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Welcome

I wish to extend a warm welcome to all our visitors to the Energy Crops Technical Training Day here at the Teagasc Crops Research Centre, Oak Park, Carlow. The event today offers an insight into the potential of renewable energy technology, to make a difference in the land-based sectors and the wider rural communities.

Reform of the Common Agricultural Policy has radically altered the economics of agricultural production. Land owners now have more flexibility to produce different crops as subsidy payments are decoupled from production. Global warming and climate change are very high on the public agenda. A whole new set of political social and market drivers will shape the market for land-based renewable energy crops.

Awareness events such as this Energy Crops Technical Training day will stimulate many farmers to consider the production of renewable energy crops on their farm. It will fuel many questions like “How can I, alone or with others, add value and develop a sustainable business opportunity within the emerging energy-from-land-based renewable sector?

Farmers have seen the food industry and other supply chains in which they operate become extremely competitive. Rationalisation and consolidation in other parts of the chain have left farmers either supplying, or being supplied with goods and services by a declining number of powerful companies. Farmers wishing to develop profitable and sustainable energy generation and supply, or business service opportunities will want to be an integral part of an efficient, effective and stable supply chain within the competitive energy market. Opportunities exist for biomass production, biodiesel, woodchip and pellet production, in addition to energy supply, distribution and marketing from waste, wind and water resources.

Farmers need to consider whether renewable crops are economical; what opportunities exist to supply the Irish energy market?; what renewable energy technologies are available?; and how can barriers be overcome to enter the market. Today’s event will challenge you to explore those opportunities and provide the information to make solid business decisions.

Finally, I wish to express my sincere appreciation to the organisers, my colleagues in Teagasc and staff from the Department of Agriculture, Fisheries and Food. I hope you have an informative and thought provoking day.

Professor Gerry Boyle
Teagasc Director

Energy Crops Agronomy – lessons to date

Barry Caslin, Teagasc, Oak Park

Introduction

Biomass energy crops have to date not yet made their full potential contribution to achieving the renewable energy targets set by the EU commission. The poor development of supply chains is the main contributory factor in this shortfall. The underlying causes of poor development are due to relatively low profitability compared to other farmed crops and the long-term commitment in diverting land from conventional agriculture to energy crops must be well researched by investing farmers. The two main fast growing energy crops identified in Ireland are willow and miscanthus. The establishment costs of both crops have been relatively high compared to conventional crop establishment. Since 2007, The Department of Agriculture, Fisheries and Food grant-aided willow and miscanthus establishment to 50% of realised establishment costs. This resulted in significant miscanthus uptake and a more modest uptake of willow between 2007 and 2009 when the initial Bioenergy Scheme finished. Prior to this some research was conducted in the energy crop sector in Teagasc, Oak Park, Carlow while much more was carried out by AFBI in Northern Ireland. However, many lessons have been learned away from the trial and research environment on-farm.

Miscanthus

Soil suitability

The vast bulk of miscanthus grown in Ireland is in Munster with greater planting in the Cork, Limerick and Tipperary areas in particular[1]. The crop is growing throughout the country on a wide range of soils, from sands to high organic matter soils. It is also tolerant of a wide range of pH, but the optimum is between pH 5.5 and 7.5. The crop has been grown on alkaline soils pH >8[2] although establishment was poor. Miscanthus is harvested over the winter and early spring months. Growing miscanthus on heavy clay soils should be avoided in circumstances where flooding or field working conditions may not suit a winter harvest.

Soil temperatures

Miscanthus will not grow at temperatures below a threshold of 6°C. This is considerably lower than for maize and therefore the potential growing season is longer. Temperature is the most important factor in the regulation of leaf expansion. A late spring frost, which destroys early spring foliage and effectively reduces the duration of the growing season, is a major constraint to long season growth in Miscanthus x giganteus. Photosynthetic capacity is optimally achieved at temperatures in excess of 12°C[3].

Water availability

Annual rainfall and soil water retention strongly influences the yield of miscanthus at any site. Miscanthus possesses good water use efficiency (the amount of water required per unit of biomass) and miscanthus roots penetrate and extract water to a depth of around 2m. However, to achieve high yields, the crop may need more water than the crops it replaces. In addition, a dense canopy means that 20-30% of rainfall is intercepted by, and evaporates off, the leaves and never reaches and infiltrates into the soil. Limited soil water availability during a growing season will prevent the crop from reaching full potential yield in that year; a loss of 90kg of biomass per hectare for each millimetre of soil water deficiency has been calculated. Irrigation is not justified by the value of the additional biomass obtained. In times of severe drought, the foliage of miscanthus will first show leaf rolling and then die back from the leaf tip. This reduces yield in a year of drought but in all cases experienced in the UK to date shows that the crop will survive and re-grow the following year[4].

Site selection

Since miscanthus will exist on the site for at least 20 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, must be considered. Impacts on wildlife, archaeology and public access must also be addressed prior to cropping. In addition, the impact of harvesting machinery on the soil should be considered. Soil diffuse pollution should be prevented by ensuring soil compaction is minimised and soils retain good structure.

Up to 10% of eligible land for the Bioenergy Scheme can remain un-cropped to accommodate landscape and access issues, with no impact on the amount of grant awarded and including any phased planting under that agreement. The positioning of these spaces also needs to be considered in terms of sympathetic landscape views whilst enhancing wildlife and minimising soil compaction.

Broadleaf weed control

Weeds, if not controlled, will compete with the crop for light, water and nutrients and thus reduce yields. The level of weed interference will depend on the stage of maturity of the crop (i.e., its ability to out-compete weeds), the degree of weed infestation at the site, and the diversity of the weed species (affected by location, season, climate and previous land use.

Weed control is essential in the establishment phase of the crop because the slow initial growth of miscanthus reduces its ability to compete. The planting process causes soil disturbance which promotes seed germination. Furthermore, the low planting densities which are used results in large unoccupied spaces where weed growth can occur. At this stage the young miscanthus plantlets can easily become overwhelmed by weeds.

A range of selective cereal herbicides can be used for weed control. Teagasc, based on information gathered by the UK miscanthus industry, has put a fact sheet together of cereal herbicides which can be applied to a miscanthus crop for broadleaf weed control.

Grass weed control

Miscanthus itself is a grass species and because of this the grass weeds can only be controlled when the crop is in senescence during the winter months with just a bamboo-like cane remaining. This is a very delicate and time critical operation and only if carried out correctly will eliminate the problematic grass weeds. Glyphosate (e.g., roundup) being a systemic herbicide will kill or check the plant if it contains green material. Some first-year crops do not lose all their green leaf so in order to spray glyphosate in such circumstances the crop should be topped during the month of January and within three weeks of topping the glyphosate should be applied. This action helps prevent glyphosate being taken in by any green matter in the plant from translocating down to the rhizome.

Glyphosate (4 litres/ha.) should be sprayed across the entire crop, normally from mid-February onwards where grass weeds are present. If there are little or no grasses present, there is no requirement for glyphosate. Topping and subsequent spraying of glyphosate is normally completed by mid-March.

Miscanthus harvest

Miscanthus can be harvested by using a maize kemper header to harvest in chipped form. However, this is a bulky commodity and the moisture content needs to be below 20% to avoid heating and for safe storage[5]. This bulky material can have a bulk density as low as 70kg/m^3.

The other option is to cut the miscanthus with a conditioner mower and bale it up, preferably into a large hesston bale. For transport reasons it is essential that the miscanthus bales are densified as much as possible. Please see the guidelines in Table 1.

Field research shows that how miscanthus is cut and presented for the baler is key to successful baling.

Harvest researchers in the UK[6] cut using a modified harvester Class machine – by making and using a reduced sized cylinder with knives attached to the carriers at the 3 o'clock and 9 o'clock points on the cylinder. The smaller diameter means there is a gap between the cylinder and the shear bar; the crop is fed in the exact same way as harvesting maize but operates at a slower speed. The machine has a two-speed rotor and is run at a low speed to reduce rotating down. This process breaks up the crop for baling.

Some of the problems of not having miscanthus baled correctly:

- Possible rejection at process site
- Disproportionate use of indoor storage space
- Excessive bale damage from handling equipment
- Bales unstorable in outside stacks, due to being open
- Hard to achieve a tidy stack and build to a sufficient height
- Increased baling cost to the producer (as a result of more bales)
- More broken bales when clearing fields, loading trailers and trucks etc
- Impossible to achieve maximum weight onto the lorries, resulting in increased haulage costs per tonne of material

Table 1. Common miscanthus bale types based on 15% moisture

Make	Bale Size (m)	Target Weight (kg)
MF190 Hesston 4900 Krone 12130	1.2m x 1.3m	500-550+
MF187	1.2m X 0.9m	360+
MF186 Class Quadrant 2200 Class Quadrant 3200 Welger D6000	1.2 m x 0.7m	330+

Willow

Soil suitability

Willow is not a demanding species in terms of its site requirements and it will flourish on a wide range of soil types and environmental conditions, and in common with other crops[7], productivity will be determined by site fertility, the availability of water, light and temperature.

Most agricultural soils with pH in the range 5.0-7.0 will produce satisfactory coppice growth. However, light sandy soils, particularly in drier areas, will have a problem with moisture availability. Highly organic or peaty soils should be avoided as initial weed control, which is vital, will be extremely difficult. Medium to heavy clay-loams with good aeration and moisture retention are ideal although they must have a capability of allowing a minimum cultivation depth of 200-250mm to facilitate mechanical planting.

Water availability

Willow coppice requires more water for its growth than any other conventional agricultural crop and hence requires a good moisture retentive soil. Areas with an annual rainfall of 900-1,000mm are best or areas where the crop has access to ground water[7]. The crop can tolerate occasional inundation but this may have implications for harvesting. It has been calculated that willow coppice can use up to 1.0m litres per tonne of dry matter produced annually.

Temperature

Willow is in its native environment in a northern temperate zone. Consequently, temperatures in Ireland are unlikely to be an issue. However, elevated sites can result in exposure problems and a reduction in the number of growing days per year. Therefore, production sites should generally be below 100m above sea level[7].

Access

Harvesting is carried out from December to April and whilst the root system of the growing coppice will support the harvesting and extraction equipment on the coppice site, hard access to the site is required. Slopes in excess of 12° are difficult for harvesting machinery particularly in wet conditions and should be avoided.

Location in the landscape

Short Rotation Coppice (SRC) has more similarities with arable cropping than conventional forestry; it has a regular harvest pattern and its deciduous nature gives a seasonal diversity of texture and colour. SRC at the end of a three-year growing cycle will be up to 8m tall and therefore creates a three dimensional mass in the landscape which arable crops do not. Poorly planted SRC plantations have the potential to adversely affect the rural landscape. However, well-designed and carefully sited plantations could bring small but important landscape improvement. In most cases, with some thought, the establishment of SRC is likely to bring, at best, a significant improvement or, at worst, no detrimental effect to most mixed agricultural landscapes[7].

SRC should not be planted on or adjacent to sites of historical importance or where it would obscure natural landscape features. Power lines will require consultation with the appropriate utility company as mature coppice can reach 8m before harvest.

Weed control

Pre-ploughing

It is important that this is carried out effectively particularly on old pasture land where the presence of perennial weeds such as docks and nettles is more likely. A translocated (systemic) herbicide (e.g., Glyphosate at 4 litres/ha) should be applied to actively growing vegetation from 15 January . To allow the herbicide to fully translocate, a period of ten days post-herbicide application should be allowed before ploughing.

Post-planting

A mix of pre-emergence residual herbicides should be applied immediately after rolling, and no later than five days after planting, for broad spectrum early season weed control. The quality of the seedbed is critical to this operation. A good, fine seedbed will allow a seal on the soil surface to be created and help reduce the need for further herbicide applications. However, depending upon the weeds present it may be necessary to apply follow-up contact sprays for specific problems. The aim is to eliminate competition from the weeds to allow the crop to grow and develop to its maximum potential. See the Teagasc factsheet on weed control in willow based on active ingredients and given off-label approval by chemical companies.

Pest and diseases

Leatherjacket larvae

Leatherjacket larvae pose a threat, particularly on former grassland or long-term set-aside. If present, control is required in the form of a suitable insecticide sprayed shortly after planting, typically alongside the pre-emergence residual herbicide application.

Fencing

Normal stock fencing is required to prevent livestock from entering the crop. Such fencing may not be required around the actual willow plantation, if the wider perimeter is already securely fenced. Rabbit/hare fencing may be needed during the first growing season after planting, during which time the shoots develop. Such protection is not required after this initial establishment period or in subsequent cycles, due to the vigorous nature of the crop. Therefore, where required, consider using temporary rabbit and hare fencing that can be moved and redeployed elsewhere. If using this fencing, a 15cm outward-facing flap of fencing must be left at the bottom of the fence, and securely pegged down.

Where present in small numbers, deer may cause localised grazing or bark stripping. Such loses can be absorbed by the vigorously growing crop. However, high deer numbers and the likelihood of heavy damage may necessitate deer fencing, or, due to the cost involved, may simply rule out the feasibility of growing SRC willow on that site. Required fencing specifications are set out on page 53 of the Forest Service Forestry Schemes Manual (2003).

Rusts

Melampsora rusts represent a serious threat to SRC willow crops, potentially affecting both productivity and survival. This threat is best countered by the use of willow varieties that have been specifically bred for resistance to this disease. Typically, a mixture of five-to-six varieties is included in the plantation, to allow adequate yield compensation should individual varieties loose productivity or die out due to increasing disease susceptibility. This measure also increases the genetic diversity within the crop, thereby reducing the selection pressure on the disease organism.

Cutback
The crop can reach a height of 2.0m or more during the first growing season. To initiate the development of multiple shoots, each stem is cut back at its base during the winter of the first year, before bud burst. Cutback is normally carried out using a finger bar mower. The cut itself should be clean and regular. The material 'harvested' at the cutback stage may have limited or no commercial value.

Harvesting
The first harvest is usually undertaken three to four years after planting, i.e., two to three years after cutback. Subsequent harvests are undertaken thereafter normally on a two to three-year cycle. Harvesting is carried out from November to the end of February, when foliage is absent and stem moisture content is at its lowest (approximately 55%). Careful planning is required to avoid excessive rutting and soil disturbance, particularly in localised wet areas.

Stools should be cut as close to the ground as possible at each harvest, as this keeps stool height as low as possible throughout the life of the crop.

Direct-chip harvesting is typically used, whereby the stems are cut and chipped by the harvester and blown into an accompanying trailer.

Whole rod harvesting systems are also becoming increasingly feasible. The harvesting of SRC willow does not fall under the remit of the 1946 Forestry Act.

Conclusions
It is clear that many questions on energy crops remain unanswered; much more work is required on the various willow clones and their yields on commercial farms in Irish climatic conditions; herbicides for weed control in willow are limited and more work is required to determine the optimal herbicide application for willow and, miscanthus grass weed control is proving difficult and the optimal treatment methods need to be researched in greater detail.

The nutrient requirements for varying soil types also needs to be determined. The biggest challenge is in reducing the overall cost of establishing energy crops. Most research on SRC willow has been conducted by AFBI in Northern Ireland. Miscanthus is relatively new in the area of biomass production and will require continuing agronomic research to ensure successful yields and that land area is put to its best use.

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The Case for Energy Crops
Dr John Finnan, Teagasc, Oak Park

Summary
Ireland is almost completely dependent on energy imports which have grown significantly, both in quantity and volume, over the last ten years. Moreover, energy imports as a percentage of total imports have grown from 3% in 1999 to almost 12% in 2008 have grown. Greenhouse gas emissions, currently above our Kyoto limit, need to be cut by 20% by 2020 and by 80% by 2050. Such cuts offer a significant challenge. Indigenous bioenergy production can help redress our over-dependence on energy imports while at the same time reducing our emissions of greenhouse gases. Forestry thinnings are the predominant source of bioenergy at present and this resource needs to be maximised. However, forestry thinnings will not be sufficient to supply our bioenergy needs and, consequently, a substantial area of energy crops will be required to meet our bioenergy targets. Energy crops can also play an important part in our society by providing a route for the disposal of sewage sludge. Quantities of sewage sludge have increased dramatically over the last ten years and disposal options are becoming limited. Energy crops have an important role to play in moving Ireland towards energy security and a low carbon economy. Teagasc is preparing for this challenge by carrying out research on energy crops as well as providing advice and policy input in this area.

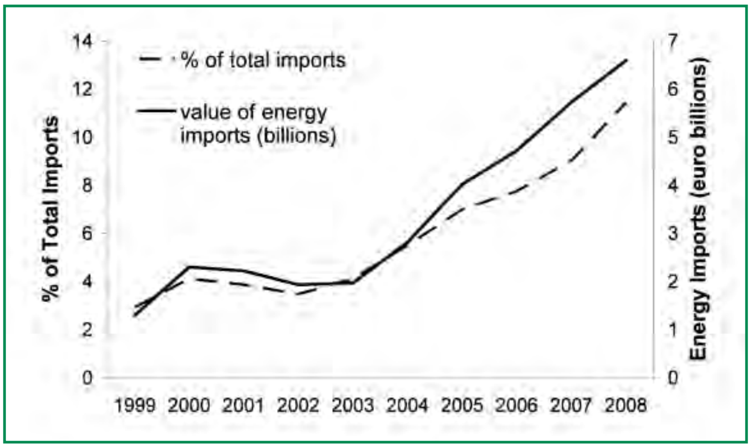
Energy imports
Ireland is almost totally dependent on energy imports, 92% of our energy needs were imported in 2006 (Howley *et al.*, 2007). The quantity and value of energy imports has increased significantly over the past 10 years. Additionally, the proportion of energy imports in relation to total imports has grown significantly from 3% in 1999 to 11.5% in 2008 (Figure 1). €6.6 billion was spent on energy imports during 2008, this represents a flow of money out of the country with a consequent adverse effect on our Gross Domestic Product and balance of trade.

Our dependence on imported energy makes our economy very vulnerable to fluctuations in the price of fossil fuels as well as to restrictions in the quantities of fossil fuels predicted as oil supplies dwindle. An oil vulnerability index developed to illustrate the sensitivity of economies to developments in the global oil industry identified Ireland as one of the most vulnerable countries in the world (Forfas, 2006).

The development of our own indigenous renewable energy supplies would mean that money which previously left our economy will instead be injected into our economy and will consequently benefit our competitiveness, national GDP, balance of trade and job creation targets. We can only realistically expect to replace part of the oil used in transportation from indigenous production of liquid biofuels. However, we can replace a substantial part of the €1.5 billion spent in 2008 on imported heating fuels with native solid fuel production, both from forestry thinnings and from energy crops.

Biomass imports
In 2007, 25,000 tonnes of wood pellets were imported into the country. Additionally, there have been suggestions that biomass for co-firing in our peat burning power stations could be sourced from abroad. The use of imported biomass to replace fossil fuels will reduce our greenhouse gas emissions. However, from the point of view of our economy and energy security, the importation of biomass is no different from the importation of fossil fuels. Money generated within the country flows out of the country with adverse effects on our economy and balance of trade.

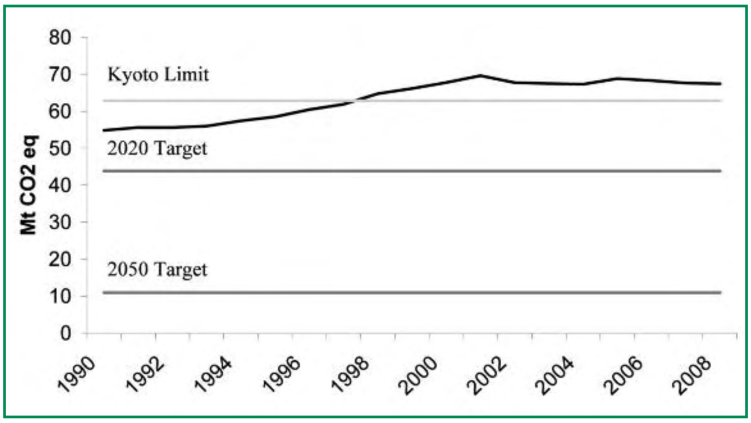
Fig. 1 Energy Imports into Ireland



Greenhouse gases

Greenhouse gas emissions from Ireland still exceed our Kyoto limit by 4.5 Mt CO_2 e.q., (EPA, 2009). The Kyoto limit allows us to exceed our 1990 emissions by 13%. In March 2007, however, EU heads of state agreed to cut emissions by at least 20% of 1990 levels by 2020 with a further commitment to cut emissions to 30% below 1990 levels in the case of an international agreement. Furthermore, the Minister for the Department of the Environment, Heritage and Local Government, John Gormley TD, in his budget speech in December 2009 committed Ireland to reducing its emissions by 80% of our 1990 levels by 2050 (Figure 2). Emissions from the energy generation (21.6%) and residential sectors (10.3%) represent a substantial proportion of national emissions. The replacement of fossil fuels with indigenous bioenergy resources can make a substantial contribution to national emission targets.

Fig. 2 Greenhouse Gas Emissions

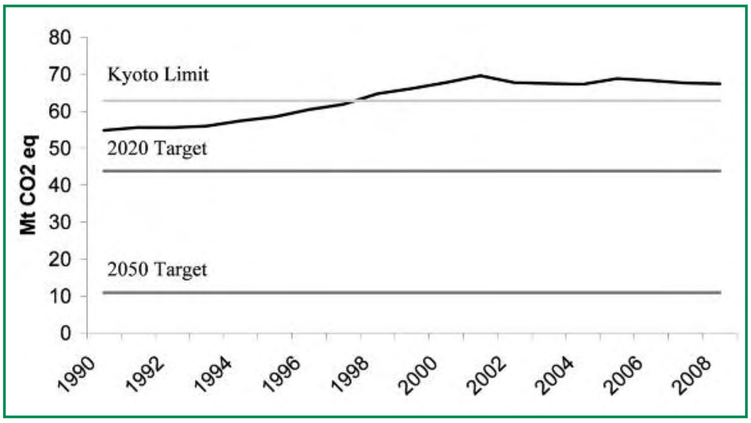


Sewage sludge

There has been a significant investment in waste water treatment facilities in the past decade with over 90% of waste water now receiving secondary or tertiary treatment (Monaghan *et al.*, 2009). Wastewater treatment plants continue to be built and upgraded. The dramatic increase in the number and scale of waste water treatment facilities has led to a substantial increase in the quantities of sewage sludge for disposal (Figure 3). The quantity of sewage sludge has almost trebled between 2000 and 2007.

Sewage sludge is either land-filled or spread on agricultural crops. However, these two options for disposal are being restricted by both the Landfill Directive (1999/31/EC) and by growing consumer opposition to sewage sludge disposal on food crops. The application of sewage sludge to energy crops offers a disposal route separate from the food chain, provides energy crop fertilization at no cost in addition to the opportunity to increase the C content of soils. Research being carried out at Oak Park is tracing the environmental fate of nutrients and heavy metals in sewage sludge.

Fig. 3 Sewage Sludge Production



Biomass availability

The most significant potential biomass resource in Ireland at present is thinnings harvested from the country's forests. While produce from state-owned forests is committed for processing, there is substantial scope to utilise thinnings from private forestry. The introduction of attractive grants has stimulated private forestry with in excess of 200,000 ha planted. Many forests are coming to a thinning stage. However, private forest thinning is at a very low level. There are several reasons for this:

- **Wind damage**: Thinning increases the risk of wind damage. Exposed sites are particularly vulnerable.
- **Accessability**: Most private forests are inaccessible from a public road and the construction of an access road is financially prohibitive. Even in cases where there is road frontage there is still a requirement to construct an entrance way into the forest.
- **Size**: Most private forests are less than 10ha and this reduces the viability of thinning particularly if road construction is necessary.
- **Distance to market**: Most of the private forestry is located in the western half of the country distant from the most populated areas.

Farmers and other private forestry owners are being encouraged to thin their forests in order to improve management and maximise profitability. Teagasc researchers have developed a methodology based on the identification of forestry clusters, areas with a sufficient percentage of forestry (Farrelly, 2007). It is hoped these efforts will result in a large increase in the percentage of forests which are thinned.

While forestry thinnings will play a major role in the provision of feedstock for bioenergy, the quantity of energy from this source will fall far short of our national requirements. This shortfall will need to be made up by a substantial energy crop area.

Teagasc and energy crops

Teagasc recently published its Foresight study which examined the prospects for Irish agriculture up to 2030. The study predicts that bioenergy and bioprocessing will be one of the four pillars of Irish agriculture in the future. Energy crops have a large role to play if this 'pillar' is to become a major part of Irish agriculture. There is a long history of energy crops research within Teagasc which commenced in the 1970s in the immediate aftermath of the first oil crisis. The bioenergy research programme is expanding to meet the challenge of this young industry. Current topics relevant to energy crops on which research is being carried out include:

- *Willow disease control*
  Rust and beetle infestations represent the major biological threats to willow plantations. Plantations can be protected against these threats by planting mixtures of willow varieties. Research is currently being carried out in this area to understand the interaction between these two threats to the longevity of willow plantations.
- *Miscanthus nutrition*
  Miscanthus is a relatively new crop and, consequently, comparatively little is understood about its nutrient requirements. Trials are being conducted at Oak Park to gain a better understanding of the nutritional requirements of miscanthus.
- *Miscanthus harvesting*
  Miscanthus can be harvested with conventional agricultural machinery but some machinery combinations can result in high harvest losses (>10%). Research is underway at Oak Park to reduce these harvest losses as well as to identify the optimum harvest window for miscanthus.
- *Bio-remediation*
  Energy crops offer a route for the disposal of sewage sludge which does not involve food crops or landfill disposal. However, the practise of sewage sludge application to energy crops needs to be environmentally benign. Research at Oak Park is investigating the environmental consequences of sewage sludge application on energy crops.
- *Investigating the potential of new energy crops*
  Willow and miscanthus both have high establishment costs as well as a period of a few years before break even. The potential of certain grasses as energy crops is being investigated at a number of sites around the country. Sowing from seed offers considerable economic advantages, early results are promising with yields of 8-9 tonnes DM/ha being recorded from Tall Fescue, Cocksfoot and Reed Canary Grass.
- *Pelleting of energy crops*
  Pelleting will be necessary if energy crops are to be used in the domestic heat market. A pellet mill in Oak Park is being used to assess the quality of energy crop pellets. Early results show that pellets of reasonable quality can be made from miscanthus.
- *Energy crop combustion*
  Energy crops have a different chemical composition in comparison to wood, the most popular biomass material. As most biomass boilers were designed to burn wood, problems such as clinker formation and corrosion may arise when energy crops are used for combustion. Research to understand and avoid these problems is also ongoing at Oak Park.

The output from this programme is being disseminated by a number of means including the Teagasc website, open days, factsheets as well as articles in the popular press. Additionally, Teagasc staff are actively involved in formulating policy in this area through participation in working groups as well as the provision of advice to government departments and other public bodies.

Conclusions

Indigenous production of bioenergy can make a major contribution to redressing the major issues of energy imports and greenhouse gas emissions. National bioenergy targets, however, cannot be met from forestry thinnings alone and a substantial acreage of energy crops will be needed. It is expected that energy crops will play a major role in the future of Irish agricultural. Teagasc is preparing for this future by conducting research on energy crops and by providing advice and policy support in this area.

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The Economics of Biomass Crops

Fintan Phelan,Teagasc, Financial Management Specialist

I wish to acknowledge the input of Daragh Clancy, Teagasc Athenry whose paper along with the other authors titled 'A Discounted Cash Flow Analysis of Financial Returns from Biomass Crops in Ireland' was helpful and Barry Caslin Teagasc, Oak Park for help with the assumptions on costs and technical performance. National Farm Survey data is used extensively in the calculations and is acknowledged.

Introduction

Farmers who diversify into biomass crops can receive establishment grants to offset up to half of the initial setup costs and they are also currently eligible for energy crop subsidies. In addition, since the introduction of the Single Payment System, EU agricultural subsidy payments are substantially de-coupled from production. This allows farmers a greater freedom to switch to alternative enterprises, such as biomass crop production, without reducing the value of their existing single farm payment entitlements. Consequently, farmers may have an important diversification opportunity which merits careful financial analysis.

From the view point of an individual farmer such analysis is not straightforward. There are important risks associated with adopting an enterprise that does not yet have a proven track record. For example, there are important questions about future demand/prices and the direction of government policy affecting biomass crops over the longer term. There is also uncertainty about potential yields since available data are based on small samples of experimental trials that have been running over a limited number of years. This makes it difficult to establish how yields are influenced by production factors and the extent of variability from site to site and over time.

These risks associated with biomass crops are accentuated by their lengthy production horizon compared with traditional enterprises. Consequently, it may not be surprising that farmers are sceptical about the prospect of biomass crops as a viable alternative agricultural enterprise. A survey of Irish farmers (Connolly *et al*., 2006) found that only 8% of respondents were willing to consider/investigate the production of biomass crops.

One of the most important factors affecting the economics of converting to a biomass crop from the perspective of the individual farmer is the current returns from the existing enterprise. Teagasc National Farm Survey shows that returns from the main farming enterprises are under pressure over time despite a rally in returns in the years 2007 and 2008. The prospects for large increases in profitability in 2010 are slim with the only reasonable increase likely in the dairy sector, albeit from a low base in 2009. In analysing the prospects for conventional enterprises it becomes increasingly difficult looking further into the future. With the long wait for return in biomass crops due to the large initial investment and the long period for which land is tied-up under the crop, it is difficult to make reasonable estimates to compare alternatives. For the farmer facing a decision to invest in an alternative system, a crucial question to be answered is what are the current returns that are being made from the existing business? Teagasc National Farm Survey (NFS) figures give the overall picture but at farm level there is a huge variation in efficiency levels between farmers in every enterprise.

When completing this financial analysis we assumed that the land used to grow the crop was previously rented. This gives us a certain cost for the land which we call the opportunity cost. It must be remembered that at farm level if a farmer decides to convert 10 acres of his 100 acre cattle farm there are fixed costs like machinery, professional fees, insurance and depreciation that now must be carried by a smaller beef enterprise, thus potentially increasing the fixed costs per animal. In our analysis we have not taken account of these costs but have chosen to allow the opportunity cost figure on the converted land to make a contribution to this also.

Looking at NFS results for 2008 (Table1) we find that there are some fixed costs that will not reduce very much if we change say 10% of our farm to a different enterprise. On many farms there have been substantial investments over the recent years in buildings which still remain as a cost to be borne by the farmer. There is also car, ESB and phone costs as well as the others listed in the table. If the average cattle rearing farmer wishes to convert part of his farm to biomass production he must make enough of a positive gross margin to cover the existing fixed costs of €261 per hectare before he is in profit. If the farmer decides to put in a biomass crop some of the fixed costs are likely to reduce over time such as machinery depreciation, as the remaining farm will be less demanding of machinery with reduced scale.

Table 1. Selected farm fixed costs (National Farm Survey 2008)

	Dairy	Dairying + other	Cattle rearing	Cattle other	Sheep	Tillage	All
UAA (Ha)	47.6	46.8	29.7	31	34.1	57.9	36.7
Fixed costs							
Car/ESB/Phone	4330	2693	1440	1502	1238	1841	1988
Interest	3397	1566	543	685	425	1823	1166
Machinery Dep.	5989	4849	1741	2302	1767	7043	3164
Buildings Dep.	6723	3967	1746	2070	1482	2184	2770
Land imp Dep.	713	432	222	162	177	164	280
Land Maintenance	1429	832	628	638	463	1183	777
Other	4185	3004	1428	1719	1502	3126	2190
Total	26766	17343	7748	9078	7054	17364	12335
€ Per UAA	562	371	261	293	207	300	336

UAA (Utilised Agricultural Area)

As said previously, the decision to put in a biomass crop should be made in light of the current efficiency of the enterprise that it replaces. The variation in enterprise efficiency on farms is huge. Similarly, there is wide variation in the level of fixed costs on farms, it is therefore important to view the averages above with this in mind. For the individual farmer making an investment decision a review of existing fixed costs that are not likely to change and the contribution that the existing farm enterprise is making to those fixed costs should be made.

There is one enterprise that is more long-term in its outlook and it is possible to make reasonable estimates of the return from it over a 20-year time scale and that is forestry. This is due to the fact that the returns from forestry are guaranteed for the first 20 years for farmers. There are a number of differences between the two investments however. With forestry you are required to obtain a felling licence when harvesting – this requires the land to be replanted, which in essence means that forestry is a permanent change of land use. While the planting of a biomass crop is not restricted by the same regulation it is likely that the decision to plant a crop will mean that the land will not be available to change to an alternative land use for a substantial period due to the large initial investment.

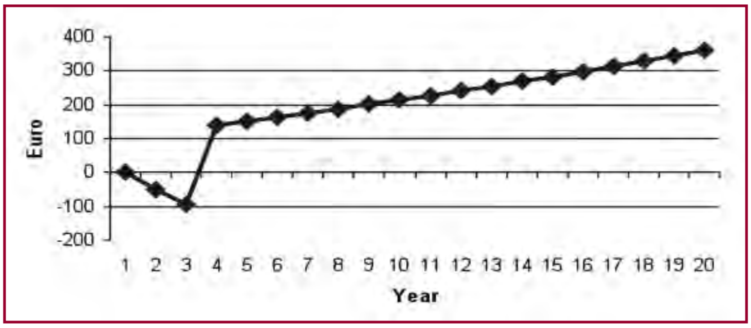
Miscanthus - base line assumptions

This paper employs the Discounted Cash Flow method to evaluate miscanthus as an investment project. The assumptions used in the calculation, on a per hectare basis are:

- All capital for establishment net of grant, borrowed
- Interest rate of 6%
- Inflation rate of 2%
- Energy inflation rate of 2%
- Discount rate for Net Present Value (NPV) 5% (used in similar papers)
- Opportunity cost of land €236 (average grassland rental price)
- Farmer not registered for vat
- Initial establishment operations costs €772
- Establishment management fee €150
- Rhizomes €1,925 + 13.5% vat
- Other establishment materials including vat on materials €580
- Harvesting cost including baling €294 when at normal cropping level
- Transport covered by the purchaser
- Yield 7t dry matter in first crop, 10t dry matter in all other crops
- No gate fee for bioremediation (spreading sludge)
- No Carbon premium
- Price received per tonne €65 (inflated by 2% per annum)
- Growing period for the crop 20 years (in trials have been grown for 15 years)
- Borrowing period for 20 years
- No grubbing cost to return the land to conventional production

The results show a positive net cash flow for miscanthus of €3,447 per hectare after 20 years. In general terms, if the net cash flow is positive then the investment should proceed, however there are many other factors that come into play in this investment that cause the NPV (net present value) to change rapidly depending on the assumptions used. These other issues and a sensitivity analysis of the main assumptions are dealt with later. The average cash flow was €199 per hectare per annum.

Miscanthus Cash Flow/Hectare



The miscanthus cash flow chart graphically demonstrates the overall flow of cash with a miscantus crop given the base lines assumptions. The initial negative cash flow is due to the fact that there is initially no crop and then a low yielding crop until the crop matures. It should be noted that the rise in cash flow as the time progresses to year 20 is completely derived from the assumed 2% increase in energy inflation year on year. There is no extra gain in yield as time progresses. The farmer is in a negative cash flow position in the initial stages of the investment;, it is possible o be positive by borrowing more initially but this will need to be repaid. This investment will exacerbate the problem if a farmer already has a cash difficulty. In the initial years the investment will need to be carried from existing reserves. It is possible that all the capital required to establish the crop, net of grant, will not need to be borrowed due to the freeing up of capital e.g., stock sales from a preceding enterprise. It should be noted however that all of the capital used to establish the crop from grant, borrowing or own resources will be fully exhausted at the end of the growth cycle of the crop, and there is no terminal or residual value from the crop at the end of 20 years. The crop will also need to be replanted at full cost unless there are further grants in the future to continue the enterprise.

Sensitivity analysis

We varied the main assumptions to examine the effect a change in each would have on the investment decision. For simplicity this is presented in terms of the average annual net cash flow. While the time value of money is not taken into account the discount rate remains constant as does the costs and yield over time. The net cash flow is the cash that is available to the farmer per hectare after making loan repayments and covering all variable and fixed cost associated with growing the crop. While the farm may have other fixed costs to stay in business these are not included in this calculation. The opportunity cost charge that may be used to cover some of these other fixed costs is included. The net cash flow in this calculation is pre-tax.

Miscanthus	Average cash flow/ha/year			
Energy inflation	**Base line**			
	1%	2%	3%	4%
	€99	€200	€316	€448
Opportunity cost				
€100	€200	€236	€300	€400
€340	€237	€200	€133	€30
Yield when fully established DM				
	9t	10t	11t	
	€134	€200	€264	
Price/tonne				
	€60	€65	€70	
	€129	€200	€269	

*Transport costs are not included in the above figures.

Willow

The results for willow are poor in almost all cases if an opportunity cost for land is included. The main extra cost associated with willow is the increased harvesting costs. This may reduce over time as specialised machines are developed. The results point to the need for greater support for establishment and the requirement to have some income generated from bioremediation (gate fee for sludge) to make the enterprise a success. These calculations assume the crop is harvested in a two-year cycle direct chip (whole stem harvesting may reduce the cost). A farmer will have a volatile cash flow with this crop due to the biannual nature of the cropping.

Willow	Average cash flow/ha/year			
Energy inflation	**Base line**			
	1%	2%	3%	4%
	-€103	-€24	€65	€168
Opportunity cost				
€100	€200	€236	€300	€400
€116	€13	-€24	-€91	-€194
Yield when fully established DM				
	18t	20t	22t	
	-€61	-€24	€12	
Price/tonne				
	€55	€60	€65	€70
	-€80	-€24	€31	€87

*Transport costs are not included in this calculation. If this were included at a cost of €12/t DM the baseline figures would decrease by €134 on average. Farmer VAT registered.

Example

Take the average cattle rearing farmer in the National Farm Survey results for 2008 as an example. The variation in efficiency between farmers means that each individual farmer making a decision must examine his/her current efficiency levels for comparison. The average cattle rearing farmer farmed 29.7 ha of UAA. He is now examining the prospect of converting 20% of the farm to a miscanthus crop. His existing fixed costs of €261 per hectare will not change if he converts to biomass. Currently, his gross margin, excluding direct payments, is €162 per hectare. To cover the risk of changing to the new enterprise, risk of taking on debt, and to offset the long cropping length and low cash flow levels in the initial years he estimates he needs to cover all his fixed costs and return a net margin of €247 per hectare (€100 per acre). The average cash flow necessary to meet the required return is €508 per hectare. Using our model with the initial loan repaid over 20 years, interest rate of 6%, general and energy inflation of 2% with no opportunity cost for land counted, and with the crop yielding 10 tDM/hectare, the farmer will need to be paid €70.20 per tonne, with transport paid for.

Other issues that should be taken into account if converting part of the farm include:

- Opinion of successors
- Limiting future options
- Potential tax free income from long-term lease of the land foregone
- Assess all alternatives e.g., forestry
- Reducing the area of the farm may impact on the scale with regard to critical mass for some enterprises
- Reduction of labour demand – potentially freeing up time for off-farm work if available
- Diversification – spreading the risk with regard to volatility of existing enterprises
- Limited cash flow in the early years of the biomass crop
- Requirement to take on debt to establish the crop – interest rate exposure
- Large initial investment can not be spread over a longer period for tax purposes – unlike capital allowances for building investment
- Quality of the land – yield potential
- Distance to potential markets
- Potential for bioremediation (gate fee for sludge) in the locality
- Future potential for carbon credits
- Future prospects for the existing enterprise

Conclusion

There are large national targets to increase energy production from our own resources. The biomass crops dealt with in this paper may make up some of the solution. There is potentially a wide range of actual results for the individual farmer given the variation shown in the sensitivity analysis. For any individual farmer investing in these crops he/she must establish the efficiency of the current enterprise that will be replaced. With the long-term nature of the enterprise and the risks involved for a farmer both in agronomy and in finance, an increase in the establishment grant for planting and guaranteed inflated returns is required. There should be better tax treatment for the initial investment allowing it to be spread over a number of years and the vat rate on rhizomes and plants should be examined. Miscanthus is showing better results than willow but this may change with cheaper harvesting systems and fees for bioremediation. Ongoing research will be required to give farmers more confidence in the returns that are available.

Energy Crops and Greenhouse Gases

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Introduction

Biomass can be used as a fossil fuel substitute for both heat and electricity generation and may reduce dependence on imports and/or carbon dioxide emissions. Consequently, the EU and several EU member states have developed policies to promote the use of biomass energy sources.

Land-use change to biomass production can contribute towards meeting both national and international renewable energy and emissions targets. Already, land-use change to forestry (LULUCF) offsets emission almost 1.5 million tonnes per annum (McGettigan *et al*., 2009) and the conversion of pasture or annual cropland to perennial biomass crops and/or short rotation coppice (SRC) also has the potential to become a significant component to meeting future Greenhouse Gas (GHG) targets. However, realisation of this mitigation potential is dependent on a) the conversion of a substantial portion of land to biomass, b) selection of suitable crop types, c) development of reliable combustion systems and d) rigorous measurement of emissions and carbon sequestration during cultivation.

Agricultural emissions and legislative demands

Under the terms of the Kyoto Protocol and Council Decision 2002/358/EC, Ireland is directed to restrict GHG emissions to 13% above 1990 emissions. These emissions are currently running at 25% above 1990 levels, which equates to a shortfall of seven million tonnes CO_2-equilvalents. Significantly, Ireland is unique among EU countries for the proportion of its greenhouse gas (GHG) emissions which originate in agriculture. According to the EPA National Inventory Report 2009, GHG emissions from the agricultural sector amounted to 17.7 million tonnes of carbon-dioxide equivalent (Mt CO_2 eq.). This comprises 25.6% of the national total, with emissions dominated by methane (CH_4) produced from enteric fermentation in the rumen of livestock and nitrous oxide (N_2O) generated from organic and mineral fertilzers. These two gases are 25 (CH_4) and 298 (N_2O) times more potent than CO_2 in terms of global warming. However, agricultural emissions have decreased by 7.7% relative to 1990 and 15.7% relative to 1998 with reductions driven by decreases in both total animal numbers and fertiliser usage. By contrast, emissions associated with power generation have risen by 46% with 40% of power generation sourced from coal and peat combustion.

The EU Commission's recent climate change and renewable energy proposals have moved greenhouse gas emissions to the forefront of the national political agenda and focussed attention on agricultural emissions. This package of proposals, coined 20/20/2020, envisages a 20% EU-wide cut in emissions relative to 1990 levels (or 14.2% relative to the new proposed baseline year of 2005). In the event of a comprehensive global climate change agreement, this target will increase to 30%. In addition, 20% of total energy and 10% of fuel must be come from renewable sources. The burden-sharing of these cuts between member states have been allocated on a GDP per capita basis and as a result, Ireland has been set a target of reducing emissions by 20% from the non emissions traded sector (ETS) by 2020 compared to 2005 levels.

Why does this pose such a particular challenge to agriculture?

- The proposed reductions, which equate to over nine million tonnes CO_2-eq, only relate to the non-ETS sector with emissions from the ETS sectors (power generation and heavy industry) to be regulated at the EU level. As these non-ETS sectors comprise only agriculture, transport and residential, there are relatively few sectors to share the burden across. As agriculture makes up 40% of non-ETS emissions, the sector may be required to shoulder a large share of the burden, despite the fact that transport has displayed the largest rise in emissions since 1990 and continues to increase.
- Although projection had forecast a decrease in agricultural emissions by as much as two million tonnes by 2020, the effects of increased and/or abolishment of quotas combined with higher global demand may confound these predicted reductions.

In addition, the 2020 proposals aim at increasing the use of liquid biofuels for transportation from the present 2% in 2005 to 10% in 2020 and increasing the share of renewable energy of the total primary energy mix from 6.4% in 2004 to 20% in 2020 and whereby bioenergy is expected to play an important role.

Clearly, biomass as a renewable energy source will, if properly managed, be an important component of both national energy and climate change mitigation policy into the future.

The role of biomass production in greenhouse gas mitigation

Although the proposed targets are onerous, GHG mitigation and the application of best management practices can provide opportunities to optimise production efficiency. Biomass production can provide an important GHG offset as follows:

- *Displacement of GHG emissions* because their usage displaces coal and oil essentially entering into a carbon recycling operation. When these biofeedstocks are combusted, the carbon is released into the atmosphere. Fossil fuel use, on the other hand, releases 100% of the contained carbon. The net GHG consequences of a biofuel then depend on the amount of fuels from fossil sources used in producing the biofuel energy in the form of petroleum and coal-based electrical energy to raise, transport, and process the feedstock into energy.
- *Soil Carbon sequestration*. As plants grow, they remove CO_2 from the atmosphere via photosynthetic processes. Some of this carbon is permanently stored in the soil carbon pools.
- *Mitigation of nitrous oxide and methane emissions* as a consequence of land-use change. Both perennial grasses, such as miscanthus and willow require less nitrogen fertilizer than pasture or arable systems. As a result, there will be lower emissions of nitrous oxide (N_2O). Also, if cattle are displaced by the cultivation of biomass, there would be an additional benefit in terms of methane reduction. However, the adoption of biomass would not necessarily impact on livestock numbers as increased stocking rates could simply compensate for reductions in available land.

Main crop types

The choice of biomass crop is dependent on the yield potential, energy value, end use, soil and climatic conditions and the ease of cultivation and processing. In general, the energy grass, Miscanthus x giganteus and Short Rotation Coppice (SRC, either willow or poplar) have been the most prevalent choice of feedstock for both heat and power generation due to their high yields (8 -12 t DM ha^{-1} for willow and 10 -16 t DM ha^{-1} for miscanthus). Switchgrass (*Panicum virgatum*) and Reed Canary Grass (*Phalaris arundinacea*) are also viable candidates for feedstocks. Reed Canary grass, in particular, may be promising, as it is more tolerant of poorer, wetter soils.

Effects on GHG emissions of land-use change to biomass cultivation

Greenhouse gas mitigation associated with land conversion from pasture or annual cropland to perennial biomass crops are usually as a result of a) reduced fertilizer inputs, b) increased CO_2 sequestration into root biomass and the soil and c) other inputs associated with cultivation (ploughing, liming, herbicides, fuel usage, grain drying, etc).

The extent of each of these reductions will be dependent on whether biomass cultivation is displacing arable land or stocked pasture. Greenhouse gas emissions can also be reduced by removal of a proportion of CO_2 via photosynthesis into C sinks. These sinks can be either perennial woody tissue or soil organic carbon (SOC). Sequestration occurs when the input of carbon dioxide is greater than removals from harvesting and decomposition. In the case of arable displacement, there will be a net increase in C-sequestration. This is due to the fact that croplands have been shown to be net emitters of CO_2 of between 1–3 tonnes CO_2 ha^{-1} yr^{-1} (Davis *et al*., 2010). Most of this carbon loss is assumed to be associated with both ploughing and extended fallow periods. Overall, C input into the soil associated with the conversion of arable land to biomass has been estimated to increase by between 2.8 and 4.1 tCO_2 ha^{-1} yr 1 for miscanthus and 1.8–2.7 tCO_2 ha^{-1} yr 1 for SRC (Rowe *et al*., 2007, see Figure 1). Indeed this is a conservative estimate. If the biomass accumulation by below-ground biomass (rhizomes and roots) is included, another 0.5–1 tCO_2 ha^{-1} yr 1 could be added to this total. It should also be noted that, in order to reach these rates of sequestration, may take two-to-three years post-establishment (Hansen *et al*., 2004). By contrast, the conversion of pasture to biomass crops (Miscanthus or SRC) is assumed to have no impact on long-term net C sequestration when using IPCC Tier 1 methodologies for estimating C-stocks. Indeed, in the short-term, losses of 2-4 tCO_2 ha^{-1} yr^{-1} may be associated with ploughing. However, recent measurements at under a range of soil types have shown that initial C loss after ploughing is much lower (20-100kg CO_2 ha^{-1}) and that total site preparation losses can be limited to circa 1 tCO_2 ha^{-1} provided the fallow period is minimised (O'Connor *et al*., 2010). Therefore, net soil C sequestration may occur on pasture conversion to biomass.

Further savings in emissions are associated with fertilizer usage. Miscanthus and SRC are N-use efficient and are considered to require between 50kg and 100kg N ha^{-1} (Styles *et al*., 2007). This would represent a decrease in N requirement up to 100kg ha^{-1}. The amount of N_2O mitigated would further depend on the soil type being cultivated as emissions are 100-200% higher on heavy soils compared to sandy soils. There is also an associated saving with the manufacture of N, P and K fertilizers. In terms of other emissions associated with cultivation, including liming, pesticide manufacture, fuel and energy usage, these emissions are generally higher than for beef systems but lower than conventional arable systems, due to lower inputs and less annual site maintenence (particularly for miscanthus).

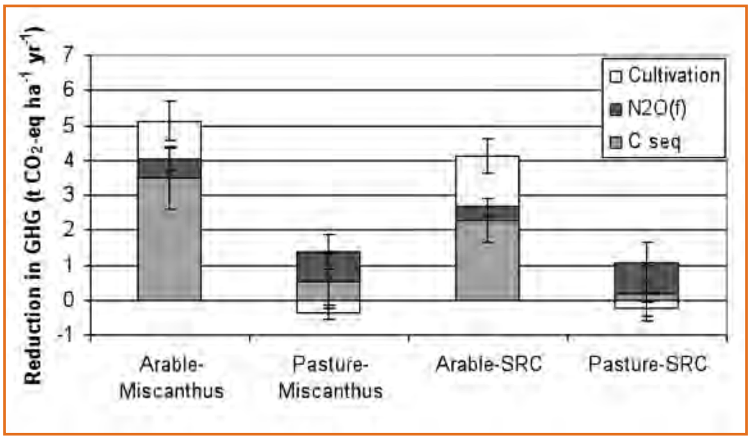

Figure 1: The comparative reductions in GHG emissions associated with the conversion of arable and pasture land to perennial biomass crops.

Regarding pasture conversion, there are no savings from the displacement of methane or nitrous oxide as it is assumed that farmers will convert a portion of their land to biomass, whilst maintaining livestock numbers on their remaining land. However, if there are whole farm conversions to biomass, a considerable amount of emissions associated with methane from enteric fermentation and manure management are displaced. The extent of the displacement will depend on both stocking rates and the type of cattle and could range from between 4 and 10t CO_2-eq ha^{-1} yr^{-1}. In addition, a further saving of in terms of N_2O associated with N excretion in the field would occur.

However, the deliberate displacement of dairy or beef cattle, particularly in efficient systems could be counter-productive in terms of global emissions, as Irish beef and milk production is comparatively efficient, especially compared to global grass-based systems (Cederberg 2001).

Displacement of fossil fuel emissions

In terms of fossil fuels replacement, the emissions associated with biomass-derived energy generation are principally associated with cultivation and the release of 1 and CH4 on combustion. By contrast, the emissions associated with gas, oil, coal or peat combustion are primarily due to CO_2 release on combustion and total emissions per unit energy produced range from three-to-seven times higher than that for biomass, depending on the energy content and the carbon content of the fossil fuel being replaced (Figure 2).

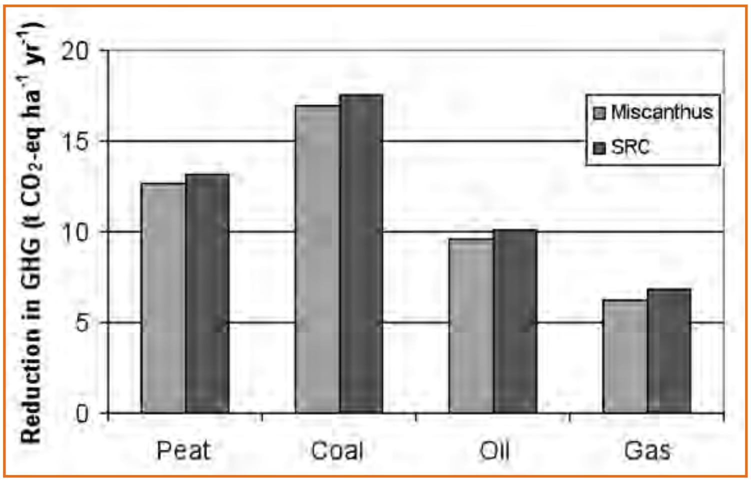

Figure 2: The reduction in GHG emissions expressed on a per hectare basis for miscanthus and SRC compared to peat, coal, oil and gas combustion

Heat production from energy crops is a low cost measure for the Government compared to other options as no major plant is required. In addition, increasing oil and gas costs make conversion to biomass commercially attractive even when boiler costs are included. Existing government support such as establishment and boiler grants may become unnecessary over time as the economics of heat production from biomass continue to improve. Indeed, if even half of the Government target of supplying 12% of national heat demand by 2020 is met by biomass, the total GHG saving from emissions displacement could equate to over 1.5 million tonnes CO_2 per year. Short rotation coppice grown on 109,000 ha would provide enough energy to replace 5% of the oil, gas and electricity used in the residential market and 15% of these fuels used in the commercial market (6.6% of the total heat market). The associated reduction in land-use emissions would equate to a further saving of 100,000 t CO_2 yr^{-1} assuming only pasture was displaced (no livestock displacement).

High GHG emissions arise from the generation of peat and coal electricity and both are highly C intensive fuels (emission factors of 90 and 118 kg CO_2 GJ^{-1}, respectively). In conjunction, the Government has an established target of 30% biomass co-firing in the three remaining peat burning power stations. If this target were to be achieved, almost one million tonnes CO_2 yr^{-1} would be displaced as emissions which arise from co-firing of energy crops are approximately 10% of electricity emissions from milled peat, when the entire fuel chain is considered. In order to meet these targets, approximately 60,000ha of agricultural land would need to be converted to perennial biomass.

Further issues and policy instruments

The principle issues surrounding biomass production are as follows:

- The cost and difficulty of crop establishment. Establishment of both willow (5 years) and miscanthus (two-three years) can be both difficult and expensive. Alongside the establishment grant, crediting farmers with the GHG-sink value of their crop may be one mechanism of aiding farmers. For instance, if 10 hectares of miscanthus is planted, sequestering 5t CO_2 ha^{-1} at a price of €20 per tonne, then the credit would be €1,000 per year.

- Whilst GHG reductions associated with carbon sequestration and either fertilizer or animal displacement can be directly credited to the agriculture sector, there is an issue as to which sector gains the credit for biomass displacement of fossil fuel emissions. While these crops are produced from the agricultural sector, the energy sector receives the benefit of the emissions reductions from both heat and electricity production. In particular, it may be preferable to focus biomass utilisation in terms of heat production as opposed to power generation. This is due to the fact, that under recent EU proposals, all GHGs associated with emissions-trading sectors (ETS) including the large industrial and power generating sectors would be directly administered by the EU, whilst individual states would only administer 'non-ETS' sectors such as agriculture and residential/ light industry emissions. Thus by focussing renewables on the non-ETS sectors, we can more effectively address our 2020 emissions targets, which principally focus on these very sectors. In addition, energy production from heat is more efficient (~90%) compared to electricity production (~35%). Thus heat production is thus the most effective way to utilise energy crop biomass although ultimately results in lower GHG savings as the fuels being replaced (oil and gas) are less carbon intensive compared to peat.

There is still considerable research to be carried out on many of these crops, particularly in terms of establishment, nutrient requirements and GHG inventories. Advances on all these fronts will improve both the productivity and mitigation potential of these crops. Other benefits associated with the cultivation of biomass crops also required further study. These include the use of energy crops (willow in particular) for remediation of sewage sludge, waste water and contaminated soils, and show considerable potential. Application of waste water for example would not only amend the water, but provide most of the nutrient requirements of the plant, eliminating the need for chemical fertilizer application. Also, biomass crops (particularly SRC) have been shown to be effective at reducing zinc levels in contaminated soils.

Biomass crops can also impact on the ecosystem water status. Due to large leaf areas and deep-rooting systems, the rate of water-use is higher compared to traditional annual crops. Also, rainfall interception is high and studies show a 50% decrease in hydrological effective rainfall compared to pasture and annual crops (Smeets *et al*., 2009). While this means that planting in areas likely to experience water shortages should be avoided, this high water use of biomass crops could be utilised as buffers to reduce the risks of local flooding. Reed Canary Grass and Switchgrass, which are more tolerant to flooding than miscanthus, may be ideal candidates for cultivation in these areas.

With regard to biodiversity impacts, studies in the UK show an increase in floral, invertebrate and avian biodiversity in SRC relative to arable (Sage *et al*., 2006). Biodiversity associated with miscanthus appears to be more analogous to arable systems. However, the body of research is extremely limited and requires considerable more work.

In conclusion, biomass offers a sustainable solution to Ireland's energy requirement whilst addressing greenhouse gas mitigation within the agricultural sector. However, considering the short time-span to the 2020 targets and the three-to-five year establishment phase of these crops, urgent policies are required to encourage a large-scale adoption of these systems.

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Application of Sewage Sludge and Biosolids to Energy Crops

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Introduction

Treated sewage sludge from sewage or wastewater, typically called 'biosolids', can improve soil structure and supply nutrients such as nitrogen (N) and phosphorus (P) and may, consequently, be a beneficial material for application to energy crops. Sewage sludge can be treated by biological, chemical or heat treatment to reduce its environmental risks and ensure it poses no threat to human or animal health.

Legislation

The spreading of sludge of municipal or industrial origin on agricultural land can impact on animal health, the environment and food safety. Consequently, there are a number of legislative restrictions on the use of sludge in agriculture.

The use of sewage sludge in agriculture is legislated under the "Waste Management Act, (Use of Sewage Sludge in Agriculture Regulations, 1998 to 2001) S.I.148/1998 and SI 267/2001." However, this did not account for energy crops as an agricultural crop and in 2008 the "Waste Management (Facility Permit and Registration) (Amendment) Regulations 2008 (S.I. 86/2008)" included the spreading of sludge to energy crops. Limits are based on absolute quantities of specified heavy metals, which may be applied annually based on a ten-year average. Sludge has to be applied in accordance with a nutrient management plan.

It is prohibited to apply untreated sludge to agricultural land unless it is injected or incorporated into the soil. In order to treat sludge it must undergo an appropriate treatment process to significantly reduce its fermentability and the health hazards resulting from its use.

In the absence of developments such as anaerobic digestion there will be few opportunities for the land spreading of municipal or industrial sludge on land producing food or feed crops. In that case the only other option would be to spread it on perennial energy crops such as willow or miscanthus.

Types of sludge

The method of sludge treatment determines the availability of phosphorus (P). Chemically treated sludge (more common) will have a lower P availability than biologically treated sludge. The moisture content of sludge varies with treatment; biological sludge has a solids content of 1-4%. In most cases, dewatering is required. There are five main processes used in Ireland to treat sewage sludge:

- Anaerobic Digestion (one hour at 70°C or two hours at 55°C).
- Thermal Drying (< 10% moisture).
- Composting (55°C for 3 – 15 days).
- Lime Stabilisation (increase pH > 12 giving 70°C for 30 minutes).
- Autothermal Thermophilic Aerobic Digestion (> 55°C).

Land application

Biosolid is an organic fertilizer of a type which is not specified in Table 9 of the nitrate regulations (SI/101/2009) which applies limits to total nitrogen (N) and total phosphorus (P) application to agricultural land. N availability for biosolids is governed by the amount specified in Table 9 SI/101/2009 in relation to cattle manure, unless a different amount has been determined in relation to the biosolid fertilizer.

When applying biosolids to land, factors such as the biosolids treatment process, existing soil nutrient levels, soil type/properties, crop nutrient requirements, biosolid application methods, and land use history can affect biosolids phytoavailability (availability of a substance to be synthesised and used in the metabolic activities of the plant).

Issues with legislation

The EPA take the definition of agriculture from that stated in "The Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998" (S.I. 148/1998); energy crops are not included in the definition as agriculture.

The Waste Management (Facility Permit and Registration) (Amendment) Regulations 2008 (S.I. No. 86 of 2008) includes sludge spreading to energy crops as potentially availing of the relief (exemption) for beneficial recycling, however, the EPA insists that a "Certificate of Registration permit" (COR) is required from the local authority to recycle sewage sludge to energy crops where the total quantity of organic waste recovered at the facility shall not exceed 1,000 tonnes per annum. Where the tonnage recovered at the facility exceeds 1,000 tonnes per annum a waste permit licence is required.

As legislation stands, sewage sludge can be recycled to land used in agriculture for food production on approval of a Nutrient Management Plan by the local authority (in conjunction with the Nitrates Directive and the Code of Good Practice for agricultural use of sewage sludge, the Code of Good Agricultural Practice for the protection of soil and water, but cannot be applied to energy crops without a COR). Currently, a COR costs €300 and will cost more based on the time and work in completing the c 50-page-document. Unless two fields are contiguous which they normally aren't, each field will need a separate COR.

Phosphorus availability in sludge

The Codes of Good Practice for the 'Use of Biosolids in Agriculture' assigns values of 9-50% for availability of P in thermally dried biosolids, See Table 1. For the anaerobic digestion process, the Codes of Good Practice reports that for low solids anaerobically digested material, P phytoavailability should be regarded at 60% for the first cropping year. High solid content material will have 35-50% P phytoavailability.
It is a combination of the existing soil P levels, the P content of the biosolids and the crop requirement that will determine the ultimate rate of P to be applied to land. Availability levels are typically 20-60% depending on the sludge treatment (Fehily, Timoney & Company, 2007).

Table 1. P phytoavailability as per Code of Good Practice for the Use of Biosolids in Agriculture

Biosolids type	% DM	Total P%	Available P%
Digested low solids	4	3% of DM	60%
Digested high solids	25	3.5% of DM	35 – 50%
Composted	65	1% of DM	20%
Lime stabilised	60	0.4% of DM	46%
Thermally dried	94	3.7% of DM	9 – 50%

It must be assumed that some of the P applied in the first year after application will become available in subsequent years. To this end, it is recommended that soil sampling be carried out once every three years to monitor soil P levels and tailor sludge application rates to satisfy the crop requirement.

Energy crops and the Nitrates Directive (SI 101 2009)

Energy crops are included in farm nutrient management as outlined in the nutrient legislation (SI 101 2009) for example areas under energy crops shall be included in determining whole farm nutrient allowances. Willow and miscanthus are treated as tillage crops under the Nitrates Directive and farm derogations and is not included in the grassland area for the overall farm calculation. As with tillage crops, farmers can apply organic nutrient sources to energy crops up to 170kg Org N/ha as in the Nitrates Directive. Tables 3 and 4 are guidance nutrient advice for miscanthus and willow and should be applied to farm nutrient management plans. These figures are complied from existing international research and will be further adjusted to match crop nutrient requirements as trial work is completed under Irish growing conditions.

Miscanthus nutrient requirements

Miscanthus is a relatively new crop to Ireland and nutrient requirements should be applied based on a recent soil test report. Table 2 shows the annual guidance nutrient requirements for a crop of miscanthus.

Table 2. Miscanthus nutrient guidance requirements*

Soil Index	Nitrogen (N) Kg/ha	Phosphorus (P) (kg/ha)	Potassium (K) (kg/ha)
1	100	23	120
2	80	13	75
3	50	0	40
4	30	0	0

Source: *Teagasc, 2008, Nutrient Guidance for Energy Crops

Crop off-takes

Research from experiments conducted throughout Europe shows that nutrient off-takes from productive miscanthus crops (10 – 15 t DM/ha) can range from: 60 – 100 kg/ha Nitrogen, 7 – 15 kg/ha, Phosphorus, 50 – 130 kg/ha Potassium, and 3 – 12 kg/ha Mg.

Relatively little is known about miscanthus and the manner in which the crop uses nutrients. Teagasc Oak Park is currently conducting trials on K usage by miscanthus but further research is needed to learn more about the crops nutrient requirements.

Livestock manures

Livestock manures are also an option in terms of meeting the nutrient requirements for energy crops. Livestock manures are governed by nutrient legislation (SI 101 of 2009, Nitrates Directive). For example, cattle slurry can be used as an effective nutrient source for miscanthus and can be applied annually to satisfy crop nutrient requirements. Cattle slurry contains a total of 5 kg N/m3, 0.8kg P/m3 and 4.3kg K /m3. Miscanthus grown on a soil P Index 1 requires approximately 28m3/ha of cattle slurry (23/0.8) to satisfy its annual P requirement. The slurry would provide 56kgN/ha and 120kg K/ha per application.

Willow nutrient requirements

Willow is a new crop to Ireland and there is little data on the crops nutrient requirements under Irish growing conditions. Nutrient advice, as shown in Table 3, indicates guidance crop nutrient requirements based on best available research information that pertains to Irish growing conditions.

Table 3. Willow nutrient guidance requirements *

Soil Index	Nitrogen (N) Kg/ha	Phosphorus (P) (kg/ha)	Potassium (K) (kg/ha)
1	130	34	155
2	100	24	135
3	75	0	120
4	40	0	0

Source: *Teagasc, 2008, Nutrient Guidance for Energy Crops

Crop off-takes

Dawson (2007)* indicated that one tonne of willow DM harvested removes approximately 15 kg of N, 2kg of P and 10 kg of K. The standard DM removal for willow in Irelands maritime climate is expected to be 10-12 t/ha per annum.

How much sludge to apply

If we take an example of a sludge with a dry matter content of a digested low solid sludge of 4% DM, a P content of 2% (20 kg per 1,000 kg dry material), and a P availability of 60%. Assuming the soil is P Index 1, the crops P requirement is 34kgP/ha. In one fresh tonne of sludge there is 0.48 kg P/ton of wet material assuming a 60% P availability (1,000 x 0.04 x 0.02 x 0.6). Therefore, 70.8t of wet sludge (34/0.48) will be required to satisfy the crops P requirement on this soil type.

Similar calculations could be carried out based on the N and K contents of the sludge and their permissible rates. For the vast majority of sludge the P application rate will be the nutrient limiting factor.

Heavy metals

It is a requirement to test all sludge for heavy metals prior to land-spreading. The metals content is normally stated in mg/kg. Table 4 shows the maximum level of heavy metals which may be applied based on soil and sludge analysis as per SI. 148/1998 and SI/267/2001.

Note: The limiting factor will usually be Phosphorus. However, in certain situations the heavy metals may dictate the application rates.

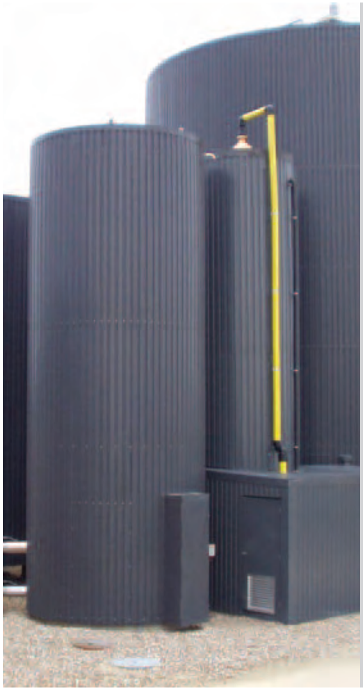
Table 4. Maximum concentrations of heavy metals in soil, sludge and maximum application rates per year as per S.I. 148/1998 and S.I. 267/2002

Nutrient	Max. values in soil (mg/kg of dry matter)*	Max. values in sludge mg/kg of DM	Max. application kg/ha/year
Cadmium (cd)	1 (soil pH 5 – 7)	20	0.05
Copper (cu)	50	1,000	7.50
Nickel (N)	30	300 *	3.00
Lead pb)	50	750	4.00
Zinc (zn)	150	2500	7.50
Mercury (Hb)	1	16	0.10
Chromium			3.50

* Where the soil pH is greater than a pH 7, the values set may be exceeded by more than 50%, provided that there is no resulting hazard to human health, the environment, or ground water.

Table 4 demonstrates that restrictions on sludge spreading may be determined by the metal content in the sludge or the metal content in the soils. Heavy metals are usually reported in mg/kg on a sludge laboratory analysis. Dividing by 1,000 will convert mg/kg to kg per tonne.

In summary, energy crops have an annual nutrient requirement as shown which can be satisfied by recycling sewage sludge or other nutrient sources where available. Indications are that by 2013 in the region of 130,000 tonnes of dry sludge will be available for land spreading. This will supply enough nutrients to satisfy the nutrient requirements of approximately 65,000 ha of crops.



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Operation of the Bioenergy Scheme

Mel McDonagh, Department of Agriculture, Fisheries and Food

Introduction

In 2007, the Department of Agriculture, Fisheries and Food (DAFF) launched a Bioenergy Scheme on a pilot basis to encourage farmers to grow willow and miscanthus as a renewable source of energy up to the end of 2009. The key objectives of the Scheme were:

1. To increase the production of miscanthus and willow in Ireland by grant aiding establishment costs.
2. To contribute to GHG emissions reduction and carbon sequestration in the agriculture sector by encouraging farmers to grow carbon neutral fuels.
3. To increase the supply of biomass feedstock which can be used to produce heat and electricity from biomass sources in line with Government targets.
4. To complement other Government measures in the area of renewable energy, such as those developed by the Department of Communications, Energy and Natural Resources.
5. To provide opportunities for farm diversification and rural employment.

The legal basis for the Scheme was Council Regulation 1782/2000 establishing common rules for direct support Schemes under the Common Agriculture Policy. This regulation authorised member states to grant aid the production of miscanthus and willow on areas declared under the EU Energy Crops Scheme in the Single Payment Scheme application. The Scheme was open to landowners or applicants who had leasehold title to the land where it was proposed to plant the crop.

Grant aid

In accordance with Regulation 1782/2000, the Scheme paid farmers a once-off capital grant of up to €1,450 per hectare to cover 50% of the costs of establishing the crop. This was the maximum level of aid permitted by the EU Commission to establish willow or miscanthus crops. The Commission made this decision on the basis that both willow and miscanthus crops are classed as agriculture crops and not afforestation, which is longer term and where higher aid rates could be justified.

The minimum area allowed under the Bioenergy Scheme per applicant was three hectares and the maximum area was 30 hectares. Eligible costs included ground preparation operations, vegetation management, planting and the purchase of planting stock. Ground preparation operations were calculated on the basis of standard costs agreed with Teagasc. Invoices were requested for the purchase of planting stock, planting and fencing where applicable.

Aid was paid in two instalments - a maximum of 75% of the grant (€1,088) in the first instalment following establishment of the crop and the remaining 25% (€362) in the year after payment of the first instalment, provided the applicant had adequately established and maintained the crop.

Pre-planting approval

To qualify for an establishment grant all applications were subject to a pre-planting approval process. Applications for pre-planting approval were processed and checked for ownership/leasehold title, end use contracts, verification of site area, ground suitability, environmental and archaeological checks, etc. All applications were accompanied by an end use contract or letter of intent with a contractor in the bioenergy market.

Site identification was established by asking applicants to declare the land parcels (Land Parcel Identification Number) of each land parcel where it was proposed to plant willow or miscanthus. On-site inspections were carried out to assess the suitability of the site for planting miscanthus or willow. Pre-planting approvals were issued up to the available level of fixed funding for each crop. Successful applicants were issued with an approval letter authorising commencement of work on the site.

Post-planting inspections

Following establishment of the crop, applications were accepted for the first instalment of the establishment grant. All applicants were inspected prior to payment of the first instalment grants. Inspections were also carried out on a selected percentage of second instalment applications. Inspections commenced in late August/early September to allow the crop sufficient time to establish and to enable an accurate assessment to be carried out.

The inspections aim to verify the area planted and identify deficiencies in crop establishment. Growers were advised in writing as to the necessary remedial work required for satisfactory establishment to ensure that crops reach full potential. Open ground was allowed on up to 10% of the site where it was necessary for the management of the crop and for environmental reasons.

Conditions for payment of aid

Eligibility for first and second instalment grants depended on meeting the terms and conditions of the Scheme, in particular the degree of satisfaction with crop establishment. Crops must be established in accordance with the Scheme provisions and the Department's Best Practice Manuals for miscanthus and willow. Where crops were not properly established payment of the aid was refused or delayed to allow proper establishment. Applicants who received aid were required to maintain and manage the crop for a minimum period of seven years from the date of approval.

Area planted

The pilot Scheme ended in 2009. It generated considerable interest from farmers in growing miscanthus and to a lesser extent willow. Overall (approx) 355 ha of willow and 2,100 ha of miscanthus were grant aided.

Table 1. Total area planted under the Bioenergy Scheme

Year	Willow (ha)	Miscanthus (ha)	Total area planted (ha)
2007	63	617	680
2008	128	774	902
2009	166	709	875
Total	**357**	**2,100**	**2,457**

The presence of contracting companies in a particular region offering contracts to farmers heavily influenced where crops were planted. The highest concentrations of miscanthus plantings were located in Tipperary (337ha), Limerick (332ha), Cork (308ha), Kilkenny (200ha) and Wexford (188ha) where most of the main companies operate. The highest concentrations of willow plantings were located in Meath (85ha), Cavan (65ha) and Monaghan (54ha).

New Bioenergy Scheme

Drawing on the experience of the Bioenergy Scheme, th**e Department is launching a new Scheme for planting miscanthus and willow over the period 2010 to 2012**. The legal basis for the Scheme has changed to Council Regulation (EC) No 1698/2005 on support for rural development by the European Agricultural Fund for Rural Development. Accordingly, the new Bioenergy Scheme will now be funded under the Department's revised Rural Development Programme from modulation funding. The new Scheme will follow a similar format to the pilot Scheme in terms of the application, pre-planting approval and payment process.

A significant change is the use of selection criteria to establish eligibility for aid. This is a requirement of EU Rural Development Regulations. It means that aid cannot be granted in the new Scheme on a first come, first served basis. Therefore, applications will be prioritised having regard to the following criteria:

- The existing system of farming and the level of expertise/knowledge with regard to growing biomass crops.
- Suitability of the site having regard to access, agronomy and environmental considerations.
- Evidence of linkages with end-users to use the biomass crop as a source of bioenergy.
- Proximity of site in relation to major end users e.g., co-firing and/or CHP (Combined Heat & Power) plants etc.
- Existing applicants who planted under the pilot phase of the Bioenergy Scheme.
- Applications capable of achieving economies of scale.

Aid payable under the Scheme

Approved costs will be grant aided up to 50%, subject to a maximum grant of €1,300 per hectare for both crops. This represents a reduction of €150 per hectare on the pilot Scheme to take account of lower establishment costs. The grant available for ground preparation operations and vegetation management will continue to be calculated in accordance with standard costs. The Department will continue to monitor the level of establishment grant over the lifetime of the Scheme. The EU and National Energy Crop Premiums ended in 2009 and will not be available over the lifetime of the Scheme. Areas planted with willow and miscanthus will continue to qualify for the Single Farm Payment and adjusted payments under REPS and the Disadvantaged Areas Scheme. There is no change to the minimum (3ha) and maximum (30ha) allowable areas under the Scheme. The period in which applicants must maintain and manage the crop remains unchanged at seven years from the date of approval.

Closing date

The closing date for receipt of applications for pre-planting approval is 31 March 2010. All relevant application forms and Best Practice Manuals are available from Biofuels Policy Unit, Department of Agriculture, Fisheries and Food, Kea-Lew Business Park, Mountrath Road, Portlaoise, Co. Laois. Telephone 057- 8692231/40; E-mail bioenergy@agriculture.gov.ie

Energy Crops Business Contacts

Quinns of Baltinglass
Main St., Baltinglass, Co. Wicklow

Quinns entered the area of energy crops in 2004 on the basis that the EU was intent on addressing the whole area of climate change following the Kyoto Protocol. We looked at the various options for both reducing greenhouse gas emissions and also reducing our dependence on fossil fuels and found that miscanthus could play a significant role in this area.

The attractions of miscanthus to Quinns were that it fitted in very well with our largely tillage growing hinterland. Much of the machinery needed to grow and harvest the crop was already available. Also, when established, miscanthus would yield an annual harvest and is much closer to other tillage crops in many respects than other energy crop options e.g., willow.

Miscanthus is extremely energy efficient and gave a positive energy ratio of 32:1. This is largely due to its low dependence on inputs; it was likened to having an oil well on the farm. In addition, it gave growers another income option and this was most welcome following the demise of the sugar beet industry.

Quinns planted their first miscanthus crop in 2005 and the following year, to show their commitment to the fledgling industry, supplied and planted miscanthus rhizomes for growers and contracted to buy back the cane for the first five harvests, at a minimum price of €60 per tonne. This pioneering of these non-grant aided crops in 2006 contributed greatly towards the successful introduction of the Bioenergy Scheme in 2007.

Market development

Quinns have committed much time and resources in efforts to develop markets for miscanthus cane. The cane harvested in 2008 and 2009 went for briquetting, equine bedding (from non-grant aided crops) and also for trial co-firing in Edenderry Power Station. There were some problems at the intake in Edenderry as their facility was designed for delivery of peat only. These problems can and will be addressed shortly and this will enable miscanthus to be included as a feedstock. In addition, the ESB peat-fired power stations in Lanesborough and Shannonbridge will commence trial miscanthus combustions shortly. The Government's White Paper on Energy in 2007 set a target of 30% substitution of peat with biomass; with some modification at the intake points at the power stations and with a REFIT Scheme in place there will be significant demand for miscanthus as a feedstock for these three peat-fired power stations in the near future.

In addition, to minimise transport and handling costs, Quinns have moved away from the idea of pelleting miscanthus to utilising miscanthus in automated big bale burning systems which are commonplace in countries such as Denmark. Quinns are currently looking at installing these burners in district heating systems where bales are delivered directly from the grower to the end user and thereby minimising handling and transport costs.

There are a number of Combined Heat and Power (CHP) plants presently in the planning process which will also provide an additional market outlet for the cane.

Quinns continue to incorporate miscanthus in briquettes for the solid fuel market. This market outlet increased hugely in 2009 and further growth is expected as the carbon tax on peat briquettes and coal impacts.

Conclusion

Overall, the market prospects for miscanthus is bright as there will be many and varied end uses for the cane from the niche markets for bedding and briquettes through to District Heating systems, CHP plants and co-firing in power stations.

Contact: Tel. 059 648 1266; www.quinns.ie

JHM Crops Ltd
Adare, Co. Limerick
Miscanthus Market Leaders

JHM Crops Ltd. is the market leader in Ireland in the growth and promotion of miscanthus and is one of the biggest businesses currently operating in Europe that is solely involved in the planting, growing and selling of miscanthus and miscanthus-based products. Currently, JHM have over 3,000 acres under contract with farmers and are continuously expanding due to the interest being shown from farmers throughout the country as well as growing demand for the end products.

JHM began in 2004 planting the first commercial crop of miscanthus in Ireland near Adare in County Limerick. From the initial success of the crop it was clear that miscanthus was suited to the Irish climate and could provide a valid alternative to imported, expensive and carbon intensive fossil fuels.

Markets for miscanthus

JHM's miscanthus logs are made from miscanthus grown by Irish farmers and can be used in stoves, open fires and all solid fuel appliances. The first of these went on sale in 2008 in County Limerick and proved very popular due to their rapid heat release rate in comparison to peat briquettes. This year they are much more widely available across the Munster region.

Miscanthus animal-bedding is biodegradable and is three times more absorbent than wood shavings. It can be used as an alternative to all animal-bedding currently available and has proved a popular choice with horse trainers and farmers alike.

Miscanthus is ideal for the heating market and JHM have a number of projects already progressing in the commercial and domestic heat sector. JHM have extensively researched the options available to those interested in burning miscanthus for heat or CHP (Combined Heat and Power) and advice is available to growers from JHM at any time. There are also benefits to growers who want to get involved in other aspects of the supply chain e.g., processing miscanthus into chip/pellet/log form. This has already happened with a processing plant in Munster which is ready to begin operation in March, with others to follow by the end of 2010. Miscanthus is also ideal for co-firing in peat power stations and JHM is working to achieve this with the relevant state agencies and Government departments. JHM sees the doubling of the area of planted miscanthus as being very achievable and, due to the development of new and established markets, is very keen to increase its network of growers to meet this ever expanding demand.

Contact: Tel. 061 – 395336; www.jhmcrops.ie

Farrelly Bros.[1] and Timberpro[2]

[1]Kieran Cross, Carnaross, Kells, Co. Meath
[2]Irishtown, Balrath, Kells, Co. Meath

Introduction

Farrelly Bros. have worked for a long number of years in the machinery contracting business in both the agricultural and construction industries and has been involved in the cutting and processing of timber for the last 13 years.

In 2006, Farrelly Bros. established Timberpro. This is a dedicated company involved in processing and marketing wood biomass. Timberpro supplies and sells woodchip and wood pellets to the domestic and commercial market. Timberpro has been very concerned about the method of pellet delivery prevalent in the Irish market. Consequently, it invested in a fleet of specialised pellet trucks. These pellet trucks are used as standard across Europe and they ensure minimum dust in the pellet and greatly reduce boiler problems.

Timberpro has also entered the wood briquette market and these are now available in garage forecourts and fuel outlets.

CHP plant

Farrelly Bros. in a joint venture with HDS Energy, Kells, County Meath, have successfully secured a site, a grid connection and have lodged a planning application, which is currently with Meath County Council, to build a Combined Heat and Power (CHP) plant. This CHP plant when in production will produce electricity for the national grid. The heat available will be harnessed to dry willow woodchip and other products.

Woodchip

There are three main markets for woodchip:

1) The proposed CHP plant has a fuel requirement of 150,000t/year and it can burn green willow woodchip.
2) The commercial market includes the following industries: food processing; manufacturing; hotel; care and many other industries.
3) The peat burning power stations will need to replace 1,000,000t of peat by 2015 with biomass. Woodchip replaces peat very effectively as proven by recent trials at Edenderry.

Willow

In order to secure a supply of woodchip for our expanding commercial market, we decided to promote the growing of willow. Following extensive research for the last number of years a promotional campaign was launched in 2007. This alternative crop was welcomed by farmers. One of willow's biggest attractions for farmers is the reduction in labour requirement and while there are establishment costs, an establishment grant is available and once established the crop lasts for 25-30 years.

Willow is very well suited to our Irish climate and has an establishment rate of between 95-100%. Like any other agricultural crop the best crops of willow are on the better land. As a general rule of thumb, if land grows good grass then it will grow good willow. If land needs drainage then it is too wet.

When comparing the net profit of willow with other enterprises (based on ACA Handbook), willow is currently the most profitable farm enterprise. It has a predicted net profit of over €200/ac/yr on good land and does not affect your entitlements or REPS etc.

Willow will provide a very valuable and much needed alternative farming enterprise. It will also provide the local economy with a reliable and guaranteed Irish supply of locally grown woodchip instead of an expensive imported fossil fuel. Farrelly Bros. have contracts available with a guaranteed price and market.

Contact: Tel. 046 9249392; Email. info@timberpro.ie; www.timberpro.ie

Kilogen Green Service Company
Dublin Road, Kilkenny

Kilogen Ltd was established in County Kilkenny in 2007 and is dedicated to the production and processing of bioenergy fuels and the delivery of green energy solutions to power companies, large industry, commercial users and the residential market.

Kilogen focuses on enabling farmers in Kilkenny and its immediate hinterland to select and grow the most appropriate energy crops for conversion into green energy solutions, and provides a support service to growers which include the licensed supply of rootstock, crop management, transport and farm contracting services.

The company has conducted extensive research into the use of energy crops as a biofuel, in particular miscanthus, and has established itself as a leading authority in this field. Miscanthus is a grass that due to its high biomass yield has been used as a bioenergy fuel in Europe since the early 1980s. The rapid growth, low mineral content, and high biomass yield of miscanthus make it a favourite choice as a biomass fuel. After harvest, it can be burned to produce heat and steam for power turbines. The resulting CO_2 emissions are equal to the amount of CO_2 that the plant used up from the atmosphere during its growing phase, and thus the process is CO_2 neutral. When mixed correctly with fossil fuels, it can be used in peat/coal-fired power stations. It can also be used as a fuel in biomass boilers and as an input for ethanol production.
Kilogen supports the development of the sterile hybrid between *M. sinensis* and *M. sacchariflorus*, Miscanthus Giganteus or "E-grass", as the best form of miscanthus for energy production. It can grow to heights of more than 3.5m in one growth season. Its dry weight annual yield can reach 25 tonnes per hectare. Miscanthus is sometimes called "Elephant Grass".

The company is also developing its knowledge on the use of willow, hemp and woodchip as alternative bioenergy products.

Kilogen's expertise in the sowing, growing, harvesting and drying of miscanthus to maximise yield and energy production is freely available to all its growers. The company has also developed a supply chain to provide rhizomes (rootstock) to new growers and is refining the system to regenerate rhizomes from existing and future three-year-old plus crops that will provide an important secondary income for growers and replace existing imported rhizomes with local regenerated rootstock. The company is also developing efficient supply chain systems to bring the crop to market that minimise grower harvesting and storage costs.

Kilogen's main customers to date have been the power companies and it is also developing multi-fuel boiler solutions that use miscanthus and other bioenergy products to meet the needs of the private sector

With the Government's policy on renewable fuels use in power stations and with an emerging private sector market, Kilogen looks forward to the future.

Contact: Tel. 056 7788108; Email. info@kilogen.ie; www.kilogen.ie

Natural Power Supply
Ballymountain, Ferrybank, Waterford

Introduction
Natural Power Supply (NPS) is a well established business in the renewable energy sector – operating in the biomass wood fuel area.

NPS was established in 2002 and brings together a combination of energy crops and agri-business experience in Ireland with technology, engineering and logistics experience from a global American company.

The company has been very successful in establishing and maintaining market leadership in what was a slow evolving renewable energy business in Ireland and has established a business model that is performing well and has the capacity to expand quickly.

NPS offers a full service business model which caters to all aspects of the customers requirements from boiler sales right through to fuel supply and boiler maintenance, and has been developing production systems on Irish farms to exploit our land bank, excellent climate for biomass production and farmer base.

The company has imported and trialled three planting systems, conducted agronomy trials for fertilizer application and pest control, and trialled varieties for rust resistance and adaptation to soil types. It has developed a rod harvesting and natural drying system specifically to suit smaller boilers which require drier timber. NPS has also put in place a production contract for growers.

Willow, Reed Canary Grass, Switch Grass, Hemp, Linseed, Miscanthus and Triticale were trialled for their suitability to our climate, soil types, and technical application to boiler use. Willow has the highest output of calorific value per hectare and ease of use, other crops have posed technical challenges to the boiler manufacturers including emissions and ash melting.

Biofiltration
One of the most lucrative areas of willow production is the willow species ability to effectively consume waste and industry by-products as part of its natural growth cycle – a process known as biofiltration. NPS were the first to demonstrate biofiltration on a large-scale in the South of Ireland using willow and proved this concept using a large- scale brewery liquid trial, which was monitored independently by experts from the soil and hydrology sciences. This system has been approved by the Environmental Protection Agency (EPA).

All of the above projects are controlled by a process of nutrient management planning for both micro and macro nutrients. NPS has a nutrient management planning template which has been accepted by all the local authorities in the environmental monitoring of these sites.

Market growth potential
Due to significant changes in both Government and private sector attitudes toward sustainable energy, the market for renewable energy is projected to grow significantly over the next 10 to 15 years. The Irish Government has targeted that the market in Ireland should be at 5% of fossil fuel heating by 2010 and 12% by 2020. For Ireland, this is a €140 million to €360 million per annum business.

Contact: Tel. 051 832777; Email. info@nps.ie; www.nps.ie

Wexgen
Moyne Industrial Estate, Old Dublin Road, Enniscorthy, Co. Wexford

Wexgen Limited is a company wholly owned by local energy crop growers and will begin manufacturing carbon neutral biomass briquettes under the GreenFlame trademark in a 12,000sq.ft manufacturing facility in the Moyne Industrial Estate, Old Dublin Road, Enniscorthy in February 2010.

Wexgen was formed in 2007 by a group of miscanthus growers who had previously planted crops. The aim was to create a viable end use for our crops and to own the process from farm to fireplace. Since our formation, we have designed and developed much improved planting and harvesting equipment and currently have over 2,000 acres of biomass crops growing in counties Wexford, Waterford, Wicklow, Carlow and Laois

WEXGEN AGRI-SERVICES DIVISION ARE LOOKING FOR MISCANTHUS GROWERS TO PLANT BIOMASS CROPS FOR THEIR NEW BRIQUETTING PLANT!

Wexgen offers farmers a complete support package from field inspections, soil tests, specialised planting equipment to ensure the best establishment rates, contracting services and now the purchase of the biomass for the GreenFlame biomass briquettes GreenFlame briquettes will be in a store near you in the coming weeks and will also be available through the www.greenflame.ie website.

Contact: Tel. 053 9238055; Email. info@greenflame.ie; www.greenflame.ie

Leegen Ltd.
Skibbereen, Co. Cork

Leegen Ltd was set up in spring 2008 under the GEGA banner. The company planted 34ha of miscanthus in 2008 and a further 150ha in 2009. The crops were planted with a specially designed company planter and all were passed for grant aid. At present the company is developing a new machine for regenerating crops. Leegen runs field walks and information meetings.

The company will pay €65 per tonne of miscanthus at 20% moisture and a bonus for lower moisture content, which provides a potential return per acre far in excess of the average tillage or beef enterprise from years three or four after crop establishment. The company is seeing interest from full-time tillage and livestock farmers who are currently experiencing low returns from their enterprises. There is also substantial interest from younger farm owners who, working away from home, benefit from the reduced workload of harvesting every year between February and April, following crop establishment.

Miscanthus is very favourable for biomass because of its high energy value at harvesting and a typical moisture content of approx. 20%, which compares favourably with other sources of biomass.

Miscanthus is used successfully in briquettes in various parts of the country and Leegen has identified this potential in County Cork. The company is in active discussions with nursing homes, private industry, community councils, state bodies and the energy division of Cork County Council with a view to supplying carbon neutral energy at a lower cost compared to oil or gas. A consultant engineer has been retained to provide technical expertise for future development and Cork Enterprise Board and Leader have been contact for advice on future projects.

Leegen Ltd will continue to be very active in the marketplace and to work with small- and medium-sized businesses and facilities to replace their use of oil or gas with a cheaper, greener fuel. The company will be marked-led and quality-driven and will grow the supply of miscanthus and other biomass products in tandem with market requirements.

The company is focused on providing excellent technological advice and support for its customers through the expertise of associate engineers and suppliers of equipment, boilers and heat plants, and will provide an efficient delivery service of the biomass to the end user. Leegen Ltd will optimise the returns to its growers, shareholders and customers using a strategy of having many smaller-sized local customers, who are in close proximity to a number of growers, providing efficient heat (and power).

Contact: Tel. 087-6540255; Email. info@leegen.ie; www.leegen.ie

Rural Generation
Derry City

Rural Generation is the world leader for over 20 years in planting willow. The company has almost 2,000 hectares planted in Ireland to date and has embarked on planting 5,000 hectares in New York and Canada last year.

Rural Generation prides itself on its know-how and its abilities. It guarantees the grower an 80% establishment rate and guarantees against disease, removing any risk for the farmer. This guarantee is unique to Rural Generation and possible only because the company plants two breeding programmes over each plantation in addition to its extensive plant husbandry expertise.

Rural Generation's 'one-stop-company' solutions, allows the farmer to derive a dual income from willow by receiving a gate fee for recycling liquid and sludge waste and from generating renewable energy using biomass fuel.

It is important to Rural Generation that the farmer has a market for his/her product. To ensure this market, RG has a series of long-term contracts for effluent and sludge disposal with a number of municipal authorities both in the north and south of Ireland. In addition, it installs biomass systems all over Ireland and currently has a market for over 10,000 tonnes of quality willow fuel.

In summary, Rural Generation has a pedigree in this industry that is recognised both nationally and internationally as 'Simply the best'; a mantle that has been earned over a long period of success. The company can offer the farmer a professional farm nutrient plan, guarantee yield and a return.

Contact: Tel. +44 7894411903; tom.brennan@ruralgeneration.com; www.ruralgeneration.com

Top: Willow harvesting at Brook Hall Estate

Bottom: Sludge cake injecting at Brook Hall Estate

IFA Bioenergy Policy Position
Irish Farmers Association, Bluebell, Dublin

Introduction
Ireland faces a significant challenge in meeting its environmental commitments on renewable energy generation and emission reductions. The new EU Renewable Energy Directive (2009/28/EC) established a mandatory national target consistent with a 20% share of energy from renewable sources and a 10% share of energy from renewable sources in transport in energy consumption by 2020.

Renewable energy, in particular bioenergy, is intimately and inextricably bound up with farmers and farming activities. Farmers as custodians of the land are committed to undertaking production in a sustainable manner. Through the effective utilisation and management of the natural resources, agriculture and forestry have a pivotal role if these renewable energy targets are to be achieved. Managed correctly, renewable energy production will not adversely affect food security, or cause volatility in food prices; in fact it will create a vibrant and sustainable rural economy.

In order to maximise the contribution that the sector can make, support structures must be put in place that will facilitate and encourage renewable energy production and incentivise farmers to diversify into bioenergy sector.

Policy proposals
The agriculture and forestry sector have the capacity to increase the production of renewable energy and alternative fuel sources. In order to exploit the potential of the bioenergy sector, a proper policy framework is needed which supports farmers to diversify into the green economy and thus creating a vibrant indigenous sustainable bioenergy sector. IFA support the implementation of the following policies:

Market development support
To stimulate market development in the bioenergy sector IFA propose the following supporting policies:

1. The introduction of a special REFIT (Renewable Energy Feed In Tariff) tariff for AD and biomass CHP of 22 cents per kWh to allow for an acceptable return on investment.
2. Introduce a co-firing REFIT tariff of 14 cents per kWh
3. Expand the REHEAT programme to include miscanthus technologies to stimulate market development.
4. Expand the Heat Fuel Conversion Programme Expansion beyond the Office of Public Works (OPW) to include all public buildings. IFA propose that converting 25% of the public sector buildings to biomass could reduce the public sector heating bill by in excess of €100 million per annum, as well as create scale in the local biomass market.
5. Use Public Service Obligation levy to provide a market to incentivise biomass production for co-firing in Ireland's three peat-burning plants.
6. A new version of MOTR II to be included in 2010 to support competitiveness in the indigenous biofuels.
7. Target MOTR schemes at the pure plant vegetable oil (PPO) sector, which is the most carbon efficient method of producing transport biofuels in the EU.

Biomass resource development

Projections to 2020 indicate that to meet the targets a biomass supply of over four million green tonnes per annum is required. The following supports are required to ensure there is not a shortfall in biomass feedstock resources:

1. An afforestation programme of at least 15,000 hectares per annum is required.
2. An annual budget of €10 million to support Forest Road Scheme is required to construct the necessary infrastructural network to access the biomass resource. The mobilisation of approximately 500,000 million m3 has been impeded due to inadequate funding of the scheme.
3. Continued support of the BioEnergy Scheme (BES) is essential if there is not be a shortfall in biomass resource.
4. Re-introduction of an annual energy payment of €125 per hectare.
5. Amendment of the BES to allow capital allowances on establishment costs of perennial Bioenergy crops such as willow and miscanthus.
6. The re-classification of BES crops (willow and miscanthus) to an agricultural crop would increase the economic viability of BES to permit bio-remediation on the crops.

Biomass mobilisation programme

Bioenergy is a new crop for farmers and mobilising the crops will require additional investment in infrastructure, specialised equipment and training to bring the biomass resource to markets. IFA propose an integrated funding programme to mobilise the resource and create confidence in supply chain for end users, the supports are needed:

1. Biomass Drying and Storage Scheme
2. Biomass Mechanisation Scheme
3. Bioenergy business and technical training, and a
4. Regionally co-ordinated and supported farm-based energy enterprises.

Research and development

IFA advocate on-farm research on real time and cost in production and transport of biomass from sources to conversion plants to end-users (from farm-to-power). Focussed training programmes on woodchip and pellet quality, storage, boiler etc. should be development to promote best practice in the supply chain and installation.

Conclusion

An integrated cross-sectoral support programme, from producer to end-user is required to stimulate uptake and to create a viable scale in the bioenergy sector. The public sector must take the lead in adopting bioenergy technologies to create confidence and scale. Increasing the use of bioenergy offers significant opportunities for Ireland to reduce greenhouse gas emissions and improve security of energy supply. It also provides access to affordable energy, which is essential to the competitiveness of Ireland’s economy.

IFA will continue to push for the introduction of the right strategies that allow farmers to benefit from new opportunities offered by the bioenergy sector and generate complementary incomes. Improving producers’ income is key to the success of the bioenergy sector.

Contact: Tel. (01) 4500266; Email. postmaster@ifa.ie; www.ifa.ie

Irish Bioenergy Association (IrBEA)
Clonmel, Co. Tipperary

National energy policy as it is being currently drafted sets a target of 12% of heat demand to be met from renewable sources by 2020, starting from a base of 1 or 2%. The majority of this will be delivered using biomass heating. The bulk of our 10% renewable transport target is also likely to be met from biomass resources, and a part of the renewable electricity target. The right policies and a strong industry are needed to meet this demand.

A range of biomass resources and technologies will be required – forest thinnings, dedicated energy crops, organic waste materials will all be used in large and small scale applications. We need to foster solid biomass in chip, pellet, log, briquette and other forms and ensure a reliable and quality-assured supply of resource is available for the different end-users.

Know-how must be developed and bioenergy projects installed at a much more rapid rate than previously. Projects need to encompass best-practice in sustainability, design and implementation, and should be solidly financed and based on rigorous business planning.

Simultaneously, applied research must be encouraged which will lead to commercial solutions that can expand the range of fuels and technology available to meet national targets.

Large-scale infrastructure will play an important part in the bioenergy industry. Our large peat power plants will have to use biomass. Industrial CHP applications will use biomass. Large multi-feedstock plants with complex processing streams and biomass-based product outputs (biorefineries) will be implemented. Probably most importantly, district heating will need to be implemented within our large city infrastructure to enable efficient supply of renewable heat.

A high level of industry co-operation and networking is required to ensure the industry can grow in a consistent manner. A stable policy environment needs to be put in place to create confidence for investors, consumers and people involved in delivering bioenergy resources and technologies to market.

The Irish Bioenergy Association (IrBEA) was founded in 1999. Its role is to promote the bioenergy industry and to develop this important sector on the island of Ireland. The overall aim of IrBEA is to promote biomass as an environmentally, economically and socially sustainable indigenous energy resource, and to promote its non-energy related benefits.

Contact: Email. contact@irbea.org; www.irbea.org

Energy Crops Manual 2010

APPENDIX I

SYMBOLS, ABBREVIATIONS AND DECIMAL PLACES

Symbol	Meaning	Symbol	Meaning
,	Decimal separator	GDP	Gross Domestic Product
.	Thousand separator	**GIC**	Gross Inland Consumption
- / n.a	Not applicable, does not exist	**h**	Hour
%	Per cent	**IEA**	International Energy Agency
€	Euro	**IRENA**	International Renewable Energy Agency
blank	Data not available	**J**	Joule
BTL	Biomass to liquid	**KG oe**	Kilogram oil equivalent
ca.	Circa = approximately	**M^3**	Cubic meter
CEPI	Confederation of European Paper Industry	**m.c/MC**	Moisture content
CHP	Combined heat & power	**MSW**	Municipal soild waste
CO_2	Carbon dioxide	**NCV**	Net Colorific Value
DH	District heating	**Nm^3**	Normal m^3
DME	Di-Methyl ether	**ODS**	Organic dry substance
EE	Energy efficiency	**ORC**	Organic rankine cycle
E85	Fuel with ethanol content of 85%	**PV**	Photovoltaic
EEA	European Environmental Agency	**RES**	Renewable Energy Sources
EREC	European Renewable Energy Council	**RME**	Rape methyl Ether
ETBE	Ethyl tertiary butyl ether	**Solid m^3**	Solid cubic meter
FAME	Fatty acid methyl ester	**toe**	Tonne of oil equivalent
FAO	Food and Agriculture Organisation	**UAA**	Utilised agricultural areas
GCV	Gross calorific value	**VAT**	Value Added Tax
		W	Watt

APPENDIX II
DECIMAL PREFIXES

101	**Deca (da)**	10-1	**Deci (d)**
102	**Hecto (h)**	10-2	**Centi (c)**
103	**Kilo (k)**	10-3	**Milli (m)**
106	**Mega (M)**	10-6	**Micro (u)**
109	**Giga (G)**	10-9	**Nano (n)**
1012	**Tera (T)**	10-12	**Pico (p)**
1013	**Peta (P)**	10-15	**Femto (f)**
1018	**Exa (E)**	10-18	**Atto (a)**

APPENDIX III
GENERAL CONVERSION FACTOR FOR ENERGY

From/to	1 MJ	1kWh	1 kg oe	Mcal
I MJ	1	0.278	0.024	0.239
1kWh	3.6	1	0.086	0.86
I kg oe	41.868	11.63	1	10
1 Mcal	4.187	1.163	0.1	1

APPENDIX IV
LIQUIDS: AVERAGE NET CALORIFIC VALUE, ENERGY CONTENT

	NCV (GJ/m³)	Density (t/m³)	NCV (GJ/t)	1m³ = x toe	1t = x toe
toe			41,868		
Diesel	38,4	0,83	42,7	0,85	1,02
Biodiesel*	32,8	0,88	37,3	0,78	0,89
Rape oil	34,3	0,915	37,5	0,82	0,9
Gasoline	31,9	0,748	42,7	0,76	1,02
Ethanol	21,2	0,794	26,7	0,51	0,64

* aslo called RME for rapeseed methyl ester or FAME for fatty methyl ester. Calorific value can change according to raw material

APPENDIX V
ENERGY CONTENT OF DIFFERENCE BIOMASS FUELS AT 0% M.C. [3]

	NCV		GCV	
	(GJ/t)	kWh/t	(GJ/t)	kWh/t
Soft wood (spruce)	**18,8**	**5.222**	**20,2**	**5.611**
Hard wood (beech)	18,4	5.111	19,8	5.500
Willow (short rotation coppice)	**18,4**	**5.111**	**19,7**	**5.472**
Straw of cereals	17,2	4.778	18,5	5.139
Straw of corn	**17,7**	**4.917**	**18,9**	**5.250**
Cereals, seeds	17	4.722	18,4	5.111
Rape, seeds	26,5	7.361	28,1	7.806
Rape, cake	20	5.556	21,8	6.056
Cereals, whole plant	17,1	4.75	18,4	5.111
Miscanthus	17,7	4.917	18,1	5.028
Hay	17,1	4.75	18,4	5.111

APPENDIX VI
TYPICAL MOISTURE CONTENT OF BIOMASS FUELS AND CORRESPONDING CALORIFIC VALUES AS RECEIVED

	GVC				NVC		
	Moisture content%	kWh/kg	GJ/t	toe/t	kWH/kg	GJ/t	toe/t
Green wood direct from the forest, freshly harvested	**60%**	**2**	**7,2**	**0,17**	**1,6**	**5,76**	**0,14**
Chips from short rotation coppices after harvest	50-55%	2,5	9	0,21	2,1	7,56	0,18
Recently harvested wood	**50%**	**2,6**	**9,36**	**0,22**	**2,2**	**7,92**	**0,19**
Saw mill residues, chips etc	40%	3,1	11,16	0,27	2,9	10,44	0,25
Wood, dried one summer in open air, demolition timber	**30%**				**3,4**	**12,24**	**0,29**
Wood, dried several years in open air	20%				3,4	12,24	0,29
Pellets	8-9%				4	16,92	0,4
Wood, dry matter	0%				4,7		0,45
Cereals as stored after harvest, straw, hay, miscanthus after harvest	13-15%				5,2	18,72	0,34
Silomaize	30%				4	14,4	
Rape seed	9%				7,1	25,6	0,61
Chicken litter as received	68%				2,6	9,6	0,22
To compare with:							
Hard coal					8,06	29	0,69
Brown coal					4,17	15	0,36
Peat					2,8	10	0,24

APPENDIX VII

EXAMPLES FOR WEIGHT AND ENERGY CONTENT (NCV) FOR 1 M^3 WOOD AT DIFFERENT WATER CONTENTS, SPECIES AND SHAPE OF THE WOOD

Species	Shape	m.c in %	t/m^3	GJ/m3	kWH/m^3
Spruce	**Solid wood**	**0**	**0,41**	**7,7**	**2.130**
Spruce	Solid wood	40	0,64	6,6	1.828
Spruce	**Stapled wood**	**25**	**0,33**	**4,5**	**1.245**
Spruce	Chips	40	0,22	2,3	640
Beech	**Solid wood**	**0**	**0,68**	**12,6**	**3.500**
	Solid wood	40	0,96	9,2	2.547
Beech	Stapled wood	25	0,5	6,3	1.739
Beech	Chips	40	0,34	3,2	892
	Pellets	9	0,69	10,8	3.300
Average figures					
Average figures for different species	Solid wood	35	0,75	7,2	2.000
Average figures for different species	Chips	35	0,3	2,9	800

APPENDIX VIII

GASEOUS FUELS

	NCV	NCV	NCV	Density	NCV
	kWh/Nm^3	MJ/m^3	toe/1000m^3	kg/Nm^3	kWH/kg
Natural Gas	9,9	36	0,86	0,73	13,6
Biogas (60% methane)	6	12,6	0,52		
Biomethane (upgraded biogas)	9,5	36	0,86	0,73	13

APPENDIX IX
CO_2 EMMISSIONS DURING THE COMBUSTION (KG)

	IPCC default emission value kg/kWh	NCV Kgoe/kg
Crude oil	0,264	0,994-1,002
Motor gasoline	**0,249**	**1,051**
Jet kerosene	0,257	1,027
Gas/Diesel oil	**0,267**	**1,010**
Residual fuel oil	0,279	0,955
Lignite	**0,364**	**0,251-0,502**
Anthracite	0,354	0,411-0,711
Oil shale and tar stands	**0,385**	**0,900**
Brown coal briquettes	0,351	0,478
Peat	**0,382**	**0,186-0,330**
Blast furnace gas	0,936	0,0239 (per MJ GCV)
Oxygen steel furnace gas	**0,655**	**0,0239 (per MJ GCV)**
Natural gas	0,202	0,0215 (per MJ GCV)
Municipal wastes (non-biomass fraction)	0,330	
Industrial wastes	0,515	
Waste oils	0,264	
Sulphite lyes (Black Liquor)	0,343	
Other primary solid biomass	0,360	
Charcoal	0,403	
Biogasline	0,255	
Biodiesels	0,255	
Other liquid biofuels	0,287	
Landfill gas	0,197	
Sludge gas	0,197	
Other biogas	0,197	
Minicipal wastes (biomass fraction)	0,360	