat	1.7	18.3	14.2	13.3
Triticale	2.0	18.3	14.1	13.3
Barley	2.1	18.5	14.2	13.5
Oats	2.9	19.3	14.9	14.1
Wood pellet	1.0	20.2	17.1 @ 8% m.c.	

Boiler output and efficiency

The grains were burned in a Benekov Pelling 27 boiler with a nominal output of 25kW. At the lower moisture content the grains gave outputs from 19-21kW, compared with 23kW for wood pellets (**Table 2**). Thermal efficiencies (the proportion of the grain energy that was recovered as useful heat) were high, close to wood pellets. Given the difference in moisture content between the grain and pellets this was a good performance.

At the higher moistures, triticale still burned very well; it gave a high output and maintained efficiency at over 80%. The outputs and efficiencies from wheat and oats were substantially reduced. Barley was extremely difficult to ignite and burned erratically; operation of the boiler with barley at this moisture was not practical.

Table 2: Boiler outputs and thermal efficiencies with cereals grains and wood pellets.

	Heat output (kW) (boiler nominal output of 25 kW)		Thermal efficiency (%)	
Fuel	14-15% m.c.	19-20% m.c.	14-15% m.c.	19-20% m.c.
Barley	19.2	13.0	85	45
Triticale	19.1	18.0	85	82
Wheat	18.7	16.4	80	70
Oats	21.0	16.0	87	73
Wood pellets @ 8% m.c.	23.0		88	

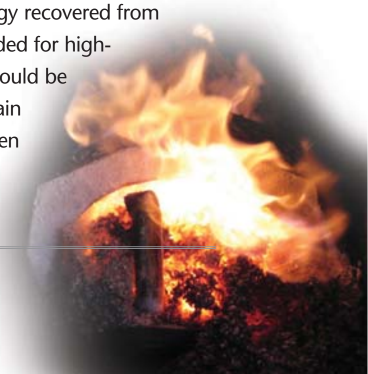
Emissions

Emission levels are sensitive to the composition of the fuel, but they are also affected by boiler design features and adjustments that might change the combustion temperature and the flow of air through and over the grate. So the results from these trials are no more than a general indication of the emission levels that might be achieved when burning grain as compared with wood pellets.
The emissions of main concern are CO and NOx. High levels of CO are usually an indicator of incomplete combustion; a limit of 500mg/kg has been set in some countries. In these trials, triticale and oats gave CO levels well under that limit; results with wheat and barley were higher and more variable. NOx emissions come from various sources and are affected by the N content of the fuel and by the combustion temperature. All the grain values were higher than those with the wood pellets, suggesting that the higher N content of the fuel was the problem. However, none of the measured values could be considered as extremely high, and careful design and setting of the boiler should allow NOx levels to be kept within reasonable bounds.

An unpleasant odour is sometimes mentioned as a problem with burning grain. However, this only occurs when the flame is restricted and the grain smoulders. One way of minimising this problem is to reduce low-load operation by under-sizing the boiler and using calorifier (buffer) tanks for heat storage.

Burning moist vs. dry grain

Should grain be dried before burning? In the triticale trial, the additional energy recovered from burning dry rather than moist grain (0.5MJ/kg) was similar to the energy needed for high-temperature drying (0.4MJ/kg). The non-energy drying cost (~ €10/tonne) would be largely counter-balanced by the cost of providing ventilation for safe moist grain storage. Therefore, in cost or energy terms there is very little difference between the two approaches.



Cereal grains are serious contenders for biomass fuels.

Clinker from grain boiler.

With oats on the other hand, the energy recovery after drying increased to 1.7MJ/kg. So the net benefit from the drying approach was about 1.2MJ/kg, or 10% of the recovered energy. In this case drying before burning would be the preferable option.

Conclusions

The basic fuel properties of cereal grains make them serious contenders as biomass fuels. They are especially suited for small boilers (10-25kW) heating single homes, where their good flow properties and relatively high energy density facilitate storage and transfer into the boiler. In these respects they are only slightly inferior to wood pellets.

When dried to 15% moisture, all grains can be burned with high output and efficiency and with reasonable emission levels. Oats has the highest heat value of the common cereals and is likely to give the highest heat output. Grains have a higher ash content than pellets, so there will be more ash to dispose of and the boiler will need more frequent attention. Clinker should only be a problem with high-moisture wheat or barley.

For those who wish to avoid the cost of drying by burning wetter grain, triticale appears to be the best prospect. Oats and wheat can be burned at reduced output and efficiency. Barley is the least suitable grain for burning at high moisture.

Grain and pellets are alternative fuels for home heating. Grain has obvious attractions for tillage farmers and possibly for other rural dwellers.

HEMP (CANNABIS SATIVA)

Introduction

Hemp is a high-yielding annual fibre crop that produces cellulose, edible proteins and oils, with over 50,000 different product applications across a whole array of industries. The crop may be grown for both its fibre and oil.

Where can hemp be grown?

Hemp favours a deep humus soil but has been grown successfully on a wide range of soil types. It is permitted to grow hemp on set-aside land, providing that an industrial end-use contract is in place. Hemp production is supported in Europe by an aid payment to primary processors (known as the Fibre Processing Aid Scheme). Hemp is a relatively low input crop; therefore, organic production is possible. Hemp straw is delivered to processing facilities in large round or heston bales – 8 x 4 x 3. Haulage costs are likely to dictate that production remains within a reasonable delivery distance of processors.

What is hemp grown for?

Hemp grown in Ireland may be used to produce both fibre and seed. Fibre varieties may reach 3m in height under Irish conditions and are selected to produce large quantities of high-quality fibre. More recently, dwarf or dual-purpose hemp varieties have been introduced. These are primarily grown for the seed oil, with small quantities of fibre also produced. Fibre hemp is a high biomass crop and also shows potential as a renewable energy feedstock.

What is hemp fibre used for?

Once extracted and processed, hemp fibres are mainly exported to Europe for manufacture of car parts, textiles and construction materials. Major car manufacturers are already using hemp biocomposites for car components such as linings and parcel shelves. Other uses for the fibre include insulation and horticultural matting. The remainder of the plant, consisting of the hurd pith or the core, can be used for horse or poultry bedding, and hemcrete is used for house exteriors or for lime blocks.

Special restrictions

Currently, only cultivars with less than 0.2% tetrahydrocannabinol (THC), the narcotic component of cannabis, may be grown for fibre and seed oil production in the EU. In Ireland, Cannabis sativa (hemp) is classed as a controlled drug under the Misuse of Drugs Regulations and possession of the material is an offence. To enable the development of an industry based on hemp, a licence to grow approved varieties of hemp can be obtained. The approved list of varieties is published by the Department of Health & Children. All varieties evaluated in this project were selected from this list and grown under licence. Further information on obtaining a licence is available from the 'Social Inclusion' section of the Department of Health & Children, Tel: 01-635 4794/635 4338.

Key points

- **Annual, spring sown;**
- **licence required from Department of Health & Children/Irish Medicines Board;**
- **fibre production needs to be within a feasible distance of processing facility;**
- **low input; and,**
- **both fibre and dual hemp crops can be grown using conventional farm machinery.**

Agronomy – fibre hemp

Commonly, no pesticides are used on the crop. The crop is fast growing and quickly forms a dense canopy, which suppresses weeds. A pre-emergence broad-spectrum herbicide will prevent competition with weeds in the early growth stages. Sowing should take place once risk of hard frosts has passed.

Fibre crops require a higher plant density than those destined for seed production. Plant density has little effect on yield as self-thinning is seen at high plant densities. At low plant densities plants compensate by producing thicker-stemmed plants, which results in lower quality fibre. Optimal fibre yield can be achieved using sowing rates of 180 seeds/m^2.

Recommended:

- **sow from late April onwards using conventional seed drill;**
- **stale seedbed approach advantageous;**
- **80-120kg N/ha applied to the seedbed;**
- **35-40kg P/ha and 100-120kg K/ha;**
- **aim for target population of 115-130 plants/m^2; and,**
- **pesticides not currently used.**

Inputs

Current fertiliser recommendations are in the order of 80-120kg N/ha, with little response visible at higher rates. Hemp flea beetle, *Phyllotreta nemorum*, may be seen although the fast growing nature of the crop means control measures are rarely necessary. Potential fungal infections include *Botrytis cinerea* and *Sclerotinia sclerotiorum*, but again control is seldom justified.

Harvesting

To facilitate extraction of fibre from the woody core, after mowing in August the crop is left in the field for three to four weeks to rett. This allows fungal and bacterial breakdown of bonds between the fibre and surrounding tissue. The crop is then rowed up and baled. The crop must be stored undercover before delivery to the factory in order to maintain fibre quality.

Productivity – fibre hemp

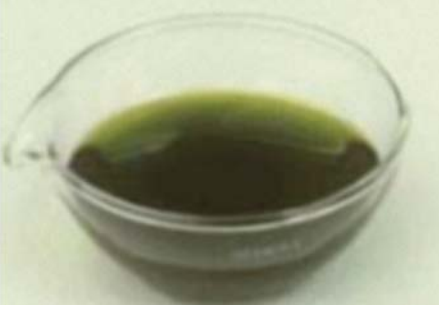
Teagasc, Oak Park achieved yields of 12t/ha during three-year research trials between 1997 and 1999. Processors requiring year-round supply may pay storage increments depending on date of delivery of the crop to the factory. Tokn Grain Products, Offaly, are offering contracts for 2008 for hemp bales ranging from €150/t for September delivery to €180/t for delivery the following August. Tokn Grain may be contacted on 087-254 3025.

Dual hemp

Recently, dwarf or dual hemp varieties have been introduced to the UK, most notably the variety finola. These varieties are much shorter, reaching just 1.5m in height, and are primarily grown for seed production. The small amount of straw produced may be used in certain fibre applications, such as composite manufacture for construction and automotive materials.

What is hemp oil used for?

Hemp oil has both industrial uses and applications in the health supplement and personal care markets. It contains many essential fatty acids thought to be of benefit to human nutrition. Hemp oil has similar industrial uses to that of linseed oil in paints and varnishes, and may also be used in printing inks and solvents.



Hemp oil.

Harvesting hemp.

Agronomy – dual hemp

Sowing rates are reduced in comparison to those used for fibre production. A sowing rate of 25kg/ha will generally give an adequate plant population.

Recommended:

- **sow late April/May;**
- **N 50kg/ha, P 25kg/ha, K 35kg/ha;**
- **no herbicides or pesticides;**
- **direct combined; and,**
- **harvest August–September.**

Harvesting and storage

The crop is harvested using a conventional combine harvester and the straw is baled for fibre use. Seed should be dried to 9% moisture and cleaned to 2% admixture.

Productivity – dual hemp

Yields of 1.25t/ha of seed are possible, with a straw yield of 1.5t/ha. Michael Harnett, Warringstown, Co. Down, will buy seed from farmers growing the dwarf varieties. Michael may be contacted on 0044 7802 276737 or mike@waringestate.com.

Miscanthus

Introduction

Miscanthus is a tall perennial C4 grass, which originated in Southeast Asia. Miscanthus has been evaluated in Europe over the past five to ten years as a new bioenergy crop. It is sometimes called elephant grass (although true elephant grass is a different species – *Pennisetum purpureum*) or 'e-grass'. Most of the miscanthus cultivars proposed as commercial crops in Europe are sterile hybrids (Miscanthus X Giganteus), which originated in Japan. As miscanthus is sterile, it produces no seed; therefore, it must be established by planting pieces of the root called 'rhizomes', which are usually collected from nursery fields where miscanthus has already been established.

Miscanthus can be harvested every year with a maize harvester or cut with a conditioner mower and baled. It can be grown in a cool climate like that of Northern Europe. Similar to other bioenergy crops, the harvested stems of miscanthus may be used as:

- **fuel for production of heat and electric power (the technology for this is proven); and,**
- **liquid biofuel after conversion to bioethanol (this technology is not yet fully developed, but there are high hopes for it).**

Miscanthus has:

- relatively high yields – 8-15t/ha (3-6t/ac) dry weight;
- low moisture content (as little as 15-20% if harvested in late winter or spring);
- annual harvests, providing a regular yearly income for the grower;
- good energy balance and energy output/input ratio compared with some other biomass options; and,
- low mineral content, especially with late winter or spring harvest, which improves fuel quality.

Miscanthus rhizome.

Soils

Miscanthus can be grown in a wide range of soil types. The optimum pH is between 5.5 and 7.0. The crop appears to perform best in heavier type soils, which are more water retentive. However, as miscanthus will be harvested in March or April it is important to plant in fields that remain trafficable for harvest. There is no nutrient requirement for the first two years after establishment. Limited research is available on miscanthus to date; however, the best available research indicates N requirement at 50kg/ha, P 13kg/ha and K at 120kg/ha. The application rates will depend on a soil analysis report.

Site selection

Since miscanthus will exist on the site for at least 15 years and can reach up to 3.5m in height, its impact on the local landscape, particularly if the site is close to a footpath or a favourite view, needs to be considered. Impacts on wildlife, archaeology and public access must also be addressed prior to planting. In addition, the impact of harvesting machinery on the soil should be considered. Soil-diffuse pollution should be prevented by ensuring that soil compaction is minimised, and that soils retain good structure. Up to 10% of eligible land for the Bioenergy Scheme can remain uncropped with miscanthus in order to accommodate landscape and access issues, with no impact on the amount of grant awarded. The positioning of these spaces also needs to be considered in terms of sympathetic landscape views, while enhancing wildlife and minimising soil compaction.
Miscanthus has the potential to encourage a greater diversity of wildlife than some agricultural crops, particularly if located in an area of low conservation value or as a link between existing habitats. It may also provide an area of sheltering habitat. Care must be taken to prevent this new habitat from adversely affecting existing conservation areas.

Harvesting.

Growing miscanthus as a fuel is very energy efficient.

Planting

Miscanthus rhizomes should be planted between March and May, and after ploughing and seedbed preparation; this reduces weed pressure as efficiently as possible and provides a good rooting zone.

Soil should be cultivated to a depth of 20cm. It is important to plant early to take advantage of high soil moistures and ensure good establishment to facilitate the formation of larger rhizome systems. The final density of established plants should be 1m^2. For this reason, one to two plants should be planted per metre squared.

Weed control

Weeds compete with the crop for light, water and nutrients, and can reduce yields. Weed control in the establishment phase of the crop is essential, because poor control severely checks the development of the crop. It is vital that proposed sites should be cleared of perennial weeds before any planting takes place. Before choosing a product, all growers should contact the Pesticide Control Service at the Department of Agriculture, Fisheries & Food, to make sure the product has the appropriate approval for use on miscanthus. Visit http://www.pcs.agriculture.gov.ie for further information.

Herbicide application must not be made on miscanthus crops greater than 1m in height, and the crop cannot subsequently be used for food or feed. A wide range of herbicides has been used effectively in Denmark and the UK, with no visible damage to the crop. Following the establishment year, an annual spring application of a broad-spectrum herbicide may be needed to control grass weeds such as common couch and annual meadowgrass and broad-leaved weeds with early season vigour (in the second year and possibly subsequent years). Glyphosate and paraquat have been used in this dormant period between harvest and initiation of spring growth but they will cause severe damage to any new shoots that might have emerged. Once the crop is mature (i.e., from the summer of the second or third year, depending on site and climate), weed interference is effectively suppressed, initially by the leaf litter layer on the soil surface and subsequently by the closure of the crop canopy, which reduces the light penetrating into the under-storey. Since there are no label recommendations, all products are used at the users' own risk.

Pests and diseases

Miscanthus species are susceptible to pests and diseases in the areas to which they are native (Asia) but, as yet, none of these has been reported in the UK or Ireland. Stem basal diseases may infect stems in the autumn or winter, reducing stem strength. There are no reported insect pests in Europe that have significantly affected the production of miscanthus. However, two 'ley' pests, the common rustic moth and ghost moth larvae, feed on miscanthus and may cause problems in the future. Rabbits can also be a problem in establishing a new miscanthus crop, as they like to feed on the fresh emerging leaf as the crop grows initially. Fencing may be required if rabbits pose a serious threat to establishment.

Harvesting

The two main methods of harvesting are:

- **direct chipping using a maize harvesting header; and,**
- **cutting with a conditioner mower and baling.**

The choice of harvesting technique should be made by considering the type of harvested material required (i.e., chips, bundles, bales or pellets) and the cost of the harvesting process.

EU BioBase research has observed that the Big-Round-Baler (Welger RP200) and the Big-Rectangular-Baler (Welger D4000) are capable of producing compact miscanthus bales with dry matter densities of approximately 120kg per cubic metre.

Miscanthus is harvested in February or March. The period can be extended until just before the buds begin to shoot in May. Although biomass losses do occur due to the late harvest date, quality reasons favour a late harvest. At harvest in early spring the biomass can be dried down to 20% water content (on a wet weight basis). Ash components such as K and Cl are leached to a great extent during the winter. A critical factor for an energy crop is the moisture content at harvest. The drier the crop, the higher the energy yield and bale value. Moisture contents as low as 15% have been obtained in the standing crop at Teagasc, Oak Park, with the maximum being approximately 40%. The stem moisture content can be halved by conditioning and drying in the field in windrows.

Crop yields

The crop yields from 10-15 tonnes of dry matter (dm) per hectare per year. The first harvest occurs two years after planting, yielding 6-10t/DM/ha. The subsequent harvest, three years after planting, will give maximum yields from 10-15t/DM/ha. However, we are still on a learning curve in determining the average yields for Ireland. Ireland's maritime climate suits the growth of miscanthus and crop yields should exceed average yields in many other European countries.

The reasons for the variation between sites in the yield in the building phase and in the plateau phase are planting density, soil type and climate. At sites where moisture supply or exposure limits yield, there may be a longer 'yield-building' phase.

Transport

The bulk density of miscanthus is very low at 70-100kg/m^2. Therefore, if the crop is harvested in chipped form it should be used for a local heat or electricity market. It is necessary to plan the production within close proximity of the end-use market. If miscanthus is baled the bulk density improves to 130-150kg/m^2. **Table 1** gives a breakdown of the weights of various bales for transport purposes.

Table 1: Miscanthus bale weights.

4 x 4 round bales	**250 - 350kg**
5 x 4 round bales	**350 - 425kg**
8 x 3 x 2	**220 - 250kg**
8 x 4 x 3	**290 - 370kg**
8 x 4 x 4	**450 - 550kg**

Taking the 8 x 4 x 4 bales as an example, it is possible to transport 10 bales per layer going three bales high. This allows transport of 30 bales on a standard 12m trailer at approx 500kg per bale. The total amount transported is 15 'wet' tonnes of miscanthus.

Bailed miscanthus.

Miscanthus with a moisture content of 20% has an energy content or calorific value of 13.7MJ/kg or 13.7GJ/t. Therefore, the total amount of energy transported is 205 gigajoules (GJ). This is equivalent to approximately 5,600 litres of kerosene. The estimated transport costs are €220-€250 for an 80km journey.

Removal of miscanthus

Miscanthus can be easily removed from an existing site by the application of a post emergence non-selective herbicide such as glyphosate. This is followed by rotovating the crop to eliminate the miscanthus rhizome.

Energy value

Miscanthus has a net calorific value, on a dry basis, of 17.76MJ/kg, with 2.7% ash content. The higher the moisture content of a fuel the lower the energy value. The energy value of 10 tonnes (1ha) of dry miscanthus would be equivalent to that of six tonnes of coal or 22 tonnes of peat at 50% moisture. **Table 2** demonstrates the energy content or calorific value of miscanthus at varying moisture contents.

Growing miscanthus as a fuel is very energy efficient. A UK lifecycle energy analysis determined an energy ratio of over 30 for miscanthus, i.e., for every unit of energy expended in producing the crop, over 30 units of energy are obtained. Miscanthus can be used for large-scale electricity power stations or for small-scale heat production in appropriate boilers.

Economics

Because there are no developed markets for miscanthus it is impossible to quote available markets. However, we can compare miscanthus in terms of its value to the kerosene oil that it can displace from the market. Miscanthus at a yield of 10 oven-dried tonnes per hectare at 20% moisture will give an overall yield of approximately 12.5t/ha.
If the yield at 20% moisture is 9t/ha in year two and 12.5t/ha from year three onwards, the farmer will require a definite price per tonne or gigajoule of energy supplied of miscanthus to justify switching to the crop. The crop is harvested annually.
One tonne of oil contains 42MJ of energy and one tonne of miscanthus at 20% moisture contains 13.7GJ of energy. One tonne of oil (1,145l) at 60c/l costs €687. If we take the energy content of miscanthus as one-third of the oil it equals €226/t. If a farmer received less than 50% of this and received €100/t this results in a figure of approximately €7.30 per GJ of energy supplied.
At this price miscanthus gives a gross margin per hectare in excess of €1,000, beating most farm enterprises. This is not taking into account Single Farm Payment and REPS, which are additional payments, nor does it take account of the opportunity cost of lower labour requirement and potential to work longer hours off farm.
To achieve this market return, the establishment of farmer supply chains for specific markets is required.

Table 2: Miscanthus price per tonne paid to farmer.

Moisture %	CV MJ/kg GJ/tonne	€3.60 GJ/tonne	€5.50 GJ/tonne	€7.50 GJ/tonne
40	9.7	€34.9	€53.3	€72.7
30	11.7	€42.1	€64.3	€87.7
20	13.7	€49.3	€75.3	€102.7
10	15.7	€56.5	€86.3	€117.7
0	17.8	€64.1	€97.9	€133.5

Table 3: Costs of establishing miscanthus.

Operational costs		Material costs	
Plough	€50	Roundup	€40
Cultivate	€30	Rhizomes	€2,200
Spray 1	€15	Sel weed killer	€40
Spray 2	€15	Subtotal	
Plant	€510		
Subtotal (A)	€620	Subtotal (B)	€2,280
		Total costs (A+B)	€2,900

Table 4: Income from miscanthus.

Sale of miscanthus €/t or €/GJ.
Energy payment for 2007, 2008, 2009 = €125/ha.
Single Farm Payment will be paid on land planted with energy crops.
REPS will be paid on first 10 hectares or 25% of holding, whichever is greater.

Oilseed Rape

Introduction

Oilseed rape (OSR) is a major worldwide source of vegetable oil, third to soya and palm. In the early 'nineties, 6,000 hectares were grown in Ireland, most of which was processed in the UK for food use. OSR production has declined in Ireland due to changes in the Common Agricultural Policy that made OSR production economically unattractive. However, there is renewed interest in the crop due to the introduction of the Single Farm Payment; an energy premium on OSR; and, demand from local biofuel processors. In 2006, 5,133 hectares of OSR was grown in Ireland (source Department of Agriculture, Fisheries & Food, 2007). Forward contracts are being offered by processors of oilseed rape at present to stimulate growing of the crop. The loss of sugar beet as a break crop has also increased interest in the crop.

OSR in a rotation

OSR offers a number of benefits when included in a crop rotation:

- **it acts as a break crop for take-all fungus in cereal rotations. The yield increase in the following cereal crops is approximately 0.7-1.5t/ha depending on soil type;**
- **it offers the opportunity to control grass weeds that are difficult to control in cereals; and,**
- **it spreads workload, due to earlier sowing and harvesting of OSR.**

OSR should not be grown more than one year in five to prevent the buildup of soil-borne disease such as club root. OSR, beans and potatoes are common hosts of the sclerotinia fungus, which is an economic disease of all three crops. OSR also acts as a host for the beet cyst eelworm.

Economics

High yield must be obtained from the crop in order to make it economically viable. Growers should aim to achieve yields of at least 4.5t/ha for winter rape and 3.0t/ha for spring rape. Below is a comparison of crop margins adapted from Teagasc Costs and Returns 2007.

	Winter wheat	Spring barley	Spring beans	Winter oats	Winter OSR	Spring OSR
Expected yield (t/ha)	10	7.5	6	8.2	4.5	3.0
Price (€/t)	150	140	170	140	260	260
Gross margin (€/ha)	585	440	436	404	382	307

When compared with wheat or barley, OSR needs to increase in price and the energy premium paid also needs to increase substantially for it to be a viable option. When measured against other break crops such as beans and beet, OSR is a marginal option given the recent increase in world commodities. Growers must know which break crop will achieve the expected yield on their farm. Each farm must assess long-term profits, including rotational and workload benefits, before deciding on a suitable cropping mix.

Crop agronomy

Soils

Free-draining, medium to heavy soils are best suited to OSR production. The crop fails to reach its yield potential on very light or waterlogged soils.

Establishment

Winter OSR should be sown between August 15 and September 15. Prepare a fine, firm level seedbed. OSR is a small seed with low reserves, therefore the seedbed and sowing depth are critical to a successful establishment. Sow to a depth of 1.5cm (0.5 inches). Ploughing followed by the one-pass drilling technique is still popular but minimum tillage as for cereals is also satisfactory.

Ideally, cultivation should be completed when soil conditions are dry, as rape does not like compaction. The seedbed should be rolled, as rape requires a consolidated seedbed to retain moisture. Spring rape can be sown from mid March to late April depending on soil conditions.

Varieties

There is no current Irish Recommended List for OSR. The UK's Home-Grown Cereals Authority (HGCA) recommended list is our best guide for variety selection (see www.hgca.com).
Yield, disease resistance, standing power and earliness of maturity are the most important factors influencing variety selection. There are a number of ways (described below) to classify OSR varieties; breeding method (conventional or hybrid); oil characteristics (double low or HEAR); and, canopy characteristics (low biomass).

OSR varieties:

- **conventional varieties are varieties bred by crossing two parent lines and self-propagating the progeny to produce a stable, fertile line;**
- **hybrid varieties are varieties bred by crossing two parent lines but not self-propagating the progeny to produce a stable fertile line. Hybrid varieties are not stable and therefore require specialised crossing each year for seed production;**
- **double low varieties are all varieties (conventional and hybrid) suitable for the food and animal feed markets, have low erucic acid and low glucosinolates;**
- **HEAR – high erucic acid rape are varieties grown specifically for industrial lubricants and are not suitable for human or animal markets. Currently, no contracts are available in Ireland for HEAR varieties; and,**
- **low biomass varieties are varieties that have been bred to have a lower percentage of non-seed biomass than taller varieties.**

Seed rate

Winter OSR: Aim to sow 70-90 seeds/m^2 for conventional varieties and 40-60 seeds/m^2 for hybrid varieties. Where seedbed conditions are poor or where problems with slugs are anticipated, higher seed rates may be justified. Expect up to 50% loss of seeds planted between sowing and springtime. Recent work has shown that very dense stands of OSR are less efficient at intercepting light and converting it to yield than open stands. The target plant population for OSR in the springtime is 30-50 plants/m^2, evenly spaced and well developed. Spring rape is normally sown at 100-120 seeds/m^2.

Lime and fertilisers

The pH for OSR should be above 6.5. Phosphorous (P) and potash (K) should be applied at sowing for soils at Index 1 but can be applied with the first split of nitrogen (N) to Index 2, 3 and 4 soils.

Table 1: Nitrates Directive (NPK) recommendations for winter and spring OSR (kg/ha).

Soil N, P, K Index	N	P	K
1	225	35	65
2	180	30	35
3	160	20	25
4	140	None	None

The first split of N (30% of the total) should be applied in late February and the remainder in late March/early April. It is unlikely that the application of N at sowing time is justified, but if it is used, it should not exceed 40 kg/ha. Fertiliser applications should not be combined drilled as this may delay germination.

Sulphur

OSR is responsive to the application of sulphur (S). A dressing of 25-40kg/ha S should be adequate. This should be applied as part of the fertiliser programme in the spring with either the first or second N application.

Magnesium

Magnesium (Mg) has a major role in plant function as it is one of the main components in the plant's chlorophyll. Mg is involved in the transport of sucrose and protein from the leaf to the developing seed. Where soils are deficient in Mg, or where conditions will induce a deficiency, apply Mg either as a fertiliser in the form of kieserite or, when liming, apply Mg limestone.

Boron

Boron (B) should be applied for OSR, especially when the soil test is below 1mg/l. Severe B deficiency causes stunting and brittle petioles, but relatively mild deficiency results in poor seed set and a reduction in seed numbers per pod and seed weight. These conditions can be induced by severe summer drought. B can be applied as part of the fertiliser programme with the P and K, or as a foliar spray. In severe B deficiency, 30% of the total B may need to be applied in the autumn and the balance in the spring for winter OSR. For spring OSR, apply B with the base fertiliser or, alternatively, apply B as a foliar spray early in the life cycle of the crop.

Weed control

Grass weeds, particularly volunteer cereals and wild oats, will reduce the yield of OSR substantially. ADAS (UK) trials show that 150 volunteer cereals/m^2 can reduce yield by 50% while the same population of broad-leaved weeds will only reduce yield by 8%. Broad-leaved weed control options are limited in OSR. Fields with high populations of charlock, cleavers or poppy may need to be avoided for rape production. As well has having yield penalties, weed seeds will incur admixture (weed seeds and chaff) penalties when sold to processors. Scutch should be controlled in the previous crop but graminicides may be used in the growing crop.

Spring rape, when sown at the correct time, normally does not warrant broadleaved weed control as it can out-compete weeds. However, grass weeds may need control as with winter rape.

Pre-sowing (winter OSR)

Trifluralin (Treflan) 2.3l/ha should be incorporated in the top 5-8cm (2-3 inches) of soil within 30 minutes of application. Susceptible weeds include: chickweed; fat hen; hempnettle; speedwells; and, polygonums.

Pre-emergence (winter OSR)

Butisan S (2.5l/ha or split 1.5 + 1.0l/ha) can be applied within 48 hours of sowing. Susceptible weeds include: annual meadowgrass; chickweed; forget-me-not; groundsel; marigold; mayweeds; parsley-piert; poppy; speedwells; shepherds purse; and, red deadnettle. Cleavers is moderately susceptible. Charlock and wild oats are moderately resistant.

Post-emergence (winter OSR)

Graminisides, e.g., Co-pilot, Falcon, Fusilade Max, Gallant Solo and Stratus Ultra, can be used from the 1-true leaf stage of OSR up to early flower bud stage. However, application is recommended early at the 2- to 3-leaf stage of the grass weed before the grass weeds are sheltered beneath the OSR canopy.

Metazachlor (e.g., Butisan S) can be used post emergence provided weeds are not beyond the maximum susceptible growth stage, e.g., marigold, speedwells and annual meadow grass up to 2-true leaves, and mayweeds up to 4-true leaves. Propyzamide (e.g., Kerb Flo) at 1.75l/ha is a soil-acting residual herbicide. It controls grassweeds, volunteer cereals, wild oats and a range of broad-leaved weeds. Cleavers is moderately susceptible up to two leaves. Apply as soon as possible after the crop has 3-true leaves in the October to January period. Weeds take four to 12 weeks to die.

Disease control

The main diseases of concern are phoma leaf spot (up to 25% yield reduction), light leaf spot (up to 50% yield reduction) and *Sclerotinia* (up to 50% reduction). Other diseases include alternaria pod spot, which can infect pods and result in pod shattering, but generally would not warrant a fungicide application. OSR is also susceptible to club root, which is controlled by rotation. Spring rape is normally disease free and, as a general rule, would not warrant any fungicide spray. For winter OSR disease a fungicide programme for the control of the main diseases, phoma and light leaf spot, will involve one to two fungicide applications based on observing threshold levels and previous cropping history.

Apply 50% rate of flusilazole or tebuconazole when 10-20% of plants show symptoms of phoma leaf spot or when symptoms of light leaf spot are found before stem extension, or if 25% of plants show symptoms at early stem extension. A second fungicide will be required if re-infection occurs in the spring.

Assess *Sclerotinia* risk by taking account of previous infections, rotations and current weather. Fungicides must be applied preventively and spray timing is more critical than product choice. The optimum is usually early to mid-flowering. Triazoles with plant growth regulator (PGR) activity, e.g., tebuconazole, have the added benefit of reducing plant height and reducing lush crop canopies. This effect will increase branching and allow more light to penetrate the canopy after flowering.

Pests

Slugs and pigeons are the most common pests of OSR in Ireland. Control slugs where anticipated by the application of metaldehyde pellets (e.g., Matarex) or methiocarb pellets (e.g., Draza). Pigeons are usually only a problem on late-sown crops. Well established crops can recover from moderate grazing. Shooting is the best method of control.

Pollen beetles are sometimes a problem at the green bud to flowering stage. Control with suitable insecticides when numbers exceed 15-20 beetles/plant at the green/yellow bud stage. Later spraying is of little benefit but is detrimental to bees. This pest is more common in spring rape, where it is routinely treated. Three beetles per plant is the threshold level in spring rape. Cabbage stem flea beetle causes ‘shot-holing’ of leaves soon after emergence and is occasionally a problem but control is only warranted if more than 25% of the leaf area is eaten at the 1-2 true leaf stage. The larvae burrow in the stem, causing lodging. The feeding action of aphids in the autumn can cause serious losses and also spread viral diseases. Cabbage stem flea beetle and aphids are controlled by suitable insecticides.

Note: Care should always be taken if applying insecticide to OSR crops in flower to avoid detrimental effects to bees.

Harvesting

Harvesting of winter OSR usually takes place from the end of July to early August. The crop can be desiccated and direct combined or swathed.

Desiccation and direct combining

Desiccation will even the crop for harvesting and is most suited to sheltered sites. It has the added benefit of controlling difficult weeds such as scutch grass and perennial weeds. However, wind losses will be incurred if harvesting is delayed when the crop is mature. Glyphosate products are applied around 14 to 21 days before harvest when two-thirds of the seeds are brown and one-third are green in pods taken from the centre of the main raceme. Diquat products are applied slightly later than glyphosate, around seven to 10 days before harvest, when all seeds in the bottom pods are brown/black and seeds in the middle pods are reddish to dark brown. Use a high water volume (300-400l/ha) if possible, as spray is contact only. Pods become more brittle than with glyphosate products. Use high ground clearance tractor/sprayer as losses can be significant when desiccating.

Swathing

Swathing is carried out approximately 14 to 21 days before harvesting when the seeds in the top pods are turning from green to brown, the middle pods are mainly brown, and lower pods are darker brown. The stubble should be 20-30cm high. Swathing will not control weeds as they are only cut. Swathing is favoured in exposed locations as the pods are not shaken by wind as much as if they were standing. However, moisture levels are harder to lower in broken weather than in a standing crop. The cost of swathing by a contractor is €15-20/acre depending on location.

Minimising seed losses

Correct setting of the combine is essential to minimise seed losses at harvest. Refer to manufacturers' recommendations for individual settings. However, some general principles apply to all machines: the table to auger setting should be increased as much as possible and the auger speed reduced; vertical knives or dividers are necessary for standing crops; and, combines and trailers should be well sealed to avoid losses.

Note: Avoid walking on OSR in heaps or across trailers as there is a risk of sinking and suffocating.

Rapecake the bi-product from crushed rapeseed – a valuable animal feed or potential fuel.

Volunteers

To reduce the amount of volunteer OSR in subsequent crops, seed lost during harvest should be left for as long as possible on the soil surface. This encourages germination of the seed. If seed is buried before it germinates it becomes dormant and can remain viable for up to 10 years in the soil. If specialty varieties of OSR are grown, varietal purity of the crop becomes more of an issue for growers, thus placing more of an emphasis on volunteer control.

Aid/marketing

Single Farm Payment

OSR is an eligible crop for drawing down Single Farm Payment entitlements. In addition to the Single Farm Payment, an Energy Crop Premium and national top-up totalling €125/ha is paid where OSR is grown under contract as an energy crop. This is regulated by the Department of Agriculture, Fisheries & Food (DAFF), Energy Section, Portlaoise.

Farmers intending to grow OSR for energy must sign a contract with a registered processor/assembler. This contract is then submitted by the processor to the DAFF so that the Energy Premium is paid to the grower with the Single Farm Payment. Processors are required to pay a refundable bond to the DAFF, which ensures that only OSR processed for biofuel is paid the energy premium.

Oilseed rape costings

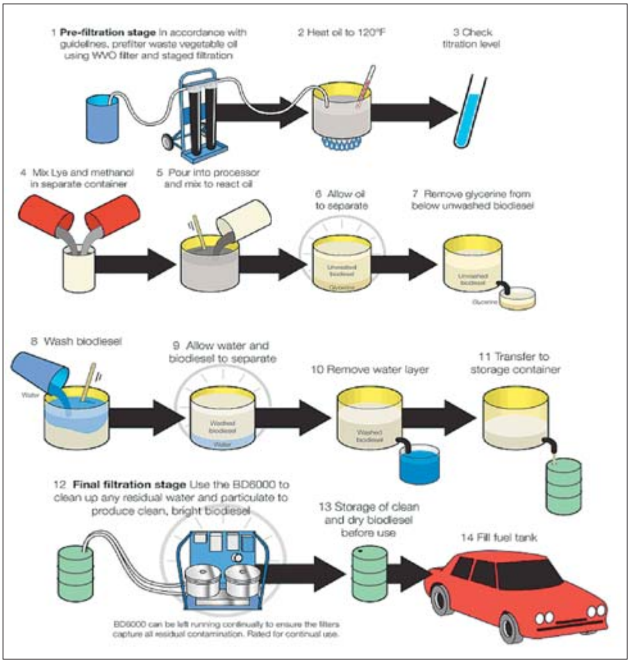
€/ha	Winter	Spring
Materials	**432**	**236**
Seed	60	50
Fertilisers	240	180
Sprays: Herbicides	80	0
Fungicides	36	0
Insecticides	16	6
Hire machinery	**435**	**344**
Plough till and sow	146	146
Roll	17	17
Spray	68	34
Fertiliser	34	17
Spreading swathing	50	0
Harvesting (including grading into storage)	120	130
Miscellaneous	**46**	**18**
Interest (7%)	18	7
Transport (€4.5/tonne)	22	11
Bird control	6	0
Total variable costs	**913**	**598**
Yield to cover variable costs	3.8	2.5
Net Price €/t	240	240
Energy crop aid	125	125

Specialty OSR markets

Some breeding programmes are targeting new high value markets, e.g., oils with specific fatty acid profile and other health benefits. Dow Agro and Monsanto currently offer UK growers specialty OSR contracts through dedicated seed assemblers. These varieties are called HOLL (high oleic low linolenic) varieties and attract a premium price. HOLL varieties produce oil that is more stable under repeated cooking conditions and is attractive for the fast food and industrial cooking industries, etc. These HOLL varieties carry a 10% yield penalty compared to the top yielding varieties on the HGCA list, but future varieties promise to be higher yielding. OSR breeders are also developing breeding lines for other premium markets, such as high value lubricants and polymers.

Pure plant oil to biodiesel

When OSR is crushed it produces one-third of its weight as pure plant oil (PPO), which can be used on modified diesel engines, and two-thirds as rape cake, which is a valuable high protein animal feed. This PPO can be further modified and turned into biodiesel.



Making biodiesel.

Biodiesel is made by chemically altering an organic oil (typically vegetable oil) through a process called 'transesterification'. Essentially, the process thins down the oil to allow it to run in an unmodified diesel engine. It is a very simple process. Vegetable oil is placed in a reaction vessel and mixed with alcohol and catalyst. After mixing for a period of time, it is then allowed to settle. It will then separate and form two distinct layers. The top layer is biodiesel and the bottom layer is the glycerol. Allowing sufficient time for complete separation, the glycerol is drained out and the remaining biodiesel is washed to remove excess catalyst and other impurities before finally being filtered for use.

Biodiesel can be made from almost any vegetable oil. All vegetable oils have different properties that make them either a good source for biodiesel or not. Biodiesel can be made from fresh vegetable oils, including but not limited to palm, rape, OSR, coconut, mustard and cotton oils. It can also be manufactured from tallow oil (animal fat) and yellow grease (used cooking oils). Several different kinds of fuels are called biodiesel; usually, biodiesel refers to an ester, or an oxygenate, made from the oil and methanol, but alkane (non-oxygenate) biodiesel, i.e., biomass to liquid (BTL) fuel is also available. Sometimes even PPO (unrefined vegetable oil) is called biodiesel. PPO requires fuel pre-heating and filtration due to issues with coagulation, and also some modification to the fuel system.

When made to the EU quality standard EN14214, biodiesel is a better lubricator than petro-diesel and tends to be a better cleaning agent for the fuel system. It also has a higher cetane rating, which means it is a better fuel. Biodiesel is not compatible with ordinary rubber. If a fuel system has rubber fittings it can be replaced with Viton to counter this. Most diesel engines today do not have rubber fittings.

REED CANARY GRASS

Fact file

Botanical name	***Phalaris arundinacea L.***
Description	**Tall native grass commonly found in wetlands**
Establishment	**By seed**
Growing season	**February to July**
Potential yields	**5-7 tonnes of dry matter per hectare (annually)**
Harvesting interval	**September to January**
Harvesting method	**Mowing followed by baling**
Potential problems	**Stem damage by pests, lodging, invasive weed**
Potential markets	**Electricity production, heat production**

Introduction

Reed canary grass (RCG; *Phalaris arundinacea L.*) is a perennial grass, which is naturally distributed throughout Europe and in temperate regions of North America and Asia. The grass is tall and leafy and in natural conditions is most commonly found growing along water margins. RCG grows rapidly under Northern European conditions and has long been recognised as a crop with a high biomass potential. Interest in RCG as an energy crop began in

Sweden in 1981 and it has since been evaluated throughout Europe. For a species to be considered as an energy crop it requires high yield potential and high dry matter content at harvest. Additionally, it should require little cultivation, few nutrients or crop protection chemicals, and the biomass should have a low concentration of minerals to make it suitable for combustion.

RCG is not grown as a crop in Ireland. However, research in the UK shows that the crop can be grown throughout England and Scotland. This work has shown that it does well in more northerly latitudes, although it does not appear to have quite the yield potential of other energy crops.

Growth

RCG can be grown from seed, and once mature it reaches a height of 150-300cm. It spreads underground by rhizomes approximately 1cm thick and can root to a depth of 3m. New shoots are produced from the underground rhizomes in early spring, typically in February or March. Flowers are produced in early summer, after which the crop matures. The crop can be expected to remain productive for up to eight years, after which its productivity declines.

Where it can be grown

RCG grows well on most soil types. It is one of the best grass species for poorer soils and is very tolerant to flooding. It thrives particularly on wet humus-rich soils where it gives the highest yields and best quality of biomass. Heavy clay soils are less suitable for establishment and early growth. It is more drought resistant than many other grass species even though it grows naturally in wet places. Optimum pH is 6-7.

Sowing

Seedling establishment is the most critical stage in the maintenance of a good RCG stand. The best stands are obtained when seed is sown no deeper than 1-2cm in a well prepared, firm seedbed. Rolling before and after sowing is highly recommended. Seed is typically sown in rows 12.5cm apart, and recommended seeding rate is 15-20kg/ha-1. The best time to sow is May.

Varieties

RCG has been used as a forage crop. Several breeding programmes have attempted to improve the nutritional quality, as well as the yielding capacity, of the crop. However, different characteristics are needed for RCG grown for bioenergy purposes. Specifically, the content of nitrogen (N) and potassium (K) should be lower, the lignin content higher and the plant morphology should be characterised by a higher share of thicker stalks. Varieties that have shown promise in trials include bamse, chiefton and palaton.

Reed canary grass can be expected to reach profitability sooner than miscanthus and switchgrass.

Weed control

Weeds compete with the crop for light, water and nutrients. The seeds of RCG are generally rather slow to germinate and weed competition can be a problem in the first year. From the second year on, weeds are less of a problem, as established stands are more competitive and the early growth pattern of RCG tends to suppress weed competition.
A contact herbicide (glyphosate, paraquat) should be applied in the autumn before sowing and again several weeks prior to sowing. After sowing, broad-leaf species can be controlled with common herbicides. Herbicides that have been used on RCG include Chlorpyrifos, Dimethoate, Mecoprop-P, Bromoxynil and Fluroxypyr. Grass weeds can be suppressed by mechanical mowing just above the RCG seedlings.

Fertilisation

Like other energy crops, the response to fertiliser is variable and appears to depend to a large extent on soil fertility. RCG appears to have greater nutrient requirements than other energy crops, particularly with regard to nitrogen. Best advice is:

- **maintain phosphorus (P) and K levels in the soil;**
- **use N sparingly in the first year to avoid stimulating weed competition; and,**
- **apply N from year two onwards at 60-100kg N/ha-1.**

Pests and diseases

RCG can be attacked by the larvae of various insect species, which kill the stems by feeding inside their base. This damage can occasionally cause significant yield reductions. Double lobed moths and

fritflies have both been associated with stem damage in RCG. Aphids and leaf miners can also attack. Significant insect damage has been reported in UK trials, with subsequent effects on yield. Grazing by rabbits and slugs may also be a problem, particularly in the establishment year.
Diseases have been reported on RCG, although not at levels that might cause concern. Brown rust, mildew, buff spot, powdery mildew and *Rhynchosporium* have all been reported.

RCG after mowing

RCG can be harvested with conventional grass harvesting machinery. The crop is typically mown first before baling. Energy crops are left in the ground over the winter period and harvested the following spring. The over-winter period allows crops to dry, avoiding the need for expensive artificial drying. Combustion quality also improves over the winter period. The optimum harvest time is different for RCG compared to other energy crops. RCG should be harvested before spring. The reasons for this earlier harvest date are related to its growing period. The crop starts growing in February and matures in July. Early maturation means that drying is completed earlier than switchgrass or miscanthus. Additionally, harvesting before growth starts in February is recommended to avoid the inclusion of new growth in the harvested material and a consequent deterioration in biomass quality. Earlier harvest date confers an advantage, as supply of biomass from energy crops will not be confined to one part of the year.
RCG can be expected to reach full yield potential in the second or third year after sowing, whereas switchgrass and miscanthus can take four to five years to reach full yield potential. Dry matter yield, however, is lower than other energy crops (<7t DM/ha) and productivity can be expected to decline after seven years or earlier.

Summary of issues

Lodging can be a problem in RCG crops and can affect biomass yield. There are differences in the degree of lodging between varieties, although crops appear to be able to recover from mild lodging. Insect pests can cause problems in RCG crops. Pests cause damage by feeding inside the base of, and killing, the stems. In many cases damage can be slight although, in UK trials, up to 50% of stems have been damaged by insects, with a subsequent effect on yield.
Although native to this country, RCG is an invasive species and can spread to adjoining fields and be difficult to control. Surrounding fields should be monitored on a regular basis to check for the presence of RCG volunteers. Two approaches can be used to control volunteers in cereal crops. Herbicides used to control grass weeds in cereal crops can be used or, alternatively, a broad-spectrum herbicide can be applied after the cereal crop has been harvested. Control in pasture is more difficult; cutting and mowing is possibly the best strategy to prevent flowering and further spread. There is little experience of this crop in Ireland and it is difficult to quantify the extent to which RCG can be expected to spread.

Economics

The economics of RCG production are dependent on fixed and variable costs, biomass yield, and the price paid by the purchaser. The least profitable year in the life of the crop is the establishment year, where the costs of establishment and weed control must be borne without any income. Profitability increases in subsequent years as biomass yields increase. A crop lifespan of up to eight years is considered possible; high initial costs can be spread over this timeframe and it is important to consider the profitability of crops over this longer period.

One approach to economics is to calculate the cost per tonne of biomass produced. This takes out the estimated value of the crop and shows what value is required for the crop to break even. A cost analysis conducted in the UK based on yields of miscanthus, RCG and switchgrass across nine sites revealed that RCG had the highest price cost per tonne of these three crops. The higher costs principally result from higher fertiliser costs, lower yields and the fact that the crop needs to be re-sown at more frequent intervals compared to other energy crops.

However, RCG can be expected to reach profitability sooner than miscanthus and switchgrass as its establishment phase is of shorter duration. Its adaptability to wetter conditions will probably render it the most profitable energy crop on poorer soils. Additionally, its earlier harvesting period might attract a premium from electricity producers and other users interested in a year-round supply of biomass.

Markets

At present, the production of electricity and heat are the largest potential markets for RCG. The Government has set a target that 30% of peat burned in the three peat-fired power stations will be replaced by biomass by 2015. This will require growing approximately 80,000 hectares of energy crops, which could include RCG. The crop can be burned to produce heat or electricity. Its combustion characteristics are similar to miscanthus, although ash content can be higher. Other potential uses include chemical processing into pulp and as a feedstock for liquid biofuel production should that technology be successfully developed.

Environmental impact

Growing RCG as an energy crop brings a number of environmental benefits over conventional arable crops:

- **improved water quality and less nitrate leaching from reduced fertiliser use;**
- **greater biodiversity and improved water quality arise from the lack of chemical inputs; and,**
- **growing RCG lessens the effect of climate change for two reasons:**
  - **first, the crop absorbs carbon dioxide from the atmosphere and stores this carbon in the soil, reducing the build-up of greenhouse gases in the atmosphere. Carbon storage rates for greenhouse gases exceed those of annual crops by as much as 20-30 times; and,**

Reed canary grass.

– **second, the use of RCG as a fuel avoids the need to use fossil fuels. Burning fossil fuels releases carbon dioxide, a greenhouse gas, into the atmosphere, and this has been largely responsible for global warming. Burning energy crops also releases carbon dioxide into the atmosphere, but the plant re-absorbs this during the following growing season. Some greenhouse gases are released during the production of RCG and during its transportation. However, the use of RCG as a source of energy results in substantially lower emissions of greenhouse gases compared to the use of fossil fuels.**

RCG does not grow as tall as miscanthus and produces an attractive purple inflorescence in midsummer. Thus, the visual impact of the crop represents an improvement over taller crops such as miscanthus.

Conclusions

RCG is an energy crop that offers alternatives to other energy crops such as miscanthus and willow. Biomass yields on mineral soils are unlikely to be as high as other energy crops and unit production costs will be higher. However, RCG is easy to establish compared to other energy crops and grows well on poor, wet soils on which other crops will struggle. Additionally, its earlier harvesting interval facilitates a greater year-round spread in biomass supply. Consequently, it occupies its own niche and should offer growers an alternative on poorer soils. RCG has not been grown commercially in Ireland, although it has been grown successfully throughout the UK and North West Europe.

RCG is easier to establish than other energy crops, although good seedbed preparation and timely weed control are still necessary during the establishment phase. The crop will take two to three years to reach full yield potential, which can be expected to be five to seven tonnes of dry matter per hectare. RCG can remain productive for up to eight years after establishment. Insect pests and lodging can be problematic, affecting biomass yield in some cases. Harvesting can be carried out with conventional grass harvesting equipment.

Supplying biomass to the peat-burning power stations is the largest potential market for RCG at present. Pellets for heat production can also be produced from the crop.

SWITCHGRASS

Introduction

Switchgrass (*Panicum virgatum*) is a native species of North America and can be found from Mexico to as far north as Canada. The species is a common component of tall grass prairies and it is likely that it has been grazed for millennia. However, only recently has it become a crop in the sense that it was intentionally planted or managed. Switchgrass transition from the relative obscurity of being a native grass to being used as a crop came generally in the 1970s, and early research concentrated on its use for forage. Its potential as an energy crop was subsequently recognised by the US Department of Energy and considerable work has been carried out to ascertain the best varieties and management techniques.

Energy crops are those crops used specifically to generate energy. Interest in crops as a source of renewable energy began in the 1970s after the first oil crisis, but interest dissipated when oil prices dropped. There is now renewed interest in crops as a source of fuel, partly because of renewed concerns over fuel security and partly in response to attempts to mitigate the impact of climate change. Good energy crops use solar radiation,

water and nutrients very efficiently to yield large amounts of biomass, and have good pest and disease resistance. These characteristics are displayed by switchgrass. In addition, as switchgrass is a grass with a perennial growth habit, soil disturbance is only necessary in the first year of a 15-year cycle. Switchgrass has yet to be grown or tested in Ireland. However, European Union-supported research shows that switchgrass can be grown throughout Europe and can be used to produce inexpensive biomass under low input conditions and at a very low environmental impact. Recent research in the UK shows that switchgrass can be grown throughout the UK with no serious pest or disease problems, and with a profitability that competes with miscanthus.

Varieties

Switchgrass varieties can generally be divided into two types; lowland types, which are generally found in floodplains; and, upland types, which are found in drier upland areas. There are a number of North American varieties within these two types that have been found to be suitable to European conditions. The most important aspect governing variety choice is the latitude of origin, or where the variety originates from in the North American continent. Varieties that originate from southern states have been shown to do best in southern locations in Europe. However, these varieties do not yield quite so well in Northern Europe and will not over-winter as well as varieties that originate from northern states in America. Varieties that originate in northern states are hardier and show better over-wintering properties; however, such varieties mature quite early and do not have high yielding potential. Varieties that grow best in Northern Europe are those that come from intermediate latitudes in North America. Switchgrass varieties that have been grown successfully in North West Europe include Cave-in-Rock, Kanlow, Shelter and Carthage.

Planting

Switchgrass will grow in a wide variety of soil types and tolerates pH values between 4.9 and 7.6. Seed can be sown with a conventional seed drill. Alternatively, seed may be direct drilled or broadcast. Rolling both before and after sowing is highly recommended, as a fine firm seedbed is desirable. Sowing depth should be no deeper than 10mm.
Switchgrass seed displays a high level of dormancy, which can be broken after proper storage. Consequently, only buy certified seed that has had a germination test. Seed rate should be between 10 and 20kg/ha. Switchgrass should be sown when the soil temperature is warm. Best results will be achieved when the soil temperatures are greater than 10°C and when there is some moisture in the seedbed, but not when it is too wet. If switchgrass is sown too early the seedlings will not be able to compete with weeds, as the grass needs high temperatures to grow. In Ireland, sowing should normally take place in May.

Switchgrass seedlings after emergence.

Weed control

Weeds can be major obstacles to switchgrass establishment. Compared to other grasses such as perennial ryegrass, growth is slow in the first year and seedlings compete badly with weeds. Most switchgrass crops will require some form of weed control in the first year.
A contact herbicide is generally used several weeks ahead and again just before seeding. Glyphosate, Paraquat and hormonal herbicides (2,4-D, Dicamba, MCPA) are often used.

For post-emergence broad-leaf weed control, 2,4-D and Dicamba are often recommended as long as the seedlings are sufficiently mature (five leaves). However, low rates are recommended, as full rates may result in seedling damage. Other broad-leaf herbicides used include Bentazon, Ioxynil, Bromoxynil, Mecoprop-P, Metsulfuron, and Chlorsulfuron. Bentazon, MCPA and Mecoprop-P (which are expected to be approved for off-label use in Ireland by the Pesticide Control Service, Department of Agriculture, Fisheries & Food), applied as late as possible, have been recommended in the UK as the safest choice for broad-leaf weed control in the establishment year. Grass weeds are harder to suppress and mechanical mowing of weeds just above switchgrass height is recommended. The objective of weed control is to ensure that enough switchgrass seedlings survive the first winter and re-grow in spring. If this is achieved no further weed control may be necessary, as mature switchgrass crops will out-compete weeds. However, weed control may be necessary in subsequent years and Bentazon, MCPA, Mecoprop-P, 2,4 D and Dicamba are recommended for broad-leaf weed control in these years.

Pest and disease control

Diseases and insect plagues have not been a problem in new or established stands, as varieties have been found to have a high level of resistance. Grazing by rabbits and hares may be a problem in some instances. Spot blotch and rust have occasionally been reported on crops in the US, and low levels of phoma have been reported on switchgrass plots in the UK. In general, diseases are not a problem in switchgrass crops grown in Europe, although inspection at regular intervals is recommended.

Nutrient requirements

Switchgrass is very thrifty in the way it uses nutrients. There are a number of reasons for this. Switchgrass has very good nutrient use efficiency, and this means that the crop does not need as many nutrients (nitrogen [N], phosphorus [P], and potassium [K]) to create a fixed amount of biomass as other, less efficient, crops. Additionally, switchgrass recycles nutrients back to the underground rhizome when the crop matures in the autumn. These nutrients are then available for growth in the following year; a reduced amount of nutrients is removed during the harvest. On fertile soils, nutrients removed during harvest can be replaced from soil reserves and nutrients released when soil organic matter is broken down. Switchgrass is very efficient at using these organic nutrients, as it grows best at high temperatures when release of organic nutrients is greatest.

Fertilisation is not recommended in the first year, as the switchgrass crop does not need the extra nutrients in the early stages of its growth. Additionally, fertilisers can stimulate weed competition. In most instances switchgrass shows no response to N fertiliser, or only up to a level of 50kg/ha. It appears that the effect of N is largely site specific and is only effective on poorer soils. N, if used, should always be used sparingly as lodging may be enhanced and any unused N may contribute to weed competition in the following spring. Fertiliser application should be delayed until later in the growing season when it is less likely to stimulate weed competition. P and K should only be applied if soil availability is low.

Harvest

Switchgrass can be harvested using conventional grass harvesting machinery, mowing and baling. Crops grown for biomass should be harvested in winter or early spring. Leaving switchgrass in the ground over the winter will allow the crop to dry, and the crop needs to be dry if it is to be stored before end use. Additionally, the nutrient content in the crop decreases over the winter period and this improves the quality of the biomass when it is used for combustion. Depending on the soil type, optimal productivity is reached after two to three years in drier soils and four to five years in heavier soils. Yield in the first year may be low and uneconomical to harvest. Yield in subsequent years will build and on good sites can be expected to exceed 10t/ha of dry matter.

Problems

Switchgrass establishment can be difficult. Good germination can be achieved by using certified seed, proper seedbed preparation and by not sowing too early. However, good weed control is necessary in the first growing season to ensure that switchgrass seedlings survive into the second year.

Lodging can be a problem in switchgrass crops and can affect biomass yield. There are differences in the degree of lodging between varieties. Less susceptible varieties do not lodge to the same degree and will lodge later than more susceptible varieties. Most crops appear to be able to recover from mild lodging. Varieties that have been reported as less susceptible to lodging include Cave-in-Rock and Kanlow.

Economics

The economics of switchgrass production are dependent on fixed and variable costs, biomass yield and the price paid by the purchaser. The least profitable year in the life of the crop is the establishment year where the costs of establishment and weed control must be borne without any income. Profitability increases in subsequent years as biomass yields increase. A crop lifespan of greater than 15 years is considered possible; high initial costs can be spread over this timeframe and it is important to consider the profitability of crops over this longer period.

One approach to economics is to calculate the cost per tonne of biomass produced. This takes out the estimated value of the crop and shows what value is required for the crop to break even. A cost analysis conducted in the UK, based on yields of miscanthus, reed canary grass and switchgrass across nine sites revealed that switchgrass had the lowest price per tonne of these three crops. The advantage of switchgrass over miscanthus is that it can be sown from seed and is thus far cheaper to establish, while its biomass yields are almost as good.

Markets

At present, the production of electricity and heat are the largest potential markets for switchgrass. The Government has set a target that 30% of peat burned in the three peat-fired power stations will be replaced with biomass by 2015. This will require growing approximately 80,000 hectares of energy crops and this could include switchgrass.

Switchgrass can be burned to produce heat or electricity. Its combustion characteristics are similar to miscanthus, although ash content can be higher. Pellets are manufactured from switchgrass in Canada and used for home heating in suitable heating appliances. Other potential markets for switchgrass include use as a reinforcing fibre, conversion to biofuels, and pulping to produce printing and writing papers.

Environmental impacts

Growing switchgrass as an energy crop brings a number of environmental benefits over conventional arable crops:

- **improved water quality and less nitrate leaching from reduced fertiliser use;**
- **greater biodiversity and improved water quality from the lack of chemical inputs; and,**
- **growing switchgrass lessens the effect of climate change for two reasons:**
  - **first, switchgrass absorbs carbon dioxide from the atmosphere and stores this in the soil. This reduces the build-up of greenhouse gases in the atmosphere. Carbon storage rates for greenhouse gases exceed those of annual crops by as much as 20-30 times; and,**
  - **second, the use of switchgrass as a fuel avoids the need to use fossil fuels. Burning fossil fuels releases carbon dioxide into the atmosphere, and this has contributed to global warming. Burning energy crops also releases carbon dioxide into the atmosphere but this carbon dioxide is re-absorbed by the plant during the following growing season so the amount of carbon dioxide in the atmosphere does not change.**

Conclusions

Switchgrass is an energy crop that offers growers an alternative to miscanthus and other energy crops. Energy crops offer considerable environmental benefits over traditional arable crops. Although biomass yields are unlikely to be as high as miscanthus and willow, unit production costs are better than miscanthus as a result of low establishment and input costs. Switchgrass has not been grown in Ireland, although problems are not envisaged as it has been grown successfully throughout the UK and North West Europe.

Good crop husbandry is essential during the establishment phase where good seedbed preparation and timely weed control is necessary for the crop to survive into the second growing season. The crop will take three to four years to build up to full yield potential, which can be expected to be 8-10t DM/ha. Switchgrass should remain productive for at least 15 years after establishment. Lodging can be a problem, although using less susceptible varieties can alleviate this. Harvesting can be carried out with conventional grass harvesting equipment.

Supplying biomass to the peat-burning power stations is the largest potential market for switchgrass. Pellets for heat production in suitable heating appliances can also be produced from switchgrass.

Wheat and beet for ethanol production

Introduction

Liquid biofuels are becoming an increasingly attractive alternative to hydrocarbon fossil fuels, driven by advances in biofuel technology, current high oil prices, government regulatory support and environmental concerns. Governments, research facilities, and major oil and gas companies, etc., are investing huge sums of money world wide into the development of a sustainable biofuel industry.
Ethanol and biodiesel are currently the two main liquid biofuels available on the market. Both of these fuels have started to penetrate the transportation sector in all major regions of the world. This section will concentrate on the production of ethanol from wheat and sugar beet.
Global ethanol output is expected to more than triple by 2020, from 51 million cubic metres (51 billion litres) in 2006, to 160 million cubic metres (160 billion litres). This is due mainly to a sharp increase in US production where, since 2000, the production of ethanol has increased 300% to 22 billion litres in 2006 (RFA, 2007).
Similar to previous years, 2006 showed strong growth in bioethanol fuel production in Europe. Total production in 2006 is estimated at 1.56 billion litres, an increase of 71% compared to 2005 production. Highest production was achieved in Germany (431 million litres), followed by Spain (402 million litres) (ebio, 2007). EU consumption of bioethanol fuel in 2006 is estimated at just over 1.7 billion litres. Imports from Brazil are estimated at just over 230 million litres. Currently, many new bioethanol facilities are in the planning and building stage across Europe and will come on stream over the next five years.

Ethanol

Ethanol (CH_3CH_2OH) may be produced from sugar crops such as sugar beet in Europe or sugar cane in Brazil. Ethanol may also be produced from cereal crops such as wheat in Ireland and Europe, and maize and wheat in the US. Ethanol is a fuel with a high octane number, an energy content of approximately 68% that of petrol, and a low tendency to create knocking in spark ignition engines. Oxygen in its molecule permits low-temperature combustion, which results in fewer emissions. New flexible fuel vehicles, of which there are over six million running mainly in Brazil, the US, Sweden, and some in Ireland, can run on up to 85% ethanol and 15% petrol (E85) blends, having had modest changes made during vehicle production.

Ethanol can also be used as a petrol additive, displacing ethyl t-butyl ether (ETBE). Ethanol is suitable for use as an octane enhancer in unleaded petrol. Increasing the oxygen content of the fuel reduces polluting emissions. At present, an EU Directive restricts the sale of ethanol for use in unmodified engines to 5% blends with petrol (Commission of European Communities, 1985).

Ethanol has been considered as a feedstock for the production of ETBE. ETBE is used as a petrol additive, which substitutes for lead as an octane enhancer. ETBE has similar properties to ethanol when blended with petrol but is more favoured by oil companies because it is easier to handle.

Production of ethanol has been largely confined to crops such as maize, soya, wheat, sugar beet and sugar cane. Other small grains such as barley have proven to date to be difficult to handle and uneconomic compared to conventional feedstocks.

Normal (hulled) barley cannot be converted to fuel ethanol using a conventional wheat-to-ethanol process without significant modifications. The abrasive nature of hulled barley, the high viscosity of barley fermentations, and the low starch and high fibre content, lead to high production costs and low ethanol yields. However, work is ongoing in the US to develop an economic process to produce ethanol from barley.

Ethanol production from wheat

Producing ethanol from wheat is completed as part of an industrial process. The process begins when the wheat is milled and water is added. This mixture is boiled as cooking gelatinises the starch. Enzymes are added to convert the starch to sugar, which is fermented by yeast. Ethanol is distilled from the fermented mixture. By-products of the production process include high protein animal feed that may be sold to farmers, as well as CO_2. Low mycotoxin levels are required in the wheat feedstock because the waste products (distillers grains, etc.) of the process are usually fed to farm animals.

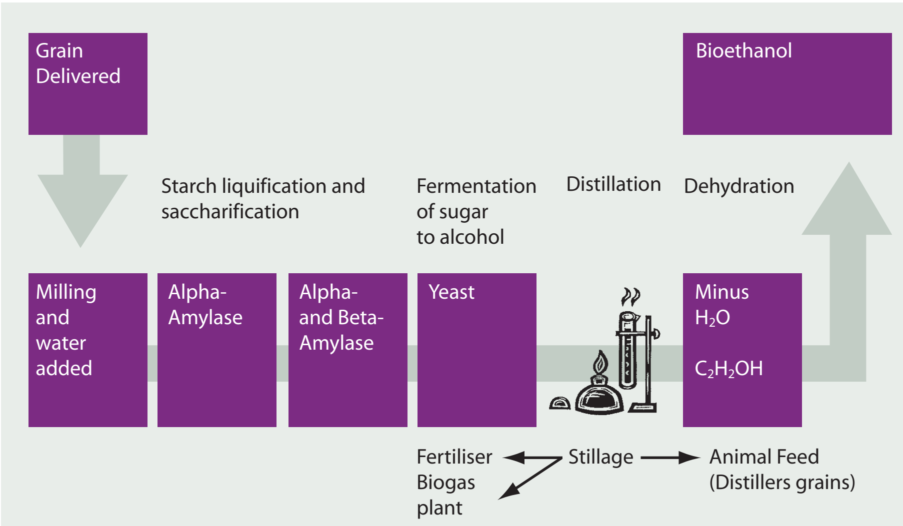


FIGURE 1: Ethanol production diagram.

One tonne of wheat grain (at 15% moisture content on a wet weight basis) will produce around 356 litres of ethanol, at current efficiency levels; however, there is reason to believe that in time this can be increased, giving an extra 30-40 litres. Therefore, a 10 tonne per hectare crop of wheat will produce 3,560 litres of ethanol.

Ethanol processors require grain that will produce high alcohol yields and have high processing efficiency. This is affected by several characteristics, one of which is the starch content, as it is the starch in the grain that is converted into ethanol. There is an inverse relationship between starch and protein in the wheat plant. Generally, high protein content will result in a lower starch content in wheat. Breeding wheat crops with a high starch content and a low protein content represents a different aim compared to previous breeding.

Measuring the starch content of wheat is difficult but an indication can be obtained by looking at the nitrogen (N) (protein) content of the grain. Normally, the aim is to achieve 2% grain N for feed wheat, but for wheat being produced for ethanol a lower value is desirable without compromising yield. It is calculated that for every 1% unit decrease in grain protein, alcohol yields increase by seven litres/dry tonne.

Other quality requirements for wheat for bioethanol include a minimum specific weight of 72kg/hl, a maximum moisture content of 15% and a maximum impurity level of 2%.

Managing wheat for bioethanol

Variety choice can have an impact on the production of alcohol, with the high-yielding feed varieties predicted to produce the highest ethanol yields. The difference between varieties regarding the total yield of ethanol is essentially the total starch produced.
Producing wheat for bioethanol is similar to the production of wheat for feed purposes. Crops are sown at the same time and management of both crops is centred on maximising yields. The bioethanol industry demands a high ratio of starch compared to protein. Fertilisation of the crop in spring may differ slightly when producing wheat for ethanol compared to producing wheat for feed. Research is ongoing into reducing the final protein content of wheat. Previous research has shown that front loading a higher proportion of N onto wheat towards the early part of the spring growing season can reduce the final protein in the grain.

Ethanol production from beet

The production process of ethanol from sugar beet is simpler than producing ethanol from wheat as the sugars in sugar beet are readily available for fermentation. The sugar beet is harvested and brought to the production facility where it is weighed, sampled for sugar content and unloaded. Tare (i.e., earth and stones) is removed and the beet is washed clean. The beet is sliced and diffusion takes place by washing it in hot water to create a sugar juice. Fermentation occurs with the addition of yeast and the ethanol is recovered through distillation and dehydration. By-products from the process include animal feed and CO_2.
Ethanol yields are approximately 90 litres per wet tonne of washed sugar beet. Assuming an average yield of 50 tonnes per hectare, then each hectare is capable of producing 4,500 litres. Fodder beet is a higher total yielding crop than sugar beet but reports vary as to its overall suitability for ethanol production due to difficulties in extracting sugar. For the moment, fodder beet remains an unproven feedstock for ethanol production.

Growing sugar beet for ethanol

Growing beet to produce sugar or for the bioethanol industry is identical. Maximisation of sugar yield per hectare is paramount. Crops for both streams are grown, managed and harvested in the same way. It is often the case that processing sugar beet for ethanol production follows on from the production of sugar for human consumption.

Economics of producing ethanol from wheat or sugar beet

A report commissioned by Cork County Council in 2006 and written by John Travers of Cooley-Clearpower sets out some of the economics of growing primarily sugar beet, and also wheat, for the production of ethanol. A number of factors determine the economic viability of such a project. The primary market for biofuels in Ireland is determined by the amount of

Ethanol yields are approximately 90 litres per wet tonne of washed sugar beet.

hydrocarbon fuel substitution that can be achieved. At current prices, there is no type of biofuel that can be produced or imported cheaper than petrol or diesel (when compared like with like, no excise relief). However, increasing regulation, environmental concerns, high oil prices, emerging government incentives and improved technology have resulted in biofuels gaining a small but growing market share.

A key driver for hydrocarbon fuel substitution is the EU Biofuels Directive (2003/30/EC), which advocates that member states replace 2% of petrol and diesel transportation fuels by 2005 and 5.75% by 2010 on an energy basis.

If the overall substitution target for 2010 were met in Ireland by producing ethanol and rapeseed, an area of about 115,000 hectares of cereals and 40,000 hectares of rapeseed would be needed (B Rice, 2006), but an option similar to this would require ethanol substitution in petrol of over 10% by volume on average. Higher proportions could be used in flexible fuel vehicles, but with very few flexible fuel vehicles on the road at present, it is difficult to see how higher levels of substitution could be achieved in the short term (B Rice, 2006).

True market demand will be determined by the quantity of biofuels that can be delivered at a cost that is competitive with alternative sources of transport fuels. At current prices ($80-90bbl oil), petrol is delivered to the pump in Ireland at a cost of 50-55c/l before excise and VAT are added (i.e., circa €1.18 per litre unleaded petrol at the pump). Currently, no source of ethanol (from local production or importation) may be delivered at less than 64c/l before excise and VAT (Clearpower Research, 2006).

The real market demand for ethanol in Ireland is therefore more likely to be determined by the volumes of ethanol that are granted excise relief in the mineral oil tax relief programme. The current programme will grant relief only to selected applicants who submitted proposals in 2006. The removal of excise duty for ethanol will enable producers or importers to deliver ethanol at a price that is competitive with petrol. These volumes have been set at 11 million

Wheat.

Ethanol.

litres in 2006, 40 million litres in 2007 and 85 million litres in 2008, 2009 and 2010. If the relief scheme was extended to ensure EU directive targets were met in Ireland, then the market size would increase to some 220 million litres of ethanol per year.

The availability of wheat or beet at a production facility would be governed by land availability and suitability to produce high yields and sustain rotation cycles. Transportation costs are also a factor to be considered as the main arable region of Ireland is along the eastern seaboard. Sugar beet is considerably bulkier to transport than wheat and therefore more expensive. This cost, and rotational constraints, limits the area and tonnage that can be economically grown around a bioethanol plant.

The price paid for any feedstock would reflect the final market value for ethanol and would generally be based on a forward contract price of the feedstock with the grower. The willingness of growers to supply wheat or sugar beet to the ethanol industry would ultimately be based on the return to the grower from selling to an ethanol plant compared to selling into the free market. Grain price fluctuations, such as the highs in 2007, are well above the point where ethanol producers could afford to match these prices and produce ethanol economically.

The economics of the distillation process dictate that a large industrial plant, capable of using either source of feedstock (wheat or sugar beet), with a capacity to produce 100 million litres of ethanol per annum, would be needed to justify the initial investment. This would need the supply of 260,000 tonnes of wheat or 27,000 hectares of wheat. The conclusion of the Cooley-Clearpower 2006 report suggests that a combination of 40,000 hectares of sugar beet and 12,000 hectares of wheat would be more realistic given that the Mallow sugar plant was still in operation at the time of publication of the report. Since then, due to the decommissioning of the Mallow plant, a green field site is the only way forward for a bioethanol plant in Ireland. The production of ethanol from either wheat or sugar beet in Ireland can only happen with the long-term support of government policy and incentives.

WILLOW

Introduction

Short rotation coppice (SRC) is a specialised form of forestry and involves growing high yielding trees at close spacing, and harvesting at regular short intervals. Willow is just such a fast-growing tree species, and coppices well. This means that when cut back, it will re-sprout from the stump producing multiple new fast-growing shoots.

Establishment

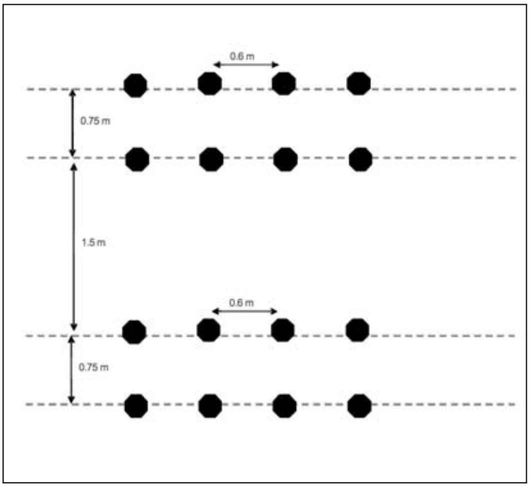
Willow can be successfully established on a relatively wide range of sites. Generally the most suitable sites are imperfectly to moderately well drained soils of good fertility, former tillage land or improved grassland. Mineral soils with a pH range of five-to-seven below 100m above sea level and slopes of less than 12° are suitable. Deep, heavy soils will produce the best yields. Poorly drained, infertile sites, including peaty sites with low pH boggy soils, and sites of particular ecological value, must be avoided.

Harvesting operations are carried out in winter (November to April), making ease of access and load bearing capacity very important. Avoid fields that are too small, too wet, too steep or too awkward. Work with neighbours to plant few, but large, good quality areas and spread the planting over at least three years to improve harvesting options. If the willow plantations are part of a larger regional scheme (e.g., co-firing in a peat power station), then one particular group of farmers could plant in one year, and possibly avail of economies of scale for the planting operation.

Good plantation design is not only important from a practical point of view; both the visual and landscape impact should also be carefully considered. For instance, the plantation shape should be sympathetic to the topography, and neither light nor views should be blocked. Establishment and management are similar to other arable systems. Good soil cultivation is essential to complement ease of planting and successful establishment. Prepare the ground well with deep ploughing; compacted soils should be sub-soiled. A plough depth of at least 20cm, preferably 25cm, is required. Before planting, cultivate lightly with harrow or rotavator. All grass and weeds, including perennial broad-leaved weeds, must be killed off prior to ploughing and again at planting so that a completely weed-free seedbed is achieved. Ensure optimum soil fertility levels (most sites will have adequate levels) and aim to establish a consolidated seedbed with a fine tilth. Preparation must be first class as there is little chance of rectifying problems when the willow crop is planted.

Planting

Planting takes place from February to May. Machine planting takes place by inserting 20-25cm-long cuttings with a minimum diameter of 9mm into the soil. Mechanised planting can achieve four to five hectares per day. The material should be sourced from one-year-old, fully dormant shoots. Modern willow clones have been developed specifically for commercial biomass production and can be purchased from speciality suppliers.



Planting arrangement.

Plant immediately or keep in cold storage before planting. Do not allow cuttings to dry out. Plant a stocking density of up to 20,000 stems per hectare (normal commercial planting density is 18,000/ha). The cuttings are inserted into the soil in a spacing structure similar to maize, i.e., in a twin row arrangement, allowing machinery to pass through the crop. The Best Practice Manual for SRC Willow, produced by the Department of Agriculture, Fisheries & Food for the BioEnergy Scheme, gives further key considerations on proper plantation layout.

Management

Vegetation control must be first-rate as recently established young willow plantations are very susceptible to weed competition. It is vitally important to have complete control of competing vegetation, especially in the first two years of establishment. Apply an overall residual herbicide post planting. Spot treatment during the growing season may be necessary.

After one year, all willow shoots are cut back to ground level to encourage the development of four to eight multiple shoots (i.e., coppicing). This will also give an excellent opportunity to carry out any additional chemical vegetation control that may be required. Growth in the second year (first year after cutback) should be about two to three metres and a final height of six to eight metres can be expected at harvest when the crop is three years old.

Willow is harvested after leaf fall over the winter (December to March) so that nutrients contained in the leaves are returned to the soil. Willow will typically be harvested for the first time four years after establishment, in the winter when the shoots are six to eight metres tall. After cutting, the stumps will re-sprout in the spring and the two- to three-year cycle recommences. Yield in the second rotation will increase. A willow plantation has a typical lifespan of 15 to 25 years.

Harvesting

Three harvesting systems exist: direct chip harvesting; whole stem rod harvesting; and, billet harvesting. At present, direct chip harvesting is the most common method. Willow is cut, chipped and blown into a container in one harvesting operation. Three to four hectares can be harvested per day depending on soil conditions and the size of the fields. This translates into a harvesting cost of €600/day or €20/tonne of dry matter.

This operation requires heavy, expensive machinery producing wet chips, typically 55% moisture content on a wet weight basis, which will require thorough drying to <20-30% moisture content before long-term storage can be considered. Specialised but expensive drying facilities can be installed to dry wood chips. Ventilated grain floors using warmed air can dry a crop of willow chip in three to six weeks. Drying costs for directly harvested willow chip can be as much as €20 per tonne of dry matter.

If wood chips above the recommended moisture content are stored without appropriate drying facilities, decomposing will begin, which may lead to a substantial loss of dry matter, and therefore energy. Mould and fungal spores could also pose serious health and safety problems. Some larger installations can burn wet chips, so the problems of drying and storage are avoided by using the fresh wood chips immediately. The chip dimensions and particle size distribution are also important quality parameters. A production of six to 12 tonnes of dry matter can be expected per hectare per year.

Nutrient management and fertilisation

Fertiliser application is not normally necessary as willow growing is focused on high quality, fertile agricultural land. Nutrients are also returned to the soil through leaf litter recycling and atmospheric nitrogen inputs.

Opportunities exist for growers to charge a gate fee for the spreading of ‘waste materials’, such as dairy sludge, brewery waste and sewage sludge. Willow roots are very effective at capturing the sludge’s nutrients and heavy metals. They are then locked up in the willow wood.

As a guide, to be confirmed with soil analysis and expected yield, nutrient application should not exceed the equivalent of 120-150kg nitrogen, 15-35kg phosphorus and 40kg potassium per hectare per year. Unfortunately, due to the nature of the crop and available equipment, the application of fertiliser in whatever form is not practically possible in commercial plantations except following harvest and before re-growth.

Economics/costs of SRF

A 50% grant towards the cost of establishment is available. However, with the grant, a payback period of seven years is anticipated. Government help is needed to develop the infrastructure around biomass supply chains. It is a brand new market and the general public, including our big heat utilisers need to be made aware of the benefits of switching to biomass. Local market access is vital, as the bulk density of the crop is low and the crop becomes unprofitable when high transport costs are incurred. The best opportunity of an economic return is for groups of farmers to develop local markets. Supply of these markets (schools, hotels, etc.,) can be organised by the farmer groups and payment for the chips made directly to the groups through either a payment per tonne of chip or per unit of heat used. Additional income may become available from charging a gate fee for spreading wastes, e.g., brewery wastes, etc. Profit margins tend to be low because a relatively low-value product (i.e., willow chips) must pay for the entire costly establishment, management and harvesting operations. Establishment and early management costs tend to be high and include ground cultivation, fencing, pre- and post-planting vegetation control, supply and planting of cuttings, and subsequent cutting back. At present, the average cost of establishing an SRF willow plantation is estimated at €3,000/ha. The fencing cost has a large impact on the cost.

Local market outlets must be secured in advance such as hotels, swimming pools or other heat users who are changing over to wood-fuelled central heating systems. Both willow and conventional wood chips can be used at the same time in a wood-fuelled boiler. Moisture content is the critical factor. Wood chip with <20% moisture will have a recoverable energy content of at least 14MJ/kg, while freshly harvested wood chip at 50% moisture from either willow plantations or from conventional forestry will be reduced to <8MJ/kg.

Willow being planted with a step planter.

In calculating the figures below, a number of assumptions are made:

- **eight harvests over a 25-year period are made;**
- **average yield achieved is 10t/ha/yr DM;**
- **cost of drying willow chip from 50% DM down to less than 20% moisture content is €12/t;**
- **establishment costs are €3,000/ha;**
- **willow harvested every three years will yield 30t at €600/ha harvesting cost;**
- **management costs €375/ha after each harvest (herbicide application, fencing repairs, exit point repairs); and,**
- **site restoration (i.e., root removal) will cost €750/ha.**

Table 1 shows the different costs associated with growing willow.

Table 1: Cost of growing willow.

Cost type	Cost (€/t DM)
Establishment	€10.50
Drying	€12
Harvesting	€20
Clearing roots	€3
Management	€9
Total:	€54.50

Willow can be planted under REPS.

Willow SRF, REPS and Disadvantaged Areas

Willow can be planted under REPS and/or in Disadvantaged Areas to a maximum of 10 hectares or 25% of the holding, whichever is the greater. The farmer may therefore receive a REPS payment of €234/ha, a Disadvantaged Area payment of €96/ha, an Energy Crops payment of €45/ha and a top-up payment of €80/ha, totalling €455/ha. Coupled with a 50% establishment grant, a willow chip crop to sell and the opportunity to revert back to agriculture, this makes it an attractive proposition.

Conversion back to agriculture

SRF willow is regarded as an agricultural crop and therefore the Forestry Act, 1946, does not apply. This means that the land can be converted back to agriculture. This can be achieved by harvesting as normal, then the following spring, young re-growth is sprayed with glyphosate and the stumps mulched with a heavy rotavator. This costs approximately €750/ha. Ploughing and reseeding is carried out into the tilth provided by the rotovation, leaving the coppice roots in place, and reseeding with grass can then be carried out. The remaining stumps in the soil will help to improve soil structure. Sowing an arable crop will take longer as a grass break is necessary to allow the willow roots to decay and facilitate ploughing.

Advantages/disadvantages

Growing willow as a fuel crop has very distinct advantages as well as disadvantages.

Advantages

- **Secure long-term local resource;**
- **potentially viable alternative farm enterprise;**
- **establishment and management similar to other arable crops;**
- **relatively low maintenance costs;**

Willow planting in progress.

Willow can be used for bio-filtration.

- using a willow plantation for biofiltration purposes offers the following benefits: economic (gate fee for sludge, etc.); environmental (nutrients that would otherwise cause pollution are soaked up, and the area can be irrigated with waste water/sludge); and, social (visual benefits, rural employment, etc.);
- very short lead-in period of only four years versus 15 for conifers;
- it is regarded as an agricultural crop and therefore the Forestry Act, 1946, does not apply, which means that the land can be converted back to agriculture; and,
- another wildlife habitat is created on farms.

Disadvantages

- Good quality land is required;
- sufficient road access is required for heavy machinery;
- wet chips are difficult to dry and will start to deteriorate rapidly, decreasing the energy value;
- poorer wood fuel quality, due to the lower proportion of wood to bark, in comparison to 'traditional' wood chip from forestry (this is not a major issue, and is debatable, as conventional chip can contain green material – needles, etc. – and, because of extraction methods, will have higher mineral [soil] contamination);
- relatively low value and bulky product;
- high establishment costs;
- usually high harvesting, storage and drying costs;
- willow plantations may be prone to diseases such as rust; and,
- markets must be in close proximity to supply (20 kilometres or less).

Willow being harvested in whole stem form.

Pests and diseases

A wide range of insects and fungal pathogens can live in willow. However, many of these pathogens and insects will not harm willow and will only enhance the biodiversity of the plantation. Songbirds can be attracted to these plantations due to the plentiful supply of food. Rust (*Melampsora*) is the major disease affecting willow. A severe attack can reduce yields by 40% and in some cases will kill the willow plants. Rust can change populations over two to three years and a resistant variety of willow can become susceptible over that period of time. It is therefore essential to sow all plantations with at least five to six different willow varieties to prevent a devastating attack of rust.

The blue and brassy willow beetle can cause some problems but populations are generally low. Control is possible but it can be difficult due to the structure of an advanced willow plantation.

Key points

- **Spray glyphosate four weeks prior to planting (Roundup at 3-5l/ha);**
- **plough to 20cm 14 days after glyphosate;**
- **power harrow, lift stones, level land;**
- **plant willow at 15,000 cuttings/ha with mechanical planter;**
- **light roll after planting;**
- **spray with 5l/Stomp/ha within 14 days of planting; and,**
- **walk plants regularly, checking for rabbit or leatherjacket damage.**

WOOD ENERGY FROM CONVENTIONAL FORESTRY

Introduction

Wood energy is a home-grown, renewable, sustainable, carbon-neutral and secure source of heat, electricity and liquid biofuel. Wood has great potential in Ireland as a source of fuel for heating. It is a proven technology, with very high efficiency, and is available locally. The demand for wood fuel is increasing rapidly. Farmers are in a good position to benefit, both as growers of energy wood and as users of cost-effective wood energy. Ireland's soil and climatic conditions are excellent for timber growth.

Wood is by far the largest source of biomass in Ireland. A desktop study commissioned by COFORD ('COFORD Strategic Study – Maximising the Potential of Wood Use for Energy Generation in Ireland', 2003) estimated that the total annual energy potential of all pulpwood, sawmill residues and harvestable forest residues produced in Ireland is currently 17.3PJ (2.3 million tonnes at 50% moisture content [MC]), which would rise to 26PJ (3.5 million green tonnes) by 2015. The price afforded by the energy market will determine how much of this potential is realised. However, the minimum annual quantities that are currently available for energy production are 3.6PJ (424,000 tonnes) and this is predicted to rise to 9.4PJ (1,106,000 tonnes at 50% MC) by 2015.

Wood fuel sources

Wood fuel can be produced from forestry timber, forest residues, arboricultural thinnings, untreated wood waste, such as sawdust and other sawmill residues, and also willow plantations (short rotation coppice [SRF]).

Conventional forestry thinnings

'Conventional' forestry provides great potential as an alternative farm enterprise and supplies different categories of wood. Larger diameter trees tend to have a higher value and include categories such as sawlog, palletwood and stakewood. Such timber provides a welcome tax-free income and is much sought after by sawmills.

Sawlog (large diameter wood) is and will remain for the foreseeable future the most profitable product that a farm forest can produce. Sawlog can be produced quicker by carrying out thinning. Thinning is the removal of a proportion of trees from a forest. This increases the quality and size of the remaining trees, allowing them to produce sawlog timber. Thinning optimises the return from the forest crop, provides periodic returns as the crop matures, and improves the biodiversity value of the forest. First thinnings involve the removal of mainly smaller diameter trees. These large pulpwood volumes have traditionally been used as the raw material for panelboards (MDF, OSB and chipboard). Most conifer forests are ready for thinning at between 14 and 24 years. In some cases the option may be to thin earlier or not to thin at all. Thinning may not be an option where the site is very exposed or very wet, where access is restricted, or where thinning is not economically viable.

Pulpmills are often located a long distance from the forests, making selling thinnings uneconomic due to the haulage distances involved. As most planting over the last 15 years has been carried out by farmers, most pulpwood will be supplied by farmers in the coming years. The emerging wood fuel market could provide the solution for this type of wood, as thinnings can be harvested locally, processed locally and provide a source of renewable heat locally. This will make such thinnings more financially viable, particularly for smaller plantations. This is a win–win situation for the local farm forest grower, the consumer and the environment.

In addition to the above mentioned thinning assortments, energy wood could be produced from the remaining assortments, such as the crown, branches, unsaleable assortments or undersized trees. This additional income can help to reduce the cost of thinning and add value to it. This should only be considered where the soil is sufficiently nutrient-rich to allow for this additional wood volume to be removed from the site rather than being returned to the soil as valuable nutrients. Nutrient-poor areas such as certain upland and bog areas may be prone to nutrient depletion. Removing energy wood from unsuitable sites could also lead to substantial soil damage by harvesting machinery.

For further information on thinning, contact your local Teagasc Forestry Development Officer, have a look at Teagasc's farm forestry leaflet on 'First Thinning in Conifers', or log on to www.teagasc.ie.

Arboricultural material

Substantial amounts of wood are regularly available on the farm. For instance, rather than regarding the cut-off material from a coppiced hedgerow as a waste product that needs to be disposed off, it could be used for fuel if handled correctly.

Waste material

Other wood waste includes wood that has been used already, e.g., wooden pallets or construction timber. This material must be avoided due to contamination with paint residues, glue, wood preservatives and plastics. Pressure-treated fencing stakes, varnished or painted furniture, chipboard, MDF or OSB cannot be used as wood fuel because of the danger of serious air pollution. To burn such material, licences and/or permits may be required, controlling the combustion plant, the acceptance of waste wood and emissions to air of NOx particulates, carbon monoxide and other substances. Legislation includes:

- **Environmental Protection Agency Act, 1992 and 2003;**
- **Waste Management Act, 1996 to 2005;**
- **Large Combustion Plant Directive (2001/80/EC);**
- **Waste Incineration Directive 2000 (2000/76/EC and S.I. 275 of 2003);**
- **Air Pollution Act, 1987; and,**
- **Planning and Development Acts, 2000.**

Wood fuel: types, harvesting and storage options

Energy wood can be used for the production of heat and electricity, or converted to liquid biofuel, but it is most commonly used for the production of heat. The most common forms of energy wood are firewood logs, wood chips and wood pellets.

Firewood

Demand for firewood in Ireland is growing rapidly. It is also the easiest wood fuel market for farmers to become involved in as normal farm machinery such as tractors, trailers and chainsaws are used. After felling, the wood should be cut and split as soon as is convenient, as this speeds up the drying process. A very efficient way of preparing firewood is to use a firewood processor, which crosscuts and splits the firewood in one operation, resulting in very efficient preparation. Firewood processors vary in size from compact, highly mobile processors to very large machines capable of processing large volumes of firewood per hour. Some of these processors are PTO driven while others have their own engine.

Once the firewood has been processed, it needs to be fully seasoned for 12 months, or preferably for two years, to bring the moisture content down to approximately 20% on a wet weight basis. Firewood is usually stacked under cover to ensure optimal ventilation, e.g., in a drying shed. Transport of either logs or firewood can take place using a tractor/trailer combination. Most firewood in Ireland is sold per tonne so it is important for the buyer to buy wood rather than water: the weight of firewood drops significantly during seasoning. Due to demand, most firewood for sale still requires additional drying when purchased: the wood's heat will otherwise be used to dry it in the appliance rather than in heating the room. Burning damp wood may also damage the chimney and produces

Energy wood can be used for the production of heat and electricity.

pollution because of incomplete combustion. Firewood is typically used in an open fire, closed stoves or in small-scale (domestic) central heating systems. The price for firewood at present appears to be approximately €60-70/t or about €160 per tractor trailer delivered. Wide regional variance may need to be taken into account, especially in or near urban areas. If properly seasoned, a tonne of firewood has the same heating value as 200-250 litres of home heating oil.

Wood chips

Logs can also be chipped and used for heat and/or electricity production. Wood can be sourced from conventional forestry, pulpwood from thinnings, willow SRF, arboricultural waste, and sawmill off-cuts. Most wood chips used in energy production are sourced from forestry thinnings, especially first thinnings and uneconomic thinnings with a large pulpwood fraction.

Drying

The importance of sufficient drying cannot be overstated. It is important to ensure that wood for energy has been allowed to dry out for 12 months or more before chipping takes place. Moisture content will have dropped from 50-60% to 35-45%. Chipping can then take place once the wood has dried out sufficiently. Wood is nearly always felled and air-dried before chipping for a number of reasons:

- **energy content is directly related to moisture content and therefore a higher price is paid for dry wood;**
- **transporting costs are lower;**
- **stacked, freshly cut wood chips will degrade (decompose, rot) rapidly, thus losing valuable dry matter while producing large amounts of fungal spores and bacteria. These can lead to severe allergies, especially if exposed repeatedly and for prolonged intervals;**
- **it is cheap and straightforward to air-dry logs while it is expensive and difficult to dry wet wood chips; and,**
- **needles and small branches are allowed to drop off, resulting in those nutrients returning to the soil.**

One of the better ways to air-dry energy wood is to remove the cut trees from the forest. Logs can be stacked at the roadside in an appropriate area of the forest where they are covered on top by a securely fastened tarpaulin. The logs can also be transported to a yard, where they are stacked either in the open with a tarpaulin on top or in an open-sided drying shed. Either option must ensure maximum ventilation around the logs. COFORD currently funds a major forest energy project investigating different harvesting and wood fuel production options. This project is run in association with Teagasc and Waterford Institute of Technology (WIT). Wood chip quality is of paramount importance. Wood fuels should conform to European-wide CEN (European Committee for Standardisation) standards. These standards are now adopted in Ireland. The most relevant technical specification is CEN-TS-14961, entitled 'Solid Biofuels, Fuel Specifications and Classes', which specifies solid biofuels. For a copy of the standards, go to the National Standards Authority of Ireland website (www.nsai.ie), or contact Sustainable Energy Ireland (SEI) for further details. Wood chips as a fuel are best suited to medium to large installations (upwards of 30kW). The type of wood chip required depends very much on the size and type of heating system.

Chipping

Moisture content, calorific value, size and uniformity of chip, and level of impurities are important elements that affect a boiler's efficiency. The smaller the boiler's heat output, the more important the size of chip and moisture content become. It is important when considering buying wood chip fuel to determine its calorific value prior to purchase, be clear about the basis on which that calorific value is expressed, and understand other parameters on which the sale may be based (e.g., dry matter weight, total weight, stacked volume or solid volume). On average, three to six tonnes of wood chips will displace 1,000 litres of home heating oil dependent on moisture content and other factors. Different sized chipping machinery is available that produces different types of chip dependent on the power of the machine, the size, the technology and the chipping mechanism. Chipping machinery ranges from small-scale wood chippers that are either trailer-based and powered by their own engines, or tractor-mounted and operated by a tractor's PTO, to huge high-capacity lorry-mounted chippers. Outputs range from a few cubic metres to 100 cubic metres per hour. The type of chipping machinery will determine to a large extent the size and type of heating system that can be supplied with fuel.

Transport and storage

Wood chips are expensive to transport and are best used locally. Transportation can take place using a tractor/trailer combination, curtain or bin lorry. Chips can also be delivered in large half tonne bags. Chips can be tipped into a reception pit or into a storepile in the corner of a shed. Wood chips can also be blown into a silo but this is a very inefficient and expensive delivery system. Wood chips should only be stored once moisture content has dropped below 30%. If long-term storage is necessary, logs should be stored in the round and chipped when required.

Wood chips.

Wood pellets

Wood pellets are usually made from dry, untreated, industrial wood waste such as sawdust, shavings or chips, which, under high pressure and temperature, are compressed and pelletised. Several pellet production plants operate in both Ireland and the UK and several more are coming on stream. Pellets are also being imported from continental Europe and other areas. This is a highly technical and industrial process and for a farmer to get involved appropriate expert advice is important.

Wood briquettes

Wood briquettes are made from compressed sawdust. Their appearance is similar to very large pellets and they have the same calorific value. For further information on wood fuel, see:

- **'Wood Energy from Farm Forests – A Basic Guide', produced by the Teagasc Forestry Development Unit;**
- **'COFORD Connects' notes, produced by COFORD; and,**
- **'Wood for Energy Production: Technology – Environment – Economy', published by COFORD in 2005.**

Important issues such as the wood fuel supply chain and quality control of the different types of wood fuel are currently being addressed by Teagasc and COFORD, and must be carefully considered.

Sales options for farmers

Farmer producers should consider different ways of selling, processing or marketing wood fuel depending on local market opportunities. All of these options, and most importantly the target market, must be carefully considered before entering the wood fuel market. Larger heat users such as hotels, swimming pools and office buildings may look at different contract options. Three basic contract options are generally used:

- **a group of farmers enter into a wood fuel supply contract to supply wood chips for a particular boiler at specified size and moisture content;**
- **a group of farmers enter into a heat supply contract based on heat requirements. They are contracted to supply an annual heat demand, expressed in kWh (kilo Watt hours). Payment is based on heat delivered plus maintenance. The farmer group supplies specified chips and carries any additional costs. The group normally carry out basic boiler maintenance. Farmers may also consider a joint venture with the boiler supplier; and,**

- **farmers may consider setting up an ESCo (Energy Supply Company) by forming a joint venture with a boiler supplier to provide the following services: supply of both boiler and wood fuel; delivery of heat as and when required; and, the provision of boiler maintenance. The heating bill will then be based on heat used plus the capital cost of the boiler.**

Farmers can opt to sell pulpwood to a wood chip supplier or to a heat provider. In this case, the forest owner's only involvement is to sell the timber. Forest owners may also opt to get involved in the business of supplying wood chip directly to a boiler under contract from the installer.

Producer groups

One of the most promising ways for farmers to add value to their produce is to form powerful producer groups. In this way, potential buyers can be offered secure, multi-annual large volumes of timber. This will result in improved timber prices and reduced costs to group members. For example, one farmer with a forest of 10ha coming up for first thinning may be able to offer 400 tonnes of timber for sale. This farmer may find it difficult to attract a buyer/contractor as overheads such as machinery transport will be high. Other issues such as location, access and distance to sawmill may also have a negative influence. However, 50 farmers with 10ha each can offer a sawmill 20,000 tonnes of timber, spread over several years and securing supply to the sawmill. Such a scheme could be organised through a group manager; this has the added advantage to the sawmill of dealing with one person only. This group manager can also organise management works to group members at reduced costs. For further information on producer groups contact the local Teagasc Forestry Development Officer for practical assistance.

Support schemes

Establishment supports

Farm forestry establishment grants

Over the past decade more than 14,000 farmers have planted a total of 250,000 hectares of forestry. Forestry planting by farmers now accounts for 90% of total afforestation compared to less than 10% in the early 1980s. Those considering planting should contact their local Teagasc Forestry Development Officer. Teagasc can help farmers to decide whether or not to change to a farm forest enterprise and, if so , whether they should do the work themselves or contract it out. It is vital to contact Teagasc before making the decision to take land out of agriculture to plant trees. There may be implications for the Single Farm Payment, compensatory allowances, Rural Environment Protection Scheme (REPS) and farm retirement pension payments. Teagasc employs a number of experienced foresters who provide a range of technical services to farmers and also meet the growing demand for forestry advice from landowners who have planted trees. Those already with plantations may want to know if the trees are healthy and growing well. If problems are identified in time, it is usually possible to correct these successfully. Another typical scenario is where the farmer would like to know if all the work has been carried out to the specifications set by the Forest Service. This service is available to all

Producer groups can be a powerful way to add value to forestry.

private forest owners and is provided free of cost. All advice is confidential, independent and objective.

Establishment grants, depending on land type and tree species, range from €3,414 to €7,604 per hectare and cover the costs to year four. The minimum area for grant aid is 0.1 hectare for broadleaves and one hectare for conifers. Current annual forestry premium rates range from €197.12 to €573.86 per hectare for up to 20 years. The Forest Environment Protection Scheme (FEPS) is an even more attractive option specifically designed for farmers participating in the Rural Environment Protection Scheme (REPS). In addition, other grant schemes may also be available, such as financial support to construct or improve forest roads. Again the local Teagasc Forestry Development Officer can help with this information.

Wood biomass harvesting machinery grant scheme

This capital grant scheme was introduced to support developing enterprises in the wood chip supply sector and will grant-aid the purchase of medium-scale wood chippers and self-contained chippers by providing up to 40% of the purchase price of this equipment. Further information is available by contacting the Forest Service, Department of Agriculture, Fisheries & Food, Johnstown Castle Estate, Co. Wexford, Tel: 053-60200. Additional support may also be available from enterprise boards and local Leader companies.

Supports for wood fuel heating appliances

Sustainable Energy Ireland administers a range of wood heating support schemes such as the Renewable Heat Deployment Programme (ReHeat) and the Greener Homes Scheme. It is very important to compare different options, products, specifications and installers very carefully before making a decision. For further information on those schemes, contact Sustainable Energy Ireland, Glasnevin, Dublin 9, Tel: 01-836 9080, or Sustainable Energy Ireland, Renewable Energy Information Office, Unit A, West Cork Business & Technology Park, Clonakilty, Co. Cork, Tel: 023-42193, or log on to www.sei.ie.

Further information

Further information is available from the local Teagasc Forestry Development Officer through the local Teagasc office, or by visiting www.teagasc.ie. Establishment and development grants are available

from the Forest Service. Further information is available from the Forest Service, Department of Agriculture, Fisheries & Food, Johnstown Castle estate, Co. Wexford, Tel: 053-60200 or visit www.agriculture.gov.ie. COFORD operate a wood energy advisory service on www.woodenergy.ie and queries about the harvesting and supply chain sector of the wood energy industry can be submitted online. Queries about boilers, stoves, approved installers, wood fuel standards, etc., can be directed to Sustainable Energy Ireland, Glasnevin, Dublin 9, Tel: 01-836 9080, or Sustainable Energy Ireland's Renewable Energy Information Office (SEI REIO): Unit A, West Cork Business & Technology Park, Clonakilty, Co. Cork. Tel: (023) 42193.

Facts and figures

- **96% of all Europe's renewable heat comes from wood (Renewable Energy World, 2005);**
- **3% of Ireland's energy requirements are from renewable sources, with biomass contributing more than wind, hydro, biogas, solar and geothermal combined (SEI);**
- **1,000 litres of home heating oil = 3-4 tonnes of wood chips (at 30% MC) = 2-2.5 tonnes of wood pellets;**
- **1 tonne of solid wood (at 60% MC, i.e. fresh) = $1m^3$ = $2.5m^3$ wood chip**
- **1 tonne of solid wood (at 30% MC) = $1.75m^3$ = $4.5m^3$ wood chip**
- **a large detached house ($200m^2$ = $2{,}150ft^2$) will need (depending on insulation levels) 10-14 tonnes of wood chips (dependent on moisture content) or six tonnes of wood pellets per year;**
- **a 5-10 kilowatt boiler output is required per $100m^2$ of house floor area (variance relates to different insulation levels);**
- **annual fuel requirement = 0.7 tonnes of wood fuel (30% MC) per kW boiler output;**
- **fuel densities in kg/m^3: wood chips: 200-250; wood pellets: 500-700; spruce firewood: 350-400; pine firewood: 440-500; ash firewood: 550-600; and, beech/oak firewood: 550-600;**
- **storage space (equivalent to 1,000 litres of home heating oil): oil: $1.5m^3$; wood pellets: $3m^3$; wood logs: $6m^3$; and, wood chips: $12m^3$;**
- **delivered energy costs – a comparison (in cent/kWh): wood chips: 2.73; wood pellets (bulk): 4.06; natural gas: 5.12-6.86; kerosene: 5.99; wood pellets (bagged): 6.49; wood briquettes: 7.68; LPG: 9.02-15.33; and, electricity: 16.29 (SEI – domestic rates);**
- **1 hectare of first thinnings will supply approximately 5,000l of oil; and,**
- **1 hectare of forest will 'grow' more than 100,000l of oil over its lifetime or more than 3,000l/ha/year.**

Please note

In contrast to many other European countries, we are still in the early stages of renewable energy development in Ireland. Those interested in renewable energy should contact all of the relevant agencies, as this sector will develop and change rapidly in the coming years.

GLOSSARY

Biodiesel
A diesel substitute or extender produced from vegetable oils or animal fats used in either unprocessed form or converted to biodiesel. The vegetable oils can come from crops such as oilseed rape or sunflowers. Diesel is sold as EN 590, which can contain a blend of 5% biodiesel. Using 100% biodiesel can cause problems with engine performance unless the vehicle has been modified for its use.

Bioenergy/biorenewable energy
A generic term covering electricity and/or heat and transport fuels derived from biomass, i.e., plant material and animal residues/wastes. A wide range of biomass can be used for energy production, including: crops grown specifically for energy production, e.g., willow, miscanthus, oil seed rape; agricultural wastes such as straw and other crop residues; forestry residues; and, wastes from a range of sources, including food production.

Bioethanol
A petrol substitute produced by the fermentation of organic materials (carbohydrates) such as sugar (beet) and starch (cereal crops). The current European specification for petrol (EN228) can contain up to 5% ethanol without any need to declare it.

Biofuels
These are potential replacements or extenders for transport fuels such as diesel or petrol derived from petroleum-based fossils fuels. Biofuels (bioethanol and biodiesel) are produced from crops such as sugar beet, cereals, oilseed rape or re-processed vegetable oils.

Biomass
Biomass, in biological terms, is the total dry weight of all living organisms within a biological community. Biomass can be used as fuel directly by burning to generate heat and power or for the production of liquid transport fuels.

Biomass energy
Heat and/or power produced using biomass as the fuel source. Biomass fuels include fast growing energy crops such as short rotation coppice and miscanthus; agricultural residues such as wheat straw; forestry residues; poultry litter; livestock and sewage slurry; and, organic municipal waste.

Bioremediation
Any process that uses plants to return a contaminated environment to its original condition.

Calorific value

The amount of heat generated by a given mass of fuel when it is completely burned, measured in joules per kilogram or gigajoules per tonne, e.g.,:

- **poultry litter oven dry 9Gj/t;**
- **straw oven dry 15Gj/t;**
- **miscanthus oven dry 16.2Gj/t;**
- **SRC oven dry 18.6Gj/t; or,**
- **coal 24-28Gj/t.**

Carbon dioxide (CO_2)

An odourless greenhouse gas produced through respiration and the decomposition of organic substances, which is harmful to the environment. It contributes approximately 60% of the potential global warming effect of man-made emissions of greenhouse gases worldwide. The burning of fossil fuels releases CO_2 fixed by plants millions of years ago and therefore increases its concentration in the atmosphere today.

Climate Change Levy

The Climate Change Levy is a tax on energy use in industry, commerce, agriculture and the public sector (not on domestic energy use) aiming to encourage these sectors to improve energy efficiency.

Co-firing

The burning of biomass fuels with coal to reduce CO_2 emissions from coal-fired power stations. Biomass can be blended in differing proportions, ranging from 2% to more than 25%. The most critical factors are fuel costs and the capital cost of the modifications to the power plant to allow co-firing. Even so, co-firing in existing power boilers could be one of the most economical ways to use biomass for energy on a large scale. There are also other environmental benefits such as lower sulphur emissions and around a 30% reduction in nitrous oxides.

Combined heat and power

A power station where the waste heat from electricity generation is utilised to heat buildings, thereby improving the overall efficiency of the power station.

Embedded generation

Electricity generation, usually on a relatively small scale, connected to the distribution network rather than to the high voltage national grid.

Energy crops

Crops grown specifically for use as fuel. They generally produce high yields, i.e., large volumes of biomass, and also have high energy potential. Energy crops are carbon neutral as the CO_2 released at fuel use is equal to that taken from the atmosphere by the plants during photosynthesis. However, energy used in planting, harvesting and processing the crops must be taken into account.

Forest residues

These become available during first and intermediate thinnings, and at final harvest in forestry operations, and are also produced as waste during woodland management. Residues include the tops, branches and foliage, which are unsuitable for most current uses but can be chipped for use as biomass fuel.

Fossil fuels

Coal, oil and natural gas are naturally occurring fuels rich in carbon and hydrogen formed by the decomposition of prehistoric organisms. They currently provide around 66% of the world's electrical power and 95% of the world's total energy demands.

Gasification

Oxygen in the form of air, steam or pure oxygen reacts at high temperature with biomass fuel to produce a combustible syngas, ash and tar product. Syngas can be more efficiently converted to energy such as electricity than would be possible by direct combustion of the original fuel.

Greenhouse gases

Those gases present in the atmosphere that trap heat from the sun and warm the earth. They include carbon dioxide, methane, water vapour, nitrous oxide, ozone and halocarbons.

Hectare

One hectare (ha) is equivalent to 10,000 square metres or 2.471 acres, approximately the size of a football pitch.

kWh

Kilowatt hour – a unit of energy. The energy of a 1kW device running for one hour, or a 100W device running for 10 hours.

kWth

1,000 watts of thermal power, i.e., heat.

Methane (CH_4)

A colourless, odourless gas formed when organic matter decomposes anaerobically. Methane is approximately 20 times more effective than carbon dioxide as a greenhouse gas. Major sources include fermentation in ruminant animals, decay of organic material in rice paddies and landfill.

Miscanthus

A perennial, high-yielding C4 grass propagated by rhizomes. The rhizomes are planted in spring at densities of between 10-20,000/ha. Harvest yields will be low for the first two or three years, depending on ground conditions. The stems produced (3-4m in height) during each summer are harvested the following March/April. Plantations should remain viable for at least 15 years.

MSW (municipal solid waste)

The waste collected from households and other places by local authorities.
Potentially a major source of energy.

MW (MWe)

Megawatt – 1,000kW or 1,000,000 watts of electrical power.

MWh

Megawatt hour – a 1MWe power station running for one hour will produce one MWh of electrical energy.

ODT

Oven-dry tonnes, i.e., the dry weight of fuel.

Pyrolysis

The thermal degradation of biomass in the absence of oxygen to produce a mixture of gaseous and liquid fuels and a solid inert residue (mainly carbon).

Renewable energy

Heat and power produced from wind, wave, tide, solar, water, geothermal and biomass sources.

Short rotation coppice (SRC)

Densely planted (15,000/ha), high-yielding, specifically bred varieties of willow harvested on a two- to four-year cycle. SRC is a woody, perennial crop with the rootstock or stool remaining in the ground after harvest, after which new shoots emerge. An SRC plantation should remain viable for 30 years. SRC is not limited or restricted to willow. There are also other forms of SRC.

APPENDIX – CROP DENSITIES

Bulk density and storage of various fuels.

Material	Typical bulk density	Storage space requirements
	Metric t/m^3	Metric m^3/t
Wheat	0.78	1.28
Barley	0.7	1.43
Oats	0.56	1.78
Softwood chip (sitka spruce) 45% moisture	0.28	3.57
Hardwood chip (beech) 45% moisture	0.35	2.86
Softwood chip (sitka spruce) dry weight	0.15	6.66
Hardwood chip (beech) dry weight	0.19	5.26
Miscanthus bale (8x4x3)	0.13	7.69
Miscanthus chip	0.09	11.1
Willow chip (25% moisture)	0.15	6.66
Wood pellets	0.65	1.54

Fuel cost comparison.

Fuel	Price per unit	kWh per unit	Cent per kWh
Wood chips (30% MC)	€120 per tonne	3,500 kWh/t	3.4 cent/kWh
Wood pellets	€200 per tonne	4,800 kWh/t	4.2 cent/kWh
Natural gas	5.12 cent/kWh	1	5.12 cent/kWh
Heating oil	€0.70 per litre	10.2 kWh/ltr	6.8 cent/kWh
Electricity	€0.14 cent/kWh	1	14 cent/kWh

Energy conversion table.

	MJ	GJ	kWh	toe	Btu
MJ	1	0.001	0.278	24 x 10-6	948
GJ	1000	1	278	0.024	948,000
kWh	3.6	0.0036	1	86 x 10-6	3,400
Ton of oil equivalent (toe)	42,000	42	11,700	1	39.5 x 106
Btu	1.055 x 10-3	1.055 x 10-6	295 x 10-6	25.3 x 10-9	1

Calorific value of fuels

Fuel	Energy density by mass GJ/tonne	Energy density by mass kWh/kg	Bulk density by volume kg/m3	Energy density by volume MJ/m3	Energy density kWh/m3
Wood chips (30% MC)	12.6	3.5	250	3,200	880
Log wood (stacked – air dry: 20% MC)	14.7	4.1	350-500	5,200-7,400	1,400-2,000
Wood (solid – oven dry)	18-20	5-5.6	400-600	7,200-12,000	2,000-3,300
Wood pellets	17-18	4.7-5.0	600-700	10,800-12,600	3,000-3,500
Miscanthus (bale – 25% MC)	13	3.6	140-180	1,800-2,300	510-650
House coal	27-31	7.5-8.6	850	25,500-25,400	7,100-7,300
Anthracite	33	9.2	1,100	36,300	10,100
Oil	42	11.7	870	36,500	10,200
Natural gas (NTP)	54	15	0.7	39	10.8
LPG	49.7	13.8	510	25,300	7,000

Contacts

Contacts	Web	Address	Telephone
Technical			
Teagasc	www.client.teagasc.ie	Teagasc, Oak Park, Carlow	(059) 9170200
Commercial			
Rural Generation (Willow)	www.ruralgeneration.com	Culmore Road, Derry, BT48 8JE, N. Ireland	(048) 7135 8215
Northern Bioenergy (Willow harvesting)	annahavil@hotmail.com	Annahavil House, 57 Tullyboy Rd, Moneymore BT45 7XW, Co. Tyrone	(048) 86762599
Natural Power Supply (Willow)	www.nps.ie	Ballymountain, Ferrybank, Waterford	(051) 832777
Quinns (miscanthus)	www.quinns.ie/ mischantus-agriculture	Main St, Baltinglass, Co. Wicklow	(059) 6481266
JHM (miscanthus)	www.jhmcrops.ie	Gortnagour, Adare, Co. Limerick	(061) 396746
GEGA (miscanthus)	www.gega.ie	Clonmel Rd, Carrick on Suir, Co. Tipperary	(059) 649822
Grant Aid			
Department of Agriculture, Fisheries & Food (Bioenergy Scheme)	www.agriculture.gov.ie	Department of Agriculture, Fisheries & Food, Biofuels Section, Kew Rd, Portlaoise, Co. Laois	(057) 8692231
Sustainable Energy Ireland	www.sei.ie	Renewable Energy Information Office, Unit West Cork Business and Technology Park, Clonakilty, Co. Cork.	(023) 42193

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If you need anything else please phone Tony or Tom

856 1166

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