Farm Level Decision-making on Bioenergy Diversification

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“This dissertation is my own original work and has not been submitted for any assessment or award at the University of Manchester or any other university”.

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Abstract

This dissertation provides context to, and an analysis of, farm diversification decision-making on bioenergy. It establishes the current context of bioenergy policy and regulations across the EU and the UK before looking at the available biomass resources and conversion technologies for energy generation. Bioenergy is an increasingly important part of the renewable energy mix. Farm diversification into biomass production, in the form of energy crops, has however been limited. Targets for production set by the government have not been achieved. This research takes a case study approach to establishing an in-depth understanding of the influences on decision-making for farm diversification. The study is conducted across three farms in South West England. The analysis was conducted in order to assess the relationship between government policy and farm production of biomass, to establish what may be working well, any barriers to the diversification decision, and to make any further recommendations.

The findings establish that the production of energy crops, in particular miscanthus, is not an economically attractive option compared to a wide array of other arable crops. The high cost of establishment of energy crops has meant that grant support has an important role in the diversification decision, a critical area for government policy. There are also a number of barriers to production in biomass identified through the case studies. The main conclusions are that for bioenergy crops to be considered as a viable diversification option greater attention will have to be given to effective grant payments and scales of production. There are also a number of recommendations for future research into farm level decision-making on bioenergy diversification.
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Chapter 1: Introduction

1.1 Introduction

“Biomass supplies will need to increase significantly and sustainably. This represents an important challenge for all parts of the supply chain and will bring new opportunities for many, including the farming industry.”

(Dti/Defra, 2007, p3)

Energy consumption throughout the world has been steadily increasing, particularly in industrialised nations. Most of this energy consumed currently comes from non-renewable sources, 97% of energy consumed in the UK is produced from non-renewable energy forms (RCEP, 2004). This is not sustainable for many reasons, most notably of which is the rising impact of climate change on society, a resultant effect of principally carbon dioxide emissions. Reduction in demand may be part of the solution to this problem, but a second critical area for the long term is the establishment of alternative renewable sources of fuel.

Biomass has been recognised as a significant element in the renewable energy generation mix, highlighted in the quotation from the UK Biomass Strategy (Dti/Defra, 2007, p3). There has been much discussion and consultation with government regarding the biomass resource, a number of critical publications made by the Royal Commission on Environmental Pollution and Defra such as the Biomass Taskforce, more recently illustrating the important role of this resource. There does however appear to be a significant gap between the policy set by government in these reports and the current uptake in production of bioenergy crops in the agricultural sector.

This dissertation looks at the role of the agricultural sector in its supply role for the biomass resource. The research looks at the links between government policy and agricultural diversification into the production of relatively novel bioenergy crops. This is of particular importance as it is clear that at present the biomass resource is struggling to make progress. Currently only 1.5% of electricity and 1% of heat is
produced from bioenergy sources, excluding energy from waste (Gill et al., 2005). Low uptake of biomass production by farmers has contributed in part to this situation; it is unlikely that there will be sufficient bioenergy crop production over the next 5-10 years to meet the demands of some of the UK’s most important energy producers (Drax, 2007).

It should be noted that this research does not intend to provide a comprehensive set of frameworks or models for analysing farmer diversification into bioenergy crop production. It intends to provide exploratory research findings that investigate issues related to farm diversification into biomass, drawing inferences that lead to recommendations for future development of bioenergy and biomass resources in the UK. It is also hoped that this research will highlight areas of policy that are working well.

This chapter outlines the aims, objectives and overview of the dissertation in order to establish the scope of the research as a whole, the background to the agricultural sector of the UK and key definitions of the biomass and bioenergy resource. The chapter also covers a number of core concepts; climate change and sustainability.

### 1.2 Aims, Objectives, Overview

The aim of this dissertation is to review the current bioenergy options in the UK and look at the options for farm diversification into biomass production. The aim will be to selectively investigate farmer decision making in case study farms.

The main objectives are:

1. To review bioenergy production in the UK and the associated policy and regulatory context, looking also at the current conversion technologies.
2. To investigate issues relating to farm diversification into bioenergy crop production, through farmer consultation using three case study farms in South West England.
3. To undertake limited consultation of expert observers and practitioners: academics, industry representatives, and farmers.

4. To make recommendations for further development of the biomass resource in the UK and comment on wider implications for farm diversification.

The dissertation will cover a wide range of issues relevant to the shift towards bioenergy production in the UK, and particularly the critical involvement and role of the agricultural sector in facilitating this transition.

Chapter 2 will first set out and comment on the regulatory and policy context associated with energy generator obligations to source from renewable sources, notably biomass. It will then review policy relating to biomass providers mainly in the agricultural and to a lesser extent forestry sectors. Chapter 3 will then build on the previous chapter to review the potential sources of biomass supporting the implementation of policy and regulatory controls. The biomass resource is relatively broad in context and therefore although all the main sources are covered, more attention will be paid to bioenergy crops, most relevant to the research of this dissertation into farm diversification. Chapter 4 covers a range of end use conversion technologies for bioenergy generation and discusses the merits of each process with regards to recent research on the efficiency and effectiveness of energy generation.

The methodology for the research carried out in this dissertation is explained in Chapter 5 and covers both the research design and approach adopted. The research uses a multiple case study design. The appropriateness and limitations of this approach to research are outlined and methods of analysis explained before results are presented and discussed in the following chapters. Chapter 6 then presents the results of the three case studies comprising explanations of decision making factors and financial information relevant to farm accounting for the production of bioenergy crops. Chapter 7 presents a more in depth discussion of the previous section on results and makes a number of inferences and recommendations regarding the further development of the biomass resource in the UK agricultural sector. Finally Chapter 8 provides a summary of the key aspects and issues of the dissertation, also making suggestions for further research opportunities.
1.3 The UK Agricultural Sector

This section will provide a brief overview of the agricultural sector in the UK as at January 2008 (Stats 01/08, 2008). Around 37% of the land on agricultural holdings is considered croppable i.e. land currently under crop, fallow, set aside or temporary grass. Almost half of this land is occupied by cereal crops; wheat, barley and oats (see Figure 1.3.2). The majority of land of about 57% is under sole right rough grazing or permanent pasture (see Figure 1.3.1).

Figure 1.3.1 Breakdown of the total area on agricultural holdings as at June 2007

![Figure 1.3.1](source: Stats 01/08, 2008)

Figure 1.3.2 Breakdown of the total cereal area as at June 2007

![Figure 1.3.2](source: Stats 01/08, 2008)

The main cereal crop produced in 2007 was wheat at 63% with slight declines of 2% in barley production on the previous year. There has however been an increasing trend in the production of oil seed rape production. The total production of bioenergy crops
do not figure in the chart as the quantities are too low and are included under a sub-heading of other non-horticultural crops in the data (Stats 01/08, 2008).

### 1.4 Biomass and Bioenergy

The terms biomass and bioenergy will be defined here in order to set the context of these terms for the discussion in this research. There does not appear to be any single definition for either of these terms in the industry but the following provide recent definitions from a Government Working Paper:

**Biomass** - used to cover a broad range of biologically derived resources including various biodegradable fractions of municipal and commercial and industrial wastes, sewage sludge, food waste, forest woodfuel, agricultural residues, wood waste and specifically grown energy crops.

**Bioenergy** - useable energy from a range of technical power generation options for converting biomass (e.g. combustion, gasification, pyrolysis, and anaerobic digestion) covering the production of heat, power and combined heat and power.

(adapted from BERR/Dti, 2007)

The research will cover both the above elements looking at a number of biomass sources covered by the literature. The literature review will also review the conversion processes for bioenergy production, although anaerobic digestion will not be included, being outside the scope of this research, which focuses on crop production for end-use in combustion processes.

### 1.5 UK Emissions Reductions

The impact of human activity on climate change is now undisputed. Evidence confirms an average rise in global temperatures of 0.74°C in the last century, equating to a rise from 280ppm CO$_2$ pre-industrial revolution to 430ppm CO$_2$ (Dti, 2007). If emissions levels were to remain at current levels under a ‘business as usual’ scenario one would expect 550ppm CO$_2$ to be reached by 2050, double the level of the pre-
industrial period. This would have severe impacts on the environment, including sea level rise, increased frequency of drought and more severe weather events. The worst impacts are likely to be seen in the less developed countries, due to geographic location and lack of financial resource to adapt (Stern, 2006 and IPCC, 2007).

The Kyoto Agreement was set up committing nations to reductions in carbon emissions by 2012. The UK is currently under an agreement to cut emissions by 12.5% based on 1990 levels by 2012 and has set a target of 60% emissions reductions by 2050, proposed by the Royal Commission on Environmental Pollution. However recent figures suggest we are likely to fall short of this target (Gill et al, 2005).

In order for government to attempt to meet this target of a 60% reduction in carbon emissions by 2050 it is crucial that it encourages non-carbon or low-carbon electrical and heat generation. Biomass as a key element in the renewable fuels base should help play an important role in climate change mitigation.

1.6 Sustainability

The widely accepted definition of economic sustainability is ‘maintenance of capital’ (Goodland, 1996, p1003) with the definition of environmental sustainability ‘maintaining natural capital’ (p1003). The concept of sustainability therefore relates to a continuing state of balance or equilibrium in which resources are in balance and may be exploited into the long term. The concept of sustainable development is the process by which one arrives at this state of balance in the context of the environment. Sustainable development was defined by the The Brundtland Report (1987) as ‘development that meets the needs of the present without compromising ability of future generations to meet their own needs’ (Goodland, 1995, p4).

There are three elements of sustainability; economic, environmental and social. The links between economic and environmental are considered the most important in terms of society today and current challenges. Economic sustainability focuses on the part of the natural resource base that provides inputs, both renewable (i.e. forests) and exhaustible (i.e. fossil fuels) into the production process (Goodland, 1995). The
The concept of environmental sustainability emphasises life-support systems with regards to these physical inputs, without which we cannot continue to exist. Notions are proposed that with increase in production greater capacity will be available to support environmental measures, although conversely this growth in itself could lead to irreparable damage to the environment (Hueting, 1990).

The concept of sustainability is central to issues and debates around energy provision. The use of fossil fuels for the production of electrical power and heat is not a sustainable option. Alternatives must therefore be sought in the form of renewable sources, of which bioenergy is likely to become a rising proportion.

1.7 Conclusion

This chapter has outlined the purpose, aims and objectives of the dissertation and set out the context of the UK agricultural sector relevant to this research. It has provided a set of definitions for the key concepts of biomass and bioenergy, terms used frequently throughout the research. This has then been set in the context of the global challenge of reducing carbon emissions in efforts to mitigate more severe climate change impacts. The focus of this section was upon the obligations of the UK to meet targets in the short and long term. Finally a definition of sustainability is included as an important underlying driver for the action being taken by governments to reduce carbon emissions, notably in the form of increased use of renewable energy.
Chapter 2: Policy and Regulatory Context

2.1 Introduction

When considering biomass and bioenergy it is important to firstly consider policy and regulatory frameworks. In the UK and across the EU the biomass resource has received significant attention and support. This chapter looks at policy from both EU and UK perspectives, identifying the mechanisms that are driving this form of renewable energy. Regulatory controls have been implemented to control and monitor the actions of energy generators, whilst a number of policies and support mechanisms have been created to encourage the development of biomass fuel production.

Naturally, underlying all biomass resource policy is the need and requirement to meet climate change targets at both the national and international level. This must be clearly reflected in policy for the biomass resource, which has, to a greater extent been integrated into responses to reports such as the Stern Review in 2006.

In UK policy development there has been a need for wider consideration of EU policy, principally the European Biomass Action Plan implemented in 2004, ensuring that all UK policy is compliant with wider EU targets (Thornley, 2006). Policy development must account for integration of EU policies, whilst also working on a local level in terms of coordination with Regional Development Agencies (RDAs) in the UK, creating an effective and unified policy for biomass and bioenergy. Due to the relatively short time period over which the following policy has been in place, it is not yet clear whether policy is effective in meeting the required targets. The following will review the policy and regulatory context at both a UK and EU level.

Section 2.2 will briefly review EU policy and UK government policy in relation to biomass and bioenergy, establishing its importance in relation to the development of the resource. Then Section 2.3 will look at certain mechanisms for the regulation of energy generators of both heat and electrical power, before going on to review policy in support of the provision of biomass from the agricultural sector. Section 2.4 addresses the issue of development of effective and efficient supply chains for the
biomass resource on a longer term basis, making the resource a viable economic option for UK energy production. The biomass supply chain will be addressed and the implications of policy on and for its development also reviewed.

2.2 UK and EU Government Policy Overview

The UK Energy White Paper in 2003 identified certain goals for energy policy that are addressed in this chapter considering policy for biomass and bioenergy. As set out by government these include putting the UK on the path to achieving a 60% cut in carbon emissions by 2050, maintaining reliability in energy supplies and promoting competitive markets in energy supply (Dti, 2007). Biomass is also considered in policy as a method of increasing security of energy supply through increased diversity of supplies (Dti/Defra, 2006).

Most notably the UK government has recently responded to an in depth investigation on biomass, commissioned by Defra to look at the potential of biomass and bioenergy as a renewable resource for the UK. The Biomass Taskforce (2005), conducted an in depth analysis of the biomass resource, the purpose of which has been to redefine government policy, with the aim of achieving maximum carbon savings from the biomass resource (BERR/Dti, 2007). Biomass has been recognised as an important tool to tackling climate change and promoting sustainable economic growth within the agricultural sector.

The UK is currently committed to reducing its carbon emissions and intends to achieve this in part through the use of renewables. Biomass, not currently produced at significant levels, is considered to be an untapped resource with potential to help deliver on meeting carbon targets (Dti/Defra, 2007). When considering policy in light of the biomass resource it may be divided into that which supports producers in the growing, processing and distributing of biomass and that which supports the generators of power.

The influence and role of wider EU policy has been critical to the implementation of national renewable energy policies, although member states have been to some extent
free to set up their own support schemes and incentive systems. Research would suggest a general desire in member states to support schemes and directives implemented by the European Commission (Thornley, 2006).

Energy policy made its first emphasis on energy dimensions of climate change in the Energy White Paper (1997), making specific reference to the promotion of the biomass resource. A target for 10,000MW of biomass installations was set and the need for member states to take action outlined, suggesting that national targets and objectives be set for 2005 and 2010 respectively. More comprehensive and integrated policy action has been seen moving on from here with more direct involvement of the EU in member state policies and biomass support mechanisms. The first legislative actions taken on renewables were made in 2001, requiring the setting of targets for renewables usage for all member states before 2010 (Thornley, 2006). The biomass resource is recognised as of significant importance to policy but also of a complex nature. Due to the complexity of developing this resource and its importance in generation of both heat and electrical power, a Biomass Action Plan was implemented in 2004 clearly outlining the role of the resource as a renewable energy source (COM (2005) 628 Final). Biomass is the only renewable resource to have warranted such a full coverage in renewable policy at the EU level (Thornley, 2006). Although there is some policy on the importance of biofuels for use in transport (Buffaria, 2006 and COM (2006), 34 Final). This is however not within the scope of this research on biomass and bioenergy.

Most recent EU discussion in the Energy Green Paper (2006) has proposed the creation of a common EU Energy Policy, including a roadmap to successful implementation of bioenergy looking at the appropriateness of conversion technologies and techniques.
2.3 Regulatory Context

The UK government has implemented a number of schemes to introduce and develop the use of renewable forms of energy in the market, in line with targets set by national policy, required under broader EU legislative actions. The Non-Fossil Fuel Obligation (NFFO) was replaced in 2002 by the Renewables Obligation (RO), representing a new opportunity for renewables to fulfil their role in the energy mix of the UK (Smith and Watson, 2002). Progress towards meeting 2010 targets for renewable fuel usage has been slow, despite wind and hydro power receiving support. Nevertheless the role of biomass under the renewables obligation is likely to be one of increasing importance and will be discussed across markets for electricity in Section 2.3.1 and heat in Section 2.3.2. Although in reality heat and electricity are often produced simultaneously, here they are treated separately.

2.3.1 Renewable Obligations for Electricity

The Renewables Obligation (RO) was introduced in February 2002 and has put energy producers under an obligation to source a rising percentage of energy from renewable sources (Dti, 2006). The policy essentially acts as a grant on energy flows (RCEP, 2004). The level of obligation to source from renewables rises annually and must be adhered to by production of Renewable Obligation Certificates (ROCs). ROCs are verification that energy producers have generated the required percentage of power from renewable sources. The RO was set at a level of 6.7% renewable electricity in 2006/7 and will rise incrementally to 15.4% in 2015/16, before remaining flat until the end of this policy in 2027. The target for 2010 is for 10% of electricity to be produced from renewable sources eligible under the RO scheme (Smith and Watson, 2002). Alongside this regulatory policy has come the expansion of support for any technological adaptations to plant, in the form of enhanced capital allowances, to be discussed later (see Chapter 3).
The supply curve in Figure 2.3.1.1 illustrates that when the price of ROCs rise, more developers will be encouraged to create renewable energy capacity, as market mechanisms introduce competition between renewable generators for ROC revenues (Smith and Watson, 2002). The producer must ensure that a certain percentage of energy produced is sourced from renewables or face a buy out price, rising with the Retail Price Index (RPI). The finances generated from buyout are recycled in the system on a pro rata basis to those with ROCs, under an incentive scheme to encourage those producers to increase their investments into renewables (Dti/Defra, 2007).

The RO is thought to have stimulated markets for renewable energy sources, including significant increases in demand for biomass in co-firing (see Chapter 4.2) (Perry and Rosillo-Calle, 2008). The policy has contributed to the establishment of a more developed supply chain in biomass, through the increases in demand (RCEP, 2004). The Renewables Obligation is however currently undergoing a process of consultation with changes being proposed to policy. The RO set a cap on the proportions of the obligation allowed from the use of co-firing, initially set at 25%, now reduced to 10% (Perry and Rosillo-Calle, 2008).

The RO was implemented as a measure to enhance support for alternative renewable sources such as wind and hydro power. The RO originally considered all forms of renewable energy under a single scheme and of equal value. It is now proposed that a system of banding is introduced, to increase support for biomass renewables in co-
firing, and also promote the use of other sources of renewable energy (Perry and Rosillo-Calle, 2008). This process is however subject to review and discussion and has not yet been implemented. The long term outcome of this is however likely to be an increase in demand for biomass in co-firing at power stations.

2.3.2 Legislation on Renewables for Heating

Biomass in the use of heating is seen as both simple and cheap. In reality electricity and heat are often produced simultaneously, known as combined heat and power (CHP) generation, however here they are treated separately for the purposes of policy review. There is currently no Renewable Obligation or equivalent for heat energy production; this has been identified as a major weakness of current policies (COM 628 Final, 2005; Perry and Rosillo-Calle, 2008).

The creation of a policy for renewable energy in heating has to take into consideration a number of issues. These range from the establishment of efficiency criteria to the appropriateness of setting targets and assessment of voluntary agreements within the market (COM 628 Final, 2005). The Royal Commission on Environmental Pollution (2004) has proposed the concept of Renewable Heat Obligations (RHOs). The obvious attractiveness of such policy, as with renewable electricity obligations, is there is little direct requirement for the use of public money. However it is argued that a renewable heat obligation would not necessarily be the most beneficial approach to promoting biomass markets and developing this resource. This is due, to the likely fact that such a scheme would take a significant amount of time to develop due to the complexities of the market, with many small producers of heat around the UK. The urgent needs for response to climate change would not be met (Gill et al, 2005).

Therefore it has been suggested that a more effective means of supporting markets for heat production in biomass markets may arise from a detailed capital grant scheme, as a far more rapid way to stimulating growth in the renewable markets. The use of streamlined capital grants being the most effective, breaking down the higher initial investment costs involved with acquiring biomass equipment (Gill et al, 2005). This has been implemented in the form of Enhanced Capital Allowances for energy
producers making investments into biomass processing plant and equipment (FES, 2007).

2.4 Policy for Biomass Production

This section will review the policy for supporting the production of biomass. There are currently four broad categories of biomass production including forestry products as a waste by-product, energy crops in the form of short rotation coppice (SRC) and miscanthus and finally imported biomass. The focus of the review will be to look at policy for the production of bioenergy crops, a category of biomass that is not produced as a by-product of other agricultural processes, but requires substantial financial investments and changes to agricultural operations. Policy for the support of the production of forestry material will then also be addressed in Section 2.4.2.

It is important to note before continuing that significant amounts of biomass are currently imported, although they are not eligible for financial support, energy producers nevertheless receive benefits for their use under the previously discussed Renewables Obligation scheme in co-firing (see Section 2.3.1) (RCEP, 2004).

2.4.1 Grants for Bioenergy Crop Production

As it currently stands there are a number of grant schemes available to farmers for the production of energy crops for bioenergy conversion. These grants are offered by both the EU under the Common Agricultural Policy (CAP) and by Defra under the Energy Crops Scheme. Grants are usually based upon the amount of land committed to the production of bioenergy crops and financial support determined by the type of crop cultivated. There is also usually a requirement for end user contracts to be established for eligibility to such schemes.

To qualify for the EU Energy Crops Scheme crops may only be grown on non-set a-side land (SAC, 2007). Set a-side is an important market mechanism of the CAP allowing the supply of markets to be regulated by the total amount of land in agricultural production. The distinction between set a-side and non-set a-side has
however less relevance for farm outputs due to world supply shortages in grain, forcing the EU to reduce set-aside levels to 0\% for 2008 under the Single Farm Payments Scheme (Spackman, 2007).

The *EU Energy Crop Scheme* currently offers a subsidy rate of €45/ha on land used for bioenergy crop production, including miscanthus, short rotation coppice (SRC) and other biofuel crops. The scheme has set an upper limit to its payments, which will decrease pro rata if the total acreage under energy crop production in the EU exceeds 1.5 million hectares (RCEP, 2004). This maximum guaranteed area (MGA) is expected to increase to 2 million hectares in the near future with wide uptake of biofuel crops across continental Europe (Jones, 2007).

The Energy Crops Scheme run by Defra in the UK offers grants for the planting establishment costs of energy crops based on the crop species. These are classified as establishment grants and have varied in value between £900-1600/hectare (RCEP, 2004). Until late 2006 the Energy Crops Scheme awarded miscanthus plantation a fixed rate of £920/hectare and SRC willow £1000/hectare (BERR/Dti, 2007). The Energy Crops Scheme was run up to the summer of 2006 before closing applications as an environmental safeguard in the case of too wider uptake of the scheme, causing too significant land use change (Dti/Defra, 2006). Planting establishment grants for 2007-2008 were nevertheless honoured at the same rates under the *Energy Crops Scheme*.

The scheme re-opened in October 2007 under the management of Rural Development Plan England and has been subject to changes, confirmed in late December 2007. Most significantly establishment grants will now be assessed on 40\% of *actual costs* of establishment, instead of a fixed hectarage rate (ECS, 2007). Therefore costs will have to be agreed on a case-by-case basis with farmers providing evidence of costs incurred. The scheme will account for work carried out by the farmer and any work contracted out. Costs will be compared to an Independent Verification and if consistent, payment made on a single quote. The scheme will also continue to take into account the eligibility of the land for payments, based on distance to end user, taking into consideration the size of the end user (Jones, 2007).
The grant payment is still made as a lump sum and serves as the only likely revenue for the following 3 years on the land dedicated to biomass production, not including the EU grant payments of up to 45euros/ha. This has caused significant cash flow issues for farm agricultural accounts and has been identified as a key issue in biomass policies (RCEP, 2004).

There are fundamental problems with the Energy Crops Scheme that have been highlighted by the Royal Commission on Environmental Pollution (2004). To be eligible for grants under the Defra scheme a contract for the crops end-use with an energy supplier must be provided by the farmer. The power suppliers are however able to benefit from the Renewables Obligation system without commitment to a grower, leaving the farmer at the disposal of power suppliers and indeed any changes in policy that may affect their demand patterns for biomass (RCEP, 2004). The scheme has also been criticised for the time it takes to apply with approximately 3 months delays in the completion of paperwork. In some situations it has also been necessary for farmers to form cooperatives in order to meet the land capacity requirements for production taking up to two months, making the scheme inflexible considering time constraints (RCEP, 2004).

Finally the schemes concerning the production of energy crops provide some support for diversifying farmers but do not render the production of such crops economically attractive. Recent analysis suggests that average incomes over a 16 year period of SRC willow or miscanthus production for medium yield land would be £187-£360/ha/yr (RCEP, 2004). This compares poorly to a wide range of alternatives in both crop and livestock production. In fact, energy crops are often only considered as viable on set a-side (Thornley, 2008). It is however thought that with 30% increases in productivity SRC willow could become a viable alternative to barley (RCEP, 2004) although no energy crop will be economically viable in the foreseeable future without further subsidisation through grant schemes.

In addition to the grant payments based on land acreage, the cost of start-up investment in capital required for cultivating such crops was subsidised by up to 50% under the Bioenergy Infrastructure Scheme (Gill et al, 2005).
2.4.2 Grants for Forestry Sources

Further grants are available for the production of wood as a biomass fuel with the implementation of the Woodland Grant Scheme (WGS) as part of the English Rural Development Program (ERDP). Over seven years between 2000 and 2006 a sum of £139 million was made available for managing existing woodlands and the plantation of new woodland areas, as a result of which forestry materials may be made available for energy use. Grants were also made available to farmers under the England Rural Development Plan for those who forego production on land, for the benefit of forested areas. A similar scheme has been run in Scotland under the Scottish Forestry Grants Scheme (SFGS) (RCEP, 2004).
2.5 Grants for Bioenergy Conversion Technologies

This section provides a review of the grants provided for the support of bioenergy conversion technologies. The review covers schemes offered in the last 4-5 years, therefore a number of these schemes are no longer operational.

The Bioenergy Capital Grants Scheme is a UK wide scheme providing up to 40% of the costs of energy generation equipment in eligible projects. The majority of the funding to date has been offered to high technology projects, for example those involving pyrolysis (see Chapter 4.4). The scheme however currently focuses too heavily on new technologies, and does not support sufficiently its main objective of supporting heat generation through combined heat and power (CHP) using biomass (RCEP, 2004). The total value of the scheme in 2005 was £66 million (Gill et al, 2005).

The Enhanced Capital Allowances (ECA) scheme allows firms operating biomass fuelled boilers to write-off one hundred percent of equipment costs in the first year of investment against taxable profits. There are also further opportunities for equipment under the Good Quality CHP scheme to qualify for ECAs. ECAs in such cases may be claimed based on the plant’s Quality Index (QI), a measure for overall efficiency, defined as the proportion of the gross calorific value of the fuel converted to electrical output (RCEP, 2004). The thresholds set to qualify for ECAs take into account a number of characteristics but have essentially been set at levels conducive to encouraging biomass powered CHP. This has been of specific importance as it is recognised that the proportions of calorific value in biomass that may be converted into electrical output are lower than that of other fuels (for further discussion see Chapter 4) (RCEP, 2004).

There are a number of smaller grant schemes run across the UK including grants made available by the Carbon Trust for carbon reduction projects and in provision of equity finance in more mature projects. In 2003 the Carbon Trust made £5 million available in grants (RCEP, 2004). The Countryside Agency through its Community Renewables Initiative provides information and support in developing community-
based partnerships for those looking to invest in bioenergy production. The Clear Skies Initiative on the other hand made grants available for households and communities in the installation of renewable technologies under a scheme worth £12.5 million from 2003-2006 (Gill et al, 2005). A similar scheme was run in Scotland under the Scottish Community and Householders Initiative. The Community Energy Programme (worth £50million) looks to support public sector district heating schemes through capital grants and has made an additional £10 million available for the periods 2005/2006 and 2007/2008 (RCEP, 2004).

2.6 Biomass Supply Chain

The supply and use of biomass should be addressed from the perspective of a biomass supply chain; in essence government policies and wider EU policies are looking to create sustainable supply chains. The creation of efficient supply chains in the long term removes the need for grant support and should create natural market conditions (Gill et al, 2005). The UK government aims are to:

“realise a major expansion in supply and use of biomass in the UK and to facilitate the development of a competitive and sustainable market and supply chain”

(Dti/Defra, p13, 2007)

The issue with the development of a biomass supply chain is whether supply should be pushing demand, or demand pulling the supply. In the context of bioenergy it would seem it is the role of demand to pull supply. The development of ROs for electricity has meant biomass has been in greater demand with increased production levels of biomass in the UK (Dti, 2006). The RO scheme has also been extended in order to allow more time for the supply base to develop in the energy crop market. It is largely understood that if Government is able to put in place correct mechanisms to develop biomass markets, then those markets will eventually establish for themselves the necessary infrastructure (Gill et al, 2005).

Whilst supply chains develop in the production of biomass for bioenergy the government has put in place a grant scheme with the objective of bridging current gaps in supply. The Biomass Infrastructure Scheme was worth £3.5 million in 2005
and is intended to help develop market infrastructures for both wood fuel and straw for energy use (Defra, 2007a).

Critical to the development of a biomass supply chain is the coordination of schemes on the local level through Regional Development Agencies (RDAs). It is the responsibility of the RDA to analyse the infrastructure needs of a region and facilitate the development of supply chains (Gill et al, 2005). The role of the RDA is thought to be critical in assessing the most appropriate strategies for implementation of bioenergy schemes in the local area, and may in the future be tied to carbon targets set on a regional basis.

**Figure 2.6.1 Diagrammatic Version of the Biomass Supply Chain**

A simple illustration of the biomass supply chain may be viewed in Figure 2.6.1 with a clear set of inputs, supply, conversion and distribution processes. The inputs of the system rely upon a number of producer groups to provide the biomass in an economically viable manner. The process of converting the crop into energy for consumption is subject to a complex system of incentives, before finally the output is sold to the market for consumption.

Further to the development of the supply chain in meeting demand, are considerations for quality standards and a certification process, ensuring that given feedstocks
consistently meet desirable standards for the conversion technologies (Gill et al, 2005). Quality standards and a certification process have not yet been established but are likely to become an important issue as the market develops and becomes more competitive.

The UK intends to increase supply of biomass considerably to deliver on its objectives of renewable energy use, intending to expand the production of energy crops, forestry products and use of organic materials, with significant resource potential identified in all categories. The emphasis of Rural Development Programmes is to promote sustainable development of supply chains also taking into consideration the potential environmental impacts of large scale shifts to biomass, to be controlled in line with EU Biomass Action Plan recommendations.

2.7 Conclusion

The policy and regulatory context is relatively complex for the development of the biomass resource, involving a combination of EU and UK policy, often complemented by regional schemes. Biomass policy has become a more important issue for government as climate change and indeed meeting carbon reduction targets becomes ever more important.

The use of renewable obligations in the supply of electricity has been proven to have reasonable success, with an incentive to produce electricity from renewable sources. Developments within this regulation to focus on the greater use of biomass in particular for co-firing may be an area of significant advance for the resource. However the topic of renewable heat obligations is much debated; it is not clear whether a heat RO would be desirable. The application of policy to energy producers can be seen as a key driver for the development of the biomass supply chain creating demand and thus encouraging supply.

For the production of bioenergy crops there have been a number of policies spanning from EU grant payments for land dedicated to crop production, to planting and production support schemes in the UK. The UK government through its Energy Crops Scheme provides grants that at present are fundamental to diversification into energy
crops not currently viable as an agricultural crop without such subsidisation. A number of schemes are also run for the support of forestry development. Bioenergy conversion technology is supported in capital cost due to high investment requirements, and across the development of technologies. ECAs and the Capital Grants Scheme support and allow the costs of investment to be minimised and in some cases written off, whilst the Carbon Trust and other organisation offer grants at various stages of implementation in either capital investment or developing new technologies.

The creation of sustainable supply chains for bioenergy markets has been identified as key to policy and regulation concerning the biomass resource and has been highlighted in the UK Biomass Strategy (2007). With significant potentials identified for the biomass resource in the UK it would seem that the creation of sustainable supply chains will require not only continued support in the production of crops and technology conversion, but also in quality assurance through processes of certification, not currently in place. In support of the transition to biomass production there has also been the Biomass Infrastructure Scheme to fund areas in need of support and development.
Chapter 3: Biomass Fuels

3.1 Introduction

The UK government responded to the Task Force (2005) with a strategy for the biomass resource defining the optimal savings possible from the use of this renewable resource. This entails complying with EU policies and meeting emissions targets through renewables, as set out by Defra and the DTI (BERR/Dti, 2007). This chapter intends to look into more detail at the biomass resource options suggested for this strategy.

This will entail reviewing each biomass resource across wide parameters to draw a clear overview of the options. It will look at the nature of the resource and the implications for its production and consideration of costs related to the more technical performance measures. The biomass resource was defined in the introduction as a broad range of biologically derived resources, which may be converted into bioenergy (BERR/Dti, 2007). It is this biomass resource that will be discussed here, whilst the subsequent conversion of the resource into bioenergy will be tackled in the following chapter.

The resources this review will cover include energy crops in Section 3.2, in Section 3.3 forestry products and finally municipal wastes in Section 3.4. In order to quantify these resources in the light of previously discussed policy, the current and prospective available resource production levels will also be reviewed for the UK in Section 3.5.
3.2 Energy Crops

Energy crops are currently grown in the UK for use in the production of combustible fuels and the production of bioliquid fuels. Bioliquid fuels for use in transportation will not be addressed here as the biomass resource addressed in the policy context concerns the use of biomass in heat and electrical power production only. The biomass crops considered suitable for growth in the UK using current agricultural methods include willow or short rotation coppice (SRC) and various grasses, notably miscanthus. Methods of cultivation, impacts on the environment and economic values will be considered for each of the crops reviewed.

3.2.1 Miscanthus

Miscanthus species are woody, perennial, rhizomatous grasses originating from tropical Asia (RDPE/Defra, 2007b). Miscanthus is a genus of approximately 20 species native to Asia and Africa. It carries out a process of modified photosynthesis known as C4. C4 involves enzymes sensitive to temperature in the photosynthesis process (RCEP, 2004). These grasses are often sensitive to colder climates and do not grow well 300m above sea level. However miscanthus has been crossed Miscanthus x Giganteus, now able to grow at colder temperatures rather than just survive, as would a maize crop. This variation of miscanthus has become the most popular type grown in the UK for biomass (RCEP, 2004). The crop is harvested annually using existing farm methods and equipment and baled using a conventional straw baler for storage in barns.

Miscanthus has been noted to have the desirable characteristics of being economical in its use of nutrients and have an efficient internal recycling system, whereby much of the nutrient is transferred and stored in the unharvested rhizome element of the plant. This has a positive effect on nutrient cycling and soil organic content, reducing
the need for artificial fertilisers (RCEP, 2004). However yield levels in the UK are currently low and it has therefore been recognised that there is still much to be understood about the production of this crop and the optimal conditions required. Particularly concerning the water resource requirements it may need. There is also some concern about the longer-term implications on land rehabilitation due to its deep root structures (RCEP, 2004).

From an economic perspective of production, a comparison across seven sites in the UK has enabled an idea of current performance to be assessed. Two sites failed to make average yields of 15odt/ha/yr (odt - oven dry tonnes), one of which was in fact not profitable at only 12odt/ha/yr. The other five however made yields of 20odt/ha/yr over two years or more (RCEP, 2004). The average harvest yield in England is thought to range between 12-16t/ha, based on a planting density of minimum 10,000rhizomes/ha (RDPE/Defra, 2007b). Normally planting densities will have to exceed these levels as planting is at best 90% effective in growth success from rhizome to stem (RDPE/Defra, 2007b). The yield from years one and two after plantation are not significant enough to be commercially worth harvesting. Therefore under normal circumstances the first crop is cut in year 3. The lifespan/lifecycle of the average plant is between 15-20 years.

The current supply prices or costs for miscanthus are in the range of £2.5-3.5/GJ (equivalent to £44-65/odt), excluding transport costs and not accounting for grant and subsidy schemes (BERR/Dti, 2007). However currently miscanthus is part of a planting grant scheme receiving £920/ha in Year 1 only under the Energy Crop Scheme and can also apply for an additional subsidy of 45 Euros/ha under the EU Common Agricultural Policy, if the crop is classified for industrial usage and not grown on set aside (SAC, 2007). The impact of this has reduced the supply cost by £0.5/GJ (equivalent to £8/odt); still excluding delivery cost (BERR/Dti, 2007).

It should also be noted that alternative markets exist for miscanthus and include the provision of high value equine bedding and a composite material for biodegradable plastics and materials in car parts. It is thought that there may be potential for the production of ethanol or even hydrogen from miscanthus in the future, for use in the transport sector (RDPE/Defra, 2007b).
3.2.2 Willow Short Rotation Coppice

Short rotation coppice (SRC) is based upon fast growing tree species repeatedly cut back at intervals (coppiced) and harvested for use as energy at intervals over the crops 15-20 year lifespan. Several species of tree may potentially be used in SRC but to date the only commercialised crop in the UK is willow (Bell et al, 2007). The crop once chipped, provides a reliable source of fuel of consistent quality for use in power generation. The understanding and development in the use of this crop is the most advanced of all energy crops due to extensive SRC willow production in Sweden leading to a greater wealth of experience (RCEP, 2004).

Willow may be suitable for a range of arable soils but thrives best on richer soils of higher moisture content. The crop once planted is cut back after the first year to stimulate faster growth over the following two years before the first harvest is taken. The crop is usually harvested every three years although cases of a harvest every two years do occur. Due to the nature of the crop a minimum site of 10ha is usually required to allow for facilitated harvesting (Bell et al, 2007). Over the first two years extensive weed control is needed and pest control implemented to ensure the willow sets become established. Some reports of fungal attacks have been made regarding “willow rust” although usually after the first two years the crop may be left alone, no longer requiring application of pesticide. Fertiliser applications are however required and there is now discussion of extending the potential use of willow SRC plantations as important sewage sinks (Bell et al, 2007). The environmental impacts of willow SRC plantations seem to be minimal and land re-instatement to for example barley relatively simple, however there is concern that the nature of the root structure can damage drainage systems (Bell et al, 2007). There are also further concerns over the
future impact of climate change decreasing yields of SRC willow due to water shortage (Taylor, 2008).

At present the economic viability of willow SRC cannot be clearly established as the likely size of commercial crop yields are yet to be seen. Yields are again measured in oven dried tonnes (odt) and are expected to be between 6-11odt/ha/yr, although on poor sites the values decrease to 3odt/ha/year, but can increase to 18odt/ha/yr on richer soils (Bell at al, 2007). Planting densities are generally between 12000-15000 cuttings/ha, although lower densities tend to yield a larger wood chip, considered as higher quality fuel (RDPE/Defra, 2007a).

The expected supply price or cost from willow SRC in its chipped form is £3-4/GJ (equivalent £60-80/odt), not including cost of delivery. There are however grants are available for plantation of £1000/ha in Year 1 through the Energy Crops Scheme and 45euros/ha on the EU Energy Crops Scheme if land is non set a-side. This affects the price of supply, which is reduced by £0.6/GJ (BERR/Dti, 2007). However in most cases in the agricultural sector, willow SRC has been growing on set a-side land, with the impact of lower yields on average and non qualification for EU subsidies on plantations (RCEP, 2004).

3.3 Forestry Products

Forestry products are a valuable biomass resource and may be divided into forest wood fuel and sawmill co-products. Trends suggest that demand for forestry products in paper pulp and the construction industry are decreasing, so opportunities for conversion to biomass supply are becoming more attractive (RCEP, 2004). Currently supply of wood from forestry is in plentiful supply and is expected to exceed demand beyond 2020 due to significant planting that took place in the 1960s (RCEP, 2004). The key issue is now to support a healthy bioenergy market to ensure the effective management of these forests through replanting.

It is important to note that at present wood fuel available for biomass arises as a consequence of other forestry activity and is therefore available at a minimal marginal cost. However over time, continued demand for forest arisings may have impacts on
costs requiring further investigation, as the industry develops to become more competitive and costs increase. Environmental impacts in this case would also need to be reconsidered as soil erosion and nutrient retention levels may also be affected (RCEP, 2004).

The second source of fuel is sawmilling co-product currently burnt or sold on to board manufacturers. It is estimated that up to 50% of the raw material (wood) becomes waste in processes of production in the wood processing industry (BERR/Dti, 2007). Therefore large quantities of material could be made available to bioenergy production in the form of wood chippings or saw dust in a later pelleted form. For the case of sawmill co-products there is currently no market value, with cost being determined by price of collection, preparation and transportation to energy users. In most cases therefore it is assumed that the cost of supply is the same as forest wood fuel, which is approximately £2-3/GJ (excluding delivery) (BERR/Dti, 2007). Wood fuel may however be supplied in pelleted form, increasing calorific values and providing greater consistency in combustion with lower moisture content levels. However the cost of supply is expected to increase by around £2/GJ due to the increased cost of handling and processing (BERR/Dti, 2007). In some cases however this is a technical requirement and the cost accepted where large quantities are manipulated at co-firing stations or storage requirements stipulate such a product.

3.4 Municipal Wastes

The maintenance of vegetation in urban areas has been recognised as a potentially important source of biomass (Gill et al, 2005). This material, classified as secondary product, falls under the legal definition of waste, and would usually be burnt onsite or committed to landfill but there is now interest in its use either in composting or as an energy source (BERR/Dti, 2007).

With rising landfill taxes and the introduction of a Landfill Directive, there is incentive for councils to look elsewhere for the disposal of their municipal green waste (RCEP, 2004). Some of the material may be suitable for composting, digestion or combustion in a pelleted form. The concern is however the storage of the waste as councils operate under spatial constraints and the moisture content of the biomass
before a certain period of storage would be too high for efficient combustion. It would therefore be most suited to small scale local district CHP plants.

In economics terms the use of municipal arisings or waste should entail a minimal marginal cost or even negative cost if transport distances are low and landfill gate fees are avoided (RCEP, 2004). However it is again expected that as the demand for biomass increases, suppliers will seek to attain a higher price for such resources (BERR/Dti, 2007).

3.5 Available Resource Quantities

The visions for the use of biomass and its potential are currently being discussed as the biomass resource becomes a more important part of energy schemes in the UK. Currently the resource may be split into that produced in the UK and biomass imported for use in energy production.

It has been suggested that somewhere in the region of one million hectares of land in the UK could be dedicated to producing non food crops, potential production of biomass (740,000ha quoted by Defra and 824,000ha quoted by the EEA) (EEA, 2006). This would equate to around 8 million tonnes of energy crop. There are 17million hectares of land holding in the UK for agricultural purposes (RCEP, 2004). The bulk of this land is considered as grades 3, 4, 5 and lower and is therefore of limited value in food production, making it suitable for bioenergy crops (RCEP, 2004). However in the light of the previous statement the yields of energy crops also vary with soil quality and climate, so producing the required levels of energy crop would require more land dedicated to the purpose of production in the long term.
The technical potential of biomass fuel production can be seen in Figure 3.5.1 for woody biomass, energy crops and straw. Straw is an important residual from agricultural crops such as wheat and oats and may be burned to generate energy.

Co-firing as a method of using biomass fuel (see Chapter 4.2) has raised the profile of energy crop production in the UK. However, co-firing still relies predominantly on importation of biomass for combustion (Perry and Rosillo-Calle, 2008). Current levels of energy crop production comprising miscanthus and willow SRC in the UK are estimated at 2,500 hectares, corresponding to yields of circa 25,000 tonnes per annum (Gill et al., 2005).

However, there are significant concerns over the levels of energy crop production in the UK as the current levels are insufficient to meet even the lower targets set by government (RCEP, 2004). It is here that the importance of forestry products, municipal wastes and imports is recognised, as a means to ease the transitions in farming over to energy crop production, allowing time for change. The forestry resource is expected to produce an average 1.3 million tonnes/year over the next decade (RCEP, 2004).

The target for 2050 is the production of 16GW of electricity in terms of installed capacity from biomass including forestry and energy crops. The efficiency however with which this target can be met depends not only on the levels of production but also on the conversion technologies implemented (discussed in Chapter 4) as efficiencies in energy conversion vary between 20-80% causing large differences in resource quantity requirement (RCEP, 2004).
3.6 Conclusion

This chapter has reviewed biomass fuels for the production of bioenergy and considered the potential of the biomass resource as it currently stands and future projections for its development. The biomass resources considered are not exhaustive, but the review covers the most geographically and economically viable options to the UK. To an extent it serves as a literature review of UK biomass resource potential.

The chapter provides a broad understanding of the implications of biomass, taking into account the nature of the resource, practical and environmental implications and the economic outcomes for each option. Such an approach is needed when looking at the UK’s transition to a greater dependence on these resources in the longer term. From looking at the use of energy crops it is clear that the crops available are suited to different conditions and require agricultural approaches to differ. The key concerns are over the levels of productivity expected that are still not well understood in the UK.

The use of forestry wood fuel and sawmill co-products has been reviewed and looks to provide a relatively low cost form of biomass for the production of bioenergy. This source of fuel should be a reliable and consistent form of energy. The use of sawmill co-products and forestry wood fuel is able to improve the levels of energy security in the UK in the shorter term and is a readily available resource. Some concern must however be taken for a sustainable approach to forest management. The use of municipal waste has also opened up an opportunity to avoid landfill at a time of rising taxes and create an energy resource that should relieve some pressures on transitions in the agricultural sector.

The transition from current production levels of 2,500 hectares under energy crop production, to the desired one million hectares dedicated by 2050, demonstrates there is clearly some way to go. However current energy requirements may be met by imports for co-firing ensuring that ROCs are met and UK carbon emissions reduced.
Chapter 4: Bioenergy Conversion Technologies

4.1 Introduction - Applications (end uses)

The end use of biomass is in production of energy in the form of heat or electricity, or in some cases both (combined heat and power). Biomass can be converted into energy through a number of methods, including combustion, gasification or pyrolysis. The advantages of these approaches differ as efficiencies in conversion of fuel to energy vary, as do the costs of investment in technology. There are also still complications with the supply of biomass affecting the operation of power production. These issues can be closely linked to the discussion of policy with reference to Enhanced Capital Allowances supporting high investment costs, and the development of sustainable supply chains. There is also an important link between the issues raised in Chapter 3 with respect to the sources of biomass and there relative use in terms of calorific energy values (/odt), critical in assessing the conversion technologies.

Biomass differs from other fuels including fossil fuels, notably in terms of two aspects. Firstly biomass has a relatively low calorific value, defined in terms of the heat released when burning a specified mass of fuel. Secondly biomass has a relatively high level of moisture in its combustion gases, because of the hydrogen present in the fuel and because biomass usually contains some moisture (RCEP, 2004). This is identified as a problem with the use of SRC willow, with particularly high moisture content of up to 50% on harvesting. There are additional costs to conversion caused by this water vapour in capturing the latent heat, increasing the need for new technologies and more complicated processes. This will be reviewed in more depth when looking at the specific conversion technologies.

Again, the main driver for the use of the biomass resource is the abatement of greenhouse gas emissions. The assessment of the bioenergy conversion options will look at this in terms of cost effectiveness, that is pounds per tonne of carbon abated (£/tC abated). Naturally this needs to be considered alongside the economic evaluation of methods.
This chapter will look at the forms of converting biomass into energy, either heat or electrical, or both in combined heat and power (CHP). Section 4.2 will address the simple combustion of biomass for heat or electricity only production and describe the applications used in this process. This section will also address the use of biomass in co-firing at existing power stations. Section 4.3 describes the CHP application and the increased efficiencies of a system able to capture and reuse heat output in power generation. Finally Section 4.4 addresses the use of gasification and pyrolysis as two significant methods of combusting biomass that lead to more effective burning of the resource to maximise energy outputs, particularly important in a resource of lower calorific value than fossil fuel.
4.2 Combustion and Co-firing

The simplest type of conversion is heat or electricity only production, whereby the combustion of biomass occurs in air. Biomass resources are solid and often relatively dry once treated, therefore ideally suited to the combustion process. The energy density of these resources varies between 15-20GJ/odt, which is around two thirds of the calorific value of coal (FES, 2007). It is therefore necessary to use considerably more resource to achieve a similar heat output.

Figure 4.2.1 Combustion Process

Figure 4.2.1 illustrates the process of combustion of biomass for a heat only production system. The biomass is burnt with air in the combustion chamber. The hot gases then pass into a heat exchanger, where they are cooled and transferred to another liquid. This liquid, usually water, is then circulated to the end user, in the case of a district heating system. The cooled gases are filtered to remove any remaining harmful particulates before being emitted into the atmosphere. This process is typically able to recover up to 70% of the net calorific value of the fuel in the form of heat and may be increased with the use of a condensing heat exchanger (RCEP, 2004). Most of the non-combustible material is removed via the bottom ash and consists mainly of minerals, disposed of separately.

Power stations dedicated to the combustion of biomass tend to be much smaller than those for fossil fuels; they tend to produce between 20-50MWe compared to 1000-2000MWe (BERR/Dti, 2007). There is nevertheless an advantage here in that the power stations may generally be located nearer to the source of fuel, minimising the
costs of transport. This has been identified by the Royal Commission on Environmental Pollution (2004) as a critical issue for the implementation of combustion plants, also going on to state that heat only production is particularly suited to areas in which there is specific local market demand for heat. Examples include areas unable to access the national grid or gas mains, which would otherwise rely on more costly and polluting sources of energy.

The costs of biomass fuels can be seen in Figure 4.2.2 from a report conducted by Future Energy Solutions (FES, 2007). Due to the calorific value of biomass being approximately one third that of coal, there are indirect implications for the costs of biomass fuel usage. Firstly handling facilities must be larger and are therefore usually more expensive to deal with the larger resource quantities. Secondly there is a need to take careful consideration of the costs of transportation (included in the figures below). Due to the low energy density of biomass fuels it becomes critical to assess the transport costs of the fuel and to look at the delivered price.

**Figure 4.2.2 Indicative Biomass Fuel Costs**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Indicative Cost £/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood chip</td>
<td>5.30 – 8.50</td>
</tr>
<tr>
<td>Wood pellets (residential supply)</td>
<td>15.30</td>
</tr>
<tr>
<td>Straw</td>
<td>7.50 – 12.50</td>
</tr>
<tr>
<td>Energy crops (as chip)</td>
<td>6.90 – 12.70</td>
</tr>
</tbody>
</table>

Source: FES Report, 2007

BERR (2007) clearly indicate that dedicated biomass power stations are substantially more expensive than fossil fuel plants, taking into account a central price assumption for natural gas and oil used in Dti energy projections, and the additional costs incurred by fossil fuel combustion under the EU Emissions Trading Scheme (EU ETS). The use of biomass in co-firing and in the use of new methods such as gasification, is however more cost efficient (see Section 4.4), and has lead to reductions in generation costs. Nonetheless there is likely to be a significant cost differential between biomass and fossil fuel energy production for the foreseeable future (BERR/Dti, 2007).

Co-firing plays an important role for the biomass resource and can be defined as the combustion of biomass fuel in existing coal installations. In this situation biomass is
used for the production of electricity in coal fired power stations and is fed in as an alternative fuel to the combustion process. This is an important means for abating carbon emissions (see Table 4.2.3) and has been recognised as a way to developing biomass supply chains by increasing demand in an incremental manner. It is also important as we are likely to be reliant on coal as a key part of our energy mix into the long term (Dti/Defra, 2007).

Table 4.2.3 Comparison of the CO2 abatement cost for energy generation using biomass

<table>
<thead>
<tr>
<th>Application</th>
<th>Biomass type</th>
<th>Load (%)</th>
<th>Fossil fuel displaced</th>
<th>CO₂ abatement cost (£/tCO₂)</th>
<th>Source: Dti/Defra, 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large industrial boiler</td>
<td>Chip</td>
<td>30%</td>
<td>Gas</td>
<td>43</td>
<td>76</td>
</tr>
<tr>
<td>Small commercial boilers</td>
<td>Pellet</td>
<td>30%</td>
<td>Gas</td>
<td>56</td>
<td>78</td>
</tr>
<tr>
<td>Small commercial boilers</td>
<td>Chip</td>
<td>30%</td>
<td>Gas</td>
<td>60</td>
<td>84</td>
</tr>
<tr>
<td>5% co-firing with wood arisings on existing coal power plant</td>
<td>–</td>
<td>60%</td>
<td>Gas</td>
<td>59</td>
<td>98</td>
</tr>
<tr>
<td>ROC Buyout price (£33/MWh) in 2006/07</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% co-firing with miscanthus on existing coal power plant</td>
<td>–</td>
<td>60%</td>
<td>Gas</td>
<td>72</td>
<td>111</td>
</tr>
<tr>
<td>10% co-firing with miscanthus on new coal power plant</td>
<td>–</td>
<td>60%</td>
<td>Gas</td>
<td>78</td>
<td>112</td>
</tr>
<tr>
<td>10% co-firing with SRC on new coal plant</td>
<td>–</td>
<td>60%</td>
<td>Gas</td>
<td>89</td>
<td>124</td>
</tr>
<tr>
<td>10% co-firing with SRC on existing coal plant</td>
<td>–</td>
<td>60%</td>
<td>Gas</td>
<td>88</td>
<td>128</td>
</tr>
</tbody>
</table>

Co-firing allows energy producers to qualify for ROCs (discussed in Chapter 2), using biomass as a form of renewable energy to meet their obligations to reduce carbon emissions. Nevertheless the use of saw dust in blending with coal, as is common practice, is considered to be a low-grade form of biomass fuel, due to high moisture content increasing gaseous emissions and resulting in lower net calorific values (RCEP, 2004). Due to this the UK government only allows onsite blended saw dust (with coal) to qualify for ROCs, in an attempt to ensure higher quality (lower moisture content) saw dust is used. This has meant energy producers are required to make significant investments in plant and processing equipment, assuming they consider they are likely to make a return on investment before the ROC scheme is terminated in 2016. If not, co-firing will not be considered. Co-firing is also limited by the government so as to ensure this does not become a means to an end and that it remains a transitional tool to the investment and development of biomass only technologies, decreasing our reliance on fossil fuel combustion (RCEP, 2004).

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4.3 Combined Heat and Power (CHP)

Combined heat and power is the simultaneous generation of heat and electrical power through a single process (BERR/Dti, 2006). Other terms for the process include co-generation and total energy, more commonly used across other member states of the European Union (BERR, 2007b). CHP provides primary energy savings compared to the previously discussed processes, whereby only heat or electrical power is generated separately. CHP uses a wide variety of fuels of which the most important at present is natural gas, though the full range of fossil fuels may be used (FES, 2007). There is also recognition for the rising importance for biomass use in combined heat and power generation. CHP is a carbon efficient process putting to use the heat produced as a by-product of electricity generation, increasing the efficiency of fuel usage compared to conventional forms of generation (Dti/Defra, 2007).

Figure 4.3.1 Combined Heat and Power Plant, using a Steam cycle for Co-generation.

Figure 4.3.1 shows a steam cycle for the production of heat and power. The hot combustion gases pass into a boiler where the water is evaporated to produce high pressure steam. This steam then passes through a steam turbine, generating electrical power. The steam on leaving at lower pressure is condensed through heat exchange with cold water and is then pumped back up to the higher working pressure. The entire system is therefore closed and water only added when deliberate venting of steam occurs. Prior to venting the combustion gases are still at a temperature higher than that of which they are vented at, and can therefore be further cooled by heat.
exchange (RCEP, 2004). Bottom ash is dealt with in the same way as in heat or electricity generation only plants.

This kind of operation has the added benefit of flexibility as the ratio of heat to electrical output may be varied. To increase heat output the turbine may be bypassed so that steam goes directly to the condenser and the plant operates in heat only mode. Switching from electrical to added heat production in the short term may also be achieved by allowing the turbine to spin without driving the electricity generator, creating ‘spinning reserve’ to supply short term increase in electricity demand (RCEP, 2004).

Steam cycles are most efficient at large scales and may be consistently 80% efficient (or more – 90% according the FES (2007)) at converting the calorific value of fuel into heat energy. However due to the generally small scale of CHP plants involved in the use of biomass, the levels of conversion efficiency to electricity can fall to 10%. This is significantly less than is likely to be considered acceptable and is caused by an inability to raise high enough steam temperatures (RCEP, 2004). These figures can be compared to a new coal fired combustion plant for electricity, running at approximately a level of 40% efficiency.

The government has set up a Good Quality CHP scheme aimed at promoting the use of good quality CHP, defined as the carbon efficient process of using the by-product of heat in electricity generation (BERR, 2007b). The scheme has a target of implementing 10GW of good quality CHP by 2010 (see Figure 4.3.2), in line with EU ETS targets for reducing international emissions (BERR, 2007b).
The costs of CHP compared to standard centralised systems are normally higher (Dti/Defra, 2007). There are therefore a number of support mechanisms in place including; exemption from climate change levy when fossil fuel powered, and the availability of financial support for biomass use under the enhanced capital allowances for plant and equipment and qualification for ROCs (BERR, 2007b).

Overall conclusions from a BERR/Dti (2007) report are however that replacement of fossil fuel with biomass resource fuel in CHP is not cost effective, even with contaminated low cost wood. The higher capital cost of CHP plants also appears to make it a less attractive option than heat or electricity only production from biomass when considered in terms of heat supply costs.

Source: BERR, 2007a
4.4 Gasification and Pyrolysis

In the case of CHP a key issue with the efficiency of systems relies upon the ability to generate sufficient heat in the steam to drive the turbines for the generation of electricity. In order to avoid this it is possible to implement a system of gasification (RCEP, 2004). In the gasification process, air (or occasionally steam) is blown through the fuel to produce a combustible gas, consisting mainly of carbon monoxide and hydrogen. The temperature in the gasifier is controlled by the careful blending of air and steam.

The gas is then burned with air, after which the hot pressurised combustion gases are passed into a gas turbine. The very high pressures generated in large plants allow for high energy conversion efficiencies to electrical power output. The gases must however be cleaned before entering the gas turbine to prevent corrosion and erosion. This may be applied before or after combustion. In Figure 4.4.1 it is shown before combustion. Heat is then recovered from the gas turbine, passing through a standard heat exchange. The gas emissions of the process are usually released untreated, and all that remains is bottom ash and char, both of which may be re-used in co-firing in conventional coal fired stations (RCEP, 2004).

Pyrolysis on the other hand involves heating the fuel without air or steam to decompose it and drive of volatile combustible gases, but is implemented in a similar manner to the above system (Figure 4.4.1). Pyrolysis does however leave a carbon rich char for use in gasification or combustion (RCEP, 2004).
The move from combustion and steam cycles to gasification or pyrolysis is suggested to be an important way to reducing the generation costs of biomass plants through improved conversion efficiency (BERR/Dti, 2007). However despite the common opinion that this could lead to some improvement, it is not thought that small plant will be able to attain the efficiencies of larger power plants without incurring unrealistic capital costs. For example the cost of integrating pre-heating measures on small plant would be uneconomic (BERR/Dti, 2007). Nevertheless improvements in generation coupled with improved energy crop production are likely to significantly improve the opportunities for dedicated biomass production.

4.5 Conclusion

The use of biomass in the generation of energy is varied, and changes with method of use and systems types. The properties of biomass make it particularly appropriate to the production of heat and use in CHP. The overall reaction when biomass fuel is combusted remains the same regardless of the method of heating or application used. However whether the fuel is combusted, gasified or pyrolysed does have an effect upon the way in which the heat is released and subsequently used.

It is clear that biomass is of quite significantly lower calorific value than other fossil fuels, including coal, and must therefore be converted as efficiently as possible in order to maximise its energy potential. Technologies for biomass power generation are well established and rely upon matching biomass supply to energy demands. The use of biomass in electricity or heat only generation would appear to be relatively simple and minimise costs of plant and equipment, illustrated through the popularity of the option in comparison to the more expensive implementation of combined heat and power.

The role of co-firing is considered to be particularly important at present as the biomass resource develops. Co-firing is able to create demand and help develop supply chains. It is however important here to ensure that co-firing does not become the dominant use of biomass and that investments are made into dedicated biomass technologies. Co-firing has an important role to play in the short to medium term.
Most concern should be directed at the fact that even with improvement in conversion efficiencies through gasification, pyrolysis and improved biomass production; it is unlikely that the biomass resource will become more cost effective than the use of fossil fuels for the foreseeable future. The costs of investments are high and the scale of plant required achieving adequate operational efficiencies seem to be prohibitive, particularly in the light of the cheaper production through fossil fuel usage. It should however be noted that well designed and properly operated biomass plant is associated with lower emissions than other fuels, including coal.
Chapter 5: Methodology

5.1 Introduction

This chapter aims to familiarise the reader with the approaches taken to the empirical aspect of the research project. The purpose of this research is to develop a deeper understanding of the influences in farm diversification into biomass production in the UK. For this, the research takes a case study design to investigations. Three case studies are used to investigate the issue of biomass production in UK farming and the relationship with government policy and support mechanisms for bioenergy crop production. This was discussed in the literature review and looked at a number of schemes, supporting and creating incentives for farmer participation.

Much of the following discussion of literature, on case study designs, will be based on the research of Robert K Yin (2003), as a significant amount of the research conducted on the case study approach has been pioneered by Yin. This work is more heavily drawn upon than that of other authors, although other contributions are recognised throughout. The chapter will first introduce the case study design constructing a clear definition of this approach to research and will review the appropriateness of its use and relevance with regards to biomass policy and farm diversification. Secondly the chapter will discuss the use of interviews as a key method of collecting data in case study design, and then thirdly, outline the reasoning for case study selections in the context of both geographical and agricultural factors taken into account for this study. Finally it will set out the criteria for the analysis of the case studies discussed.
5.2 Case Study Design

A case study approach has been used in this research looking at the agricultural sector and its reactions to new policy formulation on bioenergy crop production. The case study enables the researcher to investigate the decision-making processes of farmers in the context of their agricultural operations, assessing to a reasonable depth the reasons and wider issues involved. The case studies look at multiple sources of data and use more than one method of data collection. For the purposes of this research, unstructured interviewing, direct observations and additional document collation through discussion were used as primary methods of research.

Before continuing a definition of the case study is proposed, defined in two parts, as firstly:

…an empirical inquiry that

- investigates a contemporary phenomenon within its real-life context, especially when
- the boundaries between phenomenon and context are not clearly evident

and secondly as a method that:

- copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
- benefits from the prior development of theoretical propositions to guide data collection and analysis.

(adapted from Yin, 2003, pp13-14)

From the above definition it would appear that the case study approach is primarily a tool for use in qualitative research, as is the case in this research, although Yin (1994) insists that its use may also extend to quantitative research. The case study approach is often considered to be technically complex as in contrast to experimental design;
there are no particular standardised techniques to be implemented. The case study design requires the collection of multiple sources of data, but this should nevertheless be focussed to ensure the research is relevant. Therefore, throughout this research a set of clear objectives has been followed.

There is also further discussion as to whether this approach may be classified as inductive or deductive. It is generally considered that such an approach is deductive in the data collection and analysis process (Gray, 2006). The research carried out in this investigation is largely deductive, allowing information to be obtained across the relevant areas of farm management practice and government policies, as established in the literature review.

The case study is used for a variety of purposes from evaluation of organisational performance to policy analysis (Gray, 2006). A case study approach can prove invaluable to improving understanding, extending experience and increasing conviction about a subject (Stake, 2000). The case study approach has been identified as possessing particular strength when addressing ‘how’ and ‘why’ questions about a contemporary set of events, where the researcher has no control. ‘Who’, ‘what’ and ‘where’ questions are likely to favour a survey approach where large amounts of data need to be collected. The case study on the other hand tends to explore many subjects and themes from a far more focussed perspective and focussed range of contexts (Gray, 2006).

It has however been widely noted that case study approaches come under a considerable amount of criticism for not being accepted as reliable, objective or legitimate (Yin, 2003). One key problem is that it may be difficult to generalise from a single case. However in reality multiple cases may be looked at across the same phenomenon, just as experiments must be replicated to ensure validity. The research conducted in this project looks at three case studies relating to the issue of farm diversification into biomass production, improving the reliability and generalisability of the study. This is particularly important in the agricultural sector where circumstances vary significantly due to geography and experience and as a result mean that decision factors are rarely the same. The precise selection of these case studies and their context will be discussed in the following section. A further
criticism, although altogether less significant, has been the amount of time required to conduct an in depth case study (Yin, 2003).

The approach of this research project will therefore be to investigate the largely qualitative issues of ‘how’ and ‘why’ farm diversification may occur, looking at contemporary government policies and the influences and reactions of case study farms within the UK farming community. The research design allows for a comprehensive research strategy, covering the requirement for data collection and subsequent analysis.

5.3 Interviews

One of the most important sources of information for the case study is the interview (Yin, 2003). The interviewing technique used is however along the lines of a guided conversation rather than structured query. A persistent line of inquiry is adopted, although the flow of questioning is more fluid in a case study interview, probing into issues of greater importance as they are uncovered.

The interview used in all three case studies was a ‘focussed interview’ over a short period of time, usually around one hour’s duration. The interview remained open ended and conversational but a set of questions were used to direct the conversation and ensure the relevant information was collected (see Appendices 1-3). These questions were derived from prior understanding and knowledge of the processes involved in farm diversification and the key concerns highlighted in the literature review with biomass policy.

For the purposes of conducting an open ended interview in an unbiased manner two aspects had to be taken into consideration. Firstly a consistent and clear line of inquiry followed, and secondly, the style of questioning kept friendly and non-threatening. An example of this may the way in which the word ‘how’ rather than ‘why’ is used when looking to find out more about why a process occurred, and avoiding any risk of defensiveness on the respondents behalf (Yin, 2003, p90). As a result of this questioning style it becomes possible to understand the factual context and the
opinions of farmers in conducting the interview. In certain circumstances it was possible to ask interviewees to propose insights on issues related to policy and operational farm challenges. In conducting interviews this way the interaction developed from that of interviewer – respondent to interviewer – informant, broadening the scope of information released and creating more meaningful insights into issues of farm diversification.

5.4 Method for Case Study Selection

It has been established that multiple case studies are preferred to single case study designs for improved generalisability. The research therefore takes three case studies, each an operational farm in the south west of England. The selection of each of these farms for the purposes of this research will be discussed in the following. It should be noted that the farms were selected in the south west as this has been a region recognised as important to the development of the biomass resource and has been conducted on the grounds of convenience (Scholes, 1998). However bioenergy crop production for combustion is still in its early stages and there are therefore a limited number of current producers. The following three cases are thought to be representative of typical livestock and arable farms for the region.

The first case study (Case Study 1) is taken as a recent example of a farm that has made the decision to diversify into biomass production and is in its early stages of experience with the crop. The farm was selected due to the relatively large scale of its conversion to bioenergy crop production (relative to land available) and recent experience in the diversification process. The cost information and decision factors considered in this case are therefore up to date and provide for useful comparison to published figures on the diversification process.

The second case study (Case Study 2) is now further along the process of diversification and is entering the fourth year of production. This case enables a wider appreciation of issues encountered along this process, and to some extent a comparison of financial revenues from the crop to those predicted by experts in the field.
The third case (Case Study 3) takes an arable farm in the top 25% performing farms in the South West of England in order to establish how bioenergy crops compare to the arable crops currently in production. This farm has chosen not to diversify into biomass production, although has been approached by bioenergy crop grower groups. The case acts to provide findings in support of the hypothesised contrast in view, that energy crops are not competitive compared to cereal crops in the UK.

5.5 Research Analysis

The case studies are analysed in order to make inferences from issues highlighted in the cases relevant to the process of diversifying into bioenergy crop production. The research conducted intends to identify any links between farmer reasoning process and government schemes, and identify the wider considerations of the farmer in diversifying. This involves looking at both qualitative opinions and motives and the financial costs and benefits of alternatives.

The research analysis looks at the reasoning process of the farmer in evaluating options to diversify and draw out key influences and factors considered in this process. This is achieved through analysis of interview discussions and reference to the additional documents from each case. Additional documents include farm plans and historic information on land use possibilities.

Financial information is used in the analysis to evaluate the attractiveness of bioenergy crops to farmers. This involves the comparison of Defra recorded costing with actual on farm costs of bioenergy production. The most significant costs to the farmer occur in stages of establishment, so particular attention is paid to this area. The revenues from the crop as a commodity are also assessed. By looking at an arable farm the study also highlights the financial differences in performance between cereal crop production and biomass. Throughout, a careful consideration of grant support availability is made and included in assessing the financial viability of options, where relevant.
It should however be noted that the industry is very small and there are currently no farm costing surveys published on bioenergy crop production (Jones, 2007). The SAC provide the most comprehensive set of figures on the biomass resource, and will therefore be referenced in the analysis. However it is possible to obtain information from five organisations in the UK on the establishment costs of short rotation crops. These have been compiled by the National Farmers Union and will be used to compare actual data in the case studies presented. These sources are nevertheless to be used only as a guide as there is much debate over the impartiality of the figures and their representativeness, affecting accuracy and reliability (Jones, 2007). They do however serve to indicate the areas where costs are incurred.

5.6 Conclusion

This chapter has outlined the research approach to this study on farm diversification into the biomass resource. The method for investigating the issues is through use of three case studies, selected for their contribution and relevance to the assessment of issues surrounding bioenergy crops. The case studies use multiple sources of data collection, with significant contribution coming from the use of unstructured interviewing. The analysis looks at the use of both information on farmer decision making criteria and financial cost comparisons of the bioenergy crop production to alternative agricultural options. The study also looks specifically at the arable sector in comparing the viability of cereal crops to bioenergy crops, as a potentially more attractive option to farmers in the UK. The chapter has also given an outline of the current low levels of availability of information on farm costing related to the biomass resource.
Chapter 6: Case Study Results

6.1 Introduction

The following chapter describes the results of the case study research carried out in this investigation into farm diversification options. The research comprises three case studies, covering varying aspects of diversification issues into bioenergy crops. Each case study includes financial information supported by explanations of farm management practice and procedure, focusing also on the decision making process of the farmer. This chapter presents the findings only as a full discussion of the results is found in Chapter 7.

Case Study 1 illustrates a farm that has recently diversified into miscanthus production for bioenergy. The diversification took place in 2006 and therefore provides a recent set of figures on the costs of establishment for the crop. The second case study looks at a farm that diversified into miscanthus in 2004 and is therefore more established; meaning information from harvesting of the crop could also be obtained. The case also illustrates a difference in economic assessment being outside the Energy Crops Scheme grant program. Case Study 2 was awarded a contract for rhizome multiplication, having significant impacts on the financial dynamics of the case. Finally, Case Study 3 takes an arable farm in order to assess the economic viability of bioenergy crops (miscanthus) to arable alternatives, establishing the reasons for arable farmers having low incentives for diversifying into bioenergy crop production. All three case studies are from the South West of England and may be considered as upland farms.

Note

All land in agricultural production under the Common Agricultural Policy (CAP) is now eligible for the Single Farm Payments Scheme (since 1 January 2005), replacing most existing crop and livestock payments and breaking the link between production and support. The Energy Crop Scheme payments are however claimed separately and in addition to the Single Farm Payments; at a rate of €45/ha (SAC Handbook, 2007).
6.2 Case Study 1: Upland Miscanthus Production


6.2.1 Farm Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Farm Size:</td>
<td>40 hectares</td>
</tr>
<tr>
<td>Land in Production:</td>
<td>38 hectares</td>
</tr>
<tr>
<td>Potential Arable Production:</td>
<td>15 ha</td>
</tr>
<tr>
<td>Land in Bioenergy Production:</td>
<td>15.35ha</td>
</tr>
<tr>
<td>Contract:</td>
<td>BICAL (South West)</td>
</tr>
</tbody>
</table>

6.2.2 Introduction to Farm Management

Previously a dairying farm in the South West this farm has diversified into bioenergy crop production after a case of TB in November 2005, forcing the dairy unit to close down. The farm has also always run two chicken houses for broiler hens and this now remains the main source of farm income. At peak miscanthus production, the chicken operation will contribute 92% of farm income as a proportion.

In early 2006 a number of options were assessed for the diversification of the farm after the closure of the dairy unit. The farm is situated in an upland area and was therefore restricted to an extent on the number of available options. The production of cereal crops was discounted on the topography of the ground being unsuitable (gradients and average soil grade quality) and the option of sheep farming, on the grounds of poor profitability for this small scale of production. Bioenergy crops became a viable option for the farm although revenues were not expected to be that attractive; it was quoted as the “least worst option” for the farm.

The farmer chose not to produce willow SRC on the land, due to lower yields from the crop and significant concerns about disease in the crop (see Appendix 5). Miscanthus was therefore selected and an area of 15.35 hectares planted in winter 2006.
Image 6.2.2.1 View- from Chicken Units

Image 6.2.2.2 Crop- end of Year 1

Image 6.2.2.3 Impact of poor Spray-off (end of year 1)
Image 6.2.2.4 View of Miscanthus Crop end of Year 1 (mid winter)

Image 6.2.2.5 Miscanthus rows alongside access track
6.2.3 Establishment Cost of Miscanthus

An important consideration in diversification was the financial cost of establishing the crop. The establishment costs are those costs incurred in physically converting to the production of bioenergy crops and usually comprise all costs for the first year of production.

Below is a comparison of actual costs of establishment for miscanthus in the case study, to a number of other sources of data compiled by the NFU (see Jones, 2007). The SAC (Scottish Agricultural College)/Cambridge figures are included in all tables as these figures are currently taken by Defra in setting grant support for crop establishment, using the high or ‘standard’ cost scenario. The Energy Crops Scheme bases grants on a proportion of these establishment costs, currently 40% of establishment cost is reimbursed as subsidy grant.

The data are spread over three tables for purposes of presentation only, this has no other significance.

Table 6.2.3.1 Comparison of Establishment Costs with NIX and BICAL

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>SAC – Cambridge</th>
<th>NIX*</th>
<th>BICAL*</th>
<th>Case Study 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Cost</td>
<td>Low Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting Density rhizomes/ha</td>
<td>13,950</td>
<td>10,000</td>
<td>?</td>
<td>17,500</td>
</tr>
<tr>
<td>Cost of plants per rhizome</td>
<td>£0.08</td>
<td>£0.05</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Establishment Costs £/ha</td>
<td>117</td>
<td>117</td>
<td>?</td>
<td>118</td>
</tr>
<tr>
<td>Cultivations</td>
<td>1,169</td>
<td>500</td>
<td>2,000</td>
<td>1,675</td>
</tr>
<tr>
<td>Plants</td>
<td>349</td>
<td>250</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Planting Charge</td>
<td>?</td>
<td>200</td>
<td>?</td>
<td>n/a</td>
</tr>
<tr>
<td>Vermin Control</td>
<td>?</td>
<td>?</td>
<td>70</td>
<td>147</td>
</tr>
<tr>
<td>Topping in Year 1</td>
<td>?</td>
<td>?</td>
<td>23</td>
<td>n/a</td>
</tr>
<tr>
<td>Sprays</td>
<td>56</td>
<td>56</td>
<td>?</td>
<td>70</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>?</td>
<td>23</td>
<td>?</td>
<td>n/a</td>
</tr>
<tr>
<td>Other (sprays)</td>
<td>?</td>
<td></td>
<td></td>
<td>41</td>
</tr>
<tr>
<td><strong>Total Variable Costs</strong></td>
<td>1,691</td>
<td>923</td>
<td>2,500</td>
<td>2,104</td>
</tr>
<tr>
<td>Lifecycle</td>
<td>16</td>
<td>16</td>
<td>17.5</td>
<td>17.5</td>
</tr>
<tr>
<td>Annualised Cost</td>
<td>106</td>
<td>58</td>
<td>143</td>
<td>120</td>
</tr>
</tbody>
</table>

*NIX – *a farm management publication on the costs of farming practices
*BICAL – a large grower group working with farmers in diversification and energy generators in contract establishment
Table 6.2.3.2  Comparison of Establishment Costs of Miscanthus with ABC and BICAL

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>SAC – Cambridge</th>
<th>ABC*</th>
<th>BICAL*</th>
<th>Case Study 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Cost</td>
<td>Low Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting Density</td>
<td>13,950</td>
<td>10,000</td>
<td>14,000</td>
<td>17,500</td>
</tr>
<tr>
<td>Cost of plants</td>
<td>£0.08</td>
<td>£0.05</td>
<td>£0.09</td>
<td>?</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td><strong>Establishment Costs</strong></td>
<td><strong>£/ha</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultivations</td>
<td>117</td>
<td>117</td>
<td>120</td>
<td>118</td>
</tr>
<tr>
<td>Plants</td>
<td>1,169</td>
<td>500</td>
<td>1,260</td>
<td>1,675</td>
</tr>
<tr>
<td>Planting Charge</td>
<td>349</td>
<td>250</td>
<td>300</td>
<td>?</td>
</tr>
<tr>
<td>Vermin Control</td>
<td>n/a</td>
<td>200</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Topping in Year 1</td>
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<td>Sprays</td>
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<td>56</td>
<td>65</td>
<td>70</td>
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<td><strong>1,691</strong></td>
<td>923</td>
<td>1,770</td>
<td>2,104</td>
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<tr>
<td>Lifecycle</td>
<td>16</td>
<td>16</td>
<td>15</td>
<td>17.5</td>
</tr>
<tr>
<td><strong>Annualised Cost</strong></td>
<td>106</td>
<td>58</td>
<td>118</td>
<td>120</td>
</tr>
</tbody>
</table>

*BICAL –  see previous table

Table 6.2.3.3  Comparison of Establishment Costs of Miscanthus with WINBEG and REG

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<thead>
<tr>
<th>Assumptions</th>
<th>SAC – Cambridge</th>
<th>WINBEG*</th>
<th>REG*</th>
<th>Case Study 1</th>
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</tr>
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<td>Cost of plants</td>
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<td>£0.07</td>
<td>?</td>
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<td><strong>£/ha</strong></td>
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<td>Cultivations</td>
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<td>1,700</td>
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<td>250</td>
<td>300</td>
<td>?</td>
</tr>
<tr>
<td>Vermin Control</td>
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<td>?</td>
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<td></td>
</tr>
<tr>
<td>Topping in Year 1</td>
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<td>Fertiliser</td>
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<tr>
<td>Other (sprays)</td>
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</tr>
<tr>
<td>Lifecycle</td>
<td>16</td>
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<tr>
<td><strong>Annualised Cost</strong></td>
<td>106</td>
<td>58</td>
<td>121</td>
<td>105</td>
</tr>
</tbody>
</table>

*REG –  Rural Enterprise Gateway Fact Sheet (2007)
Graph 6.2.3.1 Comparison of the NFU Published Figures on Costs of Establishment for Miscanthus.

Graph 6.2.3.2 Total Cost of Miscanthus Establishment Compared

Source: Jones, 2007
The tables and graph 6.2.3.2 illustrate that the costs of establishment for Case Study 1 were higher than the SAC/Defra standard scenario, although not substantially and so are still consistent with figures proposed by BICAL. The reason for the higher cost is largely due to a higher cost of planting and higher herbicide costs than in the standard scenario.

6.2.4 Investment Appraisal for Miscanthus

The qualification for the Energy Crop Scheme grant was considered critical to the viability of the diversification and yet entailed a lengthy qualification process of over five months, by which time a number of neighbouring farms also applying had planted winter wheat and withdrawn from the process of diversification.

As a result of the slow application process the farm is currently suffering from lower than expected yields in the crop, as spraying-off grassland in late December was less effective due to colder temperatures of the winter (see Image 6.2.2.3). The typical period for spraying is early October before temperatures start to decline.

### Table 6.2.4.1 Costs of Establishment Net of Grant

<table>
<thead>
<tr>
<th></th>
<th>£/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting Charge</td>
<td>1675</td>
</tr>
<tr>
<td>Less Grant*</td>
<td>-920</td>
</tr>
<tr>
<td>Cultivations</td>
<td>86</td>
</tr>
<tr>
<td>Spraying</td>
<td>41</td>
</tr>
<tr>
<td>Herbicide</td>
<td>147</td>
</tr>
<tr>
<td>Topping</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total Establishment Cost Net of Grant</strong></td>
<td><strong>1049</strong></td>
</tr>
</tbody>
</table>

* Energy Crops Scheme establishment grant payment for miscanthus at £920.00/ha.

The farm qualified for the Energy Crops Scheme run by the England Rural Development Plan and therefore received £920.00/ha towards the cost of establishment. This was a set rate of grant regardless of actual costs incurred and was universally applied throughout the UK.
An agronomist has confirmed that the crop will yield average values so for the purposes of forecasting revenues it is likely that production levels will be met. The price for miscanthus is set at a guaranteed minimum however the crop is hoped, by the farmer, to make above minimum price on sale. With regards to the cost of harvesting the crop, it is to be carried out by a third party contractor in the long term to avoid higher costs of investment in machinery, although in the short term current farm machinery is sufficient for mowing the crop whilst baling will be contracted. The end user contract for the crop was established with Aberthaw Power Station in Wales and is within a 30 mile radius ‘as the crow flies’, meeting the requirement of the Energy Crops Scheme distance to end use clause.

A discounting rate of 8% was used by the farmer for their investment appraisal of miscanthus production. Although this rate may be considered appropriate under some circumstances, it is high. Therefore the net present value of cane sales has also been recalculated at a lower rate of 4% (Carney, 2008).

\[
\text{NPV} = \frac{\text{Cash Inflow}_t}{(1+r)^t}
\]

Net Present Value determined by the cash inflow at time \(t\) divided by 1 plus the rate of discounting \(r\) to the power of \(t\) number of years.

### Table 6.2.4.2 Investment Appraisal of Miscanthus over 10 year contract period (at an 8% rate of discounting)

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield ODT</th>
<th>Sales at £32/ODT</th>
<th>Harvest costs £/ha</th>
<th>GM/ha</th>
<th>Disc’rt Factor @8%</th>
<th>Disc’rt GM/ha (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.00</td>
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<tr>
<td>Year 1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0.926</td>
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</tr>
<tr>
<td>Year 2</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0.857</td>
<td>0</td>
</tr>
<tr>
<td>Year 3</td>
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<td>160</td>
<td>60</td>
<td>100</td>
<td>0.794</td>
<td>79</td>
</tr>
<tr>
<td>Year 4</td>
<td>8</td>
<td>256</td>
<td>96</td>
<td>160</td>
<td>0.735</td>
<td>118</td>
</tr>
<tr>
<td>Year 5</td>
<td>10</td>
<td>320</td>
<td>120</td>
<td>200</td>
<td>0.681</td>
<td>136</td>
</tr>
<tr>
<td>Year 6</td>
<td>12</td>
<td>384</td>
<td>144</td>
<td>240</td>
<td>0.63</td>
<td>151</td>
</tr>
<tr>
<td>Year 7</td>
<td>14</td>
<td>448</td>
<td>168</td>
<td>280</td>
<td>0.583</td>
<td>163</td>
</tr>
<tr>
<td>Year 8</td>
<td>14</td>
<td>448</td>
<td>168</td>
<td>280</td>
<td>0.54</td>
<td>151</td>
</tr>
<tr>
<td>Year 9</td>
<td>14</td>
<td>448</td>
<td>168</td>
<td>280</td>
<td>0.5</td>
<td>140</td>
</tr>
<tr>
<td>Year 10</td>
<td>14</td>
<td>448</td>
<td>168</td>
<td>280</td>
<td>0.463</td>
<td>130</td>
</tr>
</tbody>
</table>

| Net Present Value of Cane Sales | 1068 |
| Profit over 10 years | £19/ha |
Table 6.2.4.3  Investment Appraisal of Miscanthus over 10 year contract period 
(at a 4% rate of discounting)

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield ODT</th>
<th>Sales at £32/odt</th>
<th>Harvest Costs £/ha</th>
<th>GM/ha</th>
<th>Disc’t Factor @4%</th>
<th>Disc’t GM/ha (£)</th>
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</thead>
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<tr>
<td>Year 0</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>Year 1</td>
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<td>0</td>
<td>0</td>
<td>0.962</td>
<td>0</td>
</tr>
<tr>
<td>Year 2</td>
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<td>0</td>
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<td>0.925</td>
<td>0</td>
</tr>
<tr>
<td>Year 3</td>
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<td>160</td>
<td>60</td>
<td>100</td>
<td>0.889</td>
<td>89</td>
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<td>Year 4</td>
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<td>256</td>
<td>96</td>
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<td>142</td>
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<td>200</td>
<td>0.822</td>
<td>176</td>
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<tr>
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<td>144</td>
<td>240</td>
<td>0.79</td>
<td>190</td>
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<td>Year 7</td>
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<td>168</td>
<td>280</td>
<td>0.76</td>
<td>213</td>
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<td>168</td>
<td>280</td>
<td>0.731</td>
<td>205</td>
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<td>168</td>
<td>280</td>
<td>0.703</td>
<td>197</td>
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<tr>
<td>Year 10</td>
<td>14</td>
<td>448</td>
<td>168</td>
<td>280</td>
<td>0.676</td>
<td>189</td>
</tr>
</tbody>
</table>

Net Present Value of Cane Sales 1401

Profit over 10 years £352/ha

The profit improves notably by using a lower rate of discounting, which should more accurately reflect future values of the sales. An improvement from £19/ha to £352/ha would allow the farm to improve its current perceptions of the diversification decision. The crop is only expected to allow the farmer to break even over the 10 year contract period.

6.2.5 Other Considerations

The decision to diversify into bioenergy crop production was also accompanied by a number of other factors. The decision took into account ecological considerations as the land to be used was originally permanent pasture. Under the European Directive it is not permissible to plough up species rich land. The pasture was however predominantly rye and clover, both common grasses. The farm was also subject to a visit by a member of the Forestry Commission to ensure that the land was appropriate (away from Sites of Scientific Interest) and that visual impacts would not cause social problems in the vicinity of a rural village.
In order to qualify for the Energy Crops Schemes an end contract must usually be established for the use of the bioenergy crops grown. This farm intended to use the crop on the farm for heating purposes in the two large chicken rearing units and was therefore still able to qualify for the establishment grant. However due to a combination of technical and administrative challenges an end user contract has now been established with a national energy generator. The on-farm heating scheme was not allowed to qualify for infrastructure grants, previously allowed, due to an apparent double receipt of grants for the crop by introducing an on-farm conversion technology. Technical difficulties were also encountered in planning the infrastructure for heating within the existing farm building infrastructures.

The diversification for this farm entails little economic incentive. The farmer clearly states that this diversification was embarked upon for the reasons of loss of the dairy herd to TB and environmental support for the shift towards renewables. It is hoped by the farmer that an increasing importance for climate change reduction will lead to better prices in bioenergy markets in the long term.
6.3 Case Study 2: Upland Miscanthus Production

A case study of farm diversification into miscanthus production for both rhizome multiplication and cane sales, outside the UK Energy Crops Scheme.

6.3.1 Farm Specification

<table>
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<th>Specification</th>
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<td>Total Farm Size</td>
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<td>Potential Arable Production</td>
<td>27 ha</td>
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<tr>
<td>Land in Bioenergy Crop Production</td>
<td>4 ha</td>
</tr>
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<td>Contract</td>
<td>BICAL (South West)</td>
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</table>

6.3.2 Introduction to Farm Management

This is a mixed farm running approximately 67ha of land for grazing of sheep and cattle, with 4ha of land dedicated to bioenergy crop production. In the past up to 27ha has been used for the production of wheat and barley. The farm operation is run through the farmer although all the grazing is let out annually. The relatively small area of bioenergy crop is however managed by the farm. The farm diversified into the production of miscanthus in April 2004 and opted to commit to the minimum permissible contract size of 4ha. The contract offered for miscanthus at this time included rhizome multiplication, from which the main economic returns were to be derived. This farm therefore received no establishment grant for diversification into bioenergy crop production (it would contravene regulations) and also has no end contract with an energy generator, but is under a contract to supply to BICAL. The alternative considered to the production of miscanthus was barley, although prices at the time were low and therefore unattractive. The option of letting the land out was discounted as the farmer has always cultivated some of the land and wanted this practice to continue.

The decision to plant miscanthus rather than SRC willow was made on the grounds of economics, being able to make greater financial returns from the contract for rhizome multiplication in miscanthus.
Image 6.3.2.1 Miscanthus crop early Spring 2008

Image 6.3.2.2 Miscanthus cane
6.3.3 Costs of Establishment

As illustrated in Case Study 1, the establishment costs are those costs incurred in physically converting to the production of bioenergy crops and usually comprise all costs for the first year of production. Below is a comparison of actual costs of establishment for miscanthus in the case study in 2004, to a number of other recent sources of data compiled by the NFU in 2007 (see Jones, 2007). The SAC/Cambridge figures are included in all tables as these figures are currently taken by Defra in setting grant support for crop establishment, using the high or ‘standard’ cost scenario. The Energy Crops Scheme bases grants on a proportion of these establishment costs.

The data are spread over three tables for purposes of presentation only, this has no other significance.

Table 6.3.3.1 Comparison of Establishment Costs against NIX and BICAL

<table>
<thead>
<tr>
<th>Assumptions</th>
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<th>NIX*</th>
<th>BICAL*</th>
<th>Case Study 2</th>
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<td></td>
</tr>
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<td>17,500</td>
</tr>
<tr>
<td>Cost of plants</td>
<td>£0.08</td>
<td>£0.05</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td></td>
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<td>Establishment Costs</td>
<td>£/ha</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Cultivations</td>
<td>117</td>
<td>117</td>
<td>?</td>
<td>118</td>
</tr>
<tr>
<td>Plants</td>
<td>1,169</td>
<td>500</td>
<td>2,000</td>
<td>1,675</td>
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<tr>
<td>Planting Charge</td>
<td>349</td>
<td>250</td>
<td>?</td>
<td>n/a</td>
</tr>
<tr>
<td>Vermin Control</td>
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<td>200</td>
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<td></td>
</tr>
<tr>
<td>Topping in Year 1</td>
<td>?</td>
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<td>20 (SAC*)</td>
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<td>Sprays</td>
<td>56</td>
<td>56</td>
<td>?</td>
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<tr>
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<td>1,691</td>
<td>923</td>
<td>2,500</td>
<td>2,104</td>
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<td>17.5</td>
<td>17.5</td>
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<tr>
<td>Annualised Cost</td>
<td>106</td>
<td>58</td>
<td>143</td>
<td>120</td>
</tr>
</tbody>
</table>

*NIX – a farm management publication on the costs of farming practices
*BICAL – a large grower group working with farmers in diversification and energy generators in contract establishment
*SAC – Figure calculated from The Farm Management Handbook 2007/2008 28th Edition
Table 6.3.3.2 Comparison of Establishment Costs of Miscanthus against ABC and BICAL

<table>
<thead>
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<th>ABC</th>
<th>BICAL</th>
<th>Case Study 2</th>
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<td>Low Cost</td>
<td></td>
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</tr>
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<td>rhizomes/ha</td>
<td>13,950</td>
<td>10,000</td>
<td>14,000</td>
<td>17,500</td>
</tr>
<tr>
<td>Cost of plants</td>
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<tr>
<td>per rhizome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Establishment Costs    | £/ha             |         |         |              |
| Cultivations           | 117              | 117     | 120     | 118          |
| Plants                 | 1,169            | 500     | 1,260   | 1,675        |
| Planting Charge        | 349              | 250     | 300     | ?            |
| Vermin Control         | n/a              | 200     | n/a     |              |
| Topping in Year 1      | n/a              | 18      | 20 (SAC)|              |
| Sprays                 | 56               | 56      | 65      | 70           |
| Fertiliser             |                 |         |         |              |
| Total Variable Costs   | 1,691            | 923     | 1,770   | 2,104        |
| Lifecycle              | 16               | 16      | 15      | 17.5         |
| Annualised Cost        | 106              | 58      | 118     | 120          |

*BICAL – see previous table

Table 6.3.3.3 Comparison of Establishment Costs of Miscanthus against WINBEG and REG

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>SAC – Cambridge</th>
<th>WINBEG*</th>
<th>REG*</th>
<th>Case Study 2</th>
</tr>
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<td>Low Cost</td>
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<td></td>
</tr>
<tr>
<td>rhizomes/ha</td>
<td>13,950</td>
<td>10,000</td>
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</tr>
<tr>
<td>Cost of plants</td>
<td>£0.08</td>
<td>£0.05</td>
<td>£0.07</td>
<td>?</td>
</tr>
<tr>
<td>per rhizome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Establishment Costs    | £/ha             |         |       |              |
| Cultivations           | 117              | 117     | 83    | ?            |
| Plants                 | 1,169            | 500     | 1,300 | 1,700        |
| Planting Charge        | 349              | 250     | 300   | n/a          |
| Vermin Control         | n/a              | ?       | n/a   |              |
| Topping in Year 1      | n/a              | ?       | 20 (SAC)|              |
| Sprays                 | 56               | 56      | 80    | 138          |
| Fertiliser             |                 |         |       |              |
| Total Variable Costs   | 1,691            | 923     | 1,811 | 1,845        |
| Lifecycle              | 16               | 16      | 15    | 17.5         |
| Annualised Cost        | 106              | 58      | 121   | 105          |

*REG – Rural Enterprise Gateway Fact Sheet (2007)
The tables and Graph 6.3.3.1 clearly illustrate the substantially higher costs of establishment for miscanthus for this farm, Case Study 2. A key difference is the proportion of cost arising from the cost of plants that is dependent on the density of planting, often particular to each farm (Carver, 2008). It is also thought that the costs of rhizomes in 2004 were higher than in 2006/2007.

Graph 6.3.3.2 Index of Fertiliser and Spray Chemical Costs 2000-2006

Source: Jones, 2007
The Index of Prices in Graph 6.3.3.2 illustrate that costs associated with herbicide application have remained largely unchanged over the period 2000-2006. The cost of herbicide application is in line with what may be considered normal farm costs for application through contractors.

The costs of topping, carried out by the farmer are estimated at £20/ha as an industry standard taken from the SAC Farm Management Handbook (2007). This is also considered to be a normal cost in the first year of establishment.

6.3.4 Farm Outputs - Rhizome Multiplication

The farm was awarded a contract for rhizome multiplication in 2004 at the point of establishing the contract with BICAL. Such a contract involves lifting all the rhizomes originally planted and removing a proportion of the multiplied roots for resale. This normally occurs two years after planting and provides an additional revenue source from the crop. The revenue from the sale of rhizomes enabled the farm to make a profit on the production of miscanthus after substantial cost outflows in Year 1 of establishment. This can be seen in Table 6.3.4.1, based on a one-off total single payment of £15,640 (ex-farm) to the farmer for the total number of rhizomes lifted.

<table>
<thead>
<tr>
<th>Table 6.3.4.1 Profit from Rhizome Multiplication in Year 2</th>
<th>£/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting Charge</td>
<td>2,700</td>
</tr>
<tr>
<td>Revenue rhizomes sales*</td>
<td>-3,910</td>
</tr>
<tr>
<td>Cultivations</td>
<td>?</td>
</tr>
<tr>
<td>Spraying</td>
<td>n/a</td>
</tr>
<tr>
<td>Herbicide</td>
<td>138</td>
</tr>
<tr>
<td>Topping</td>
<td>20</td>
</tr>
<tr>
<td>Total Profit Net of Rhizome Sales</td>
<td>1,052</td>
</tr>
</tbody>
</table>

*Revenue from rhizome multiplication per hectare in Year 2 (sales to BICAL)
6.3.5 Farm Outputs – Cane Sales

The first cane harvest was made in 2007, three years after the establishment of the crop. The expected yield from the cane was lower than projected by their agronomist, but was expected by the farmer due to the patchy uptake and growth of the crop from the point of establishment. The costs of harvesting and the revenues received for the crop ex farm can be seen in Table 6.3.5.1.

Table 6.3.5.1 Profit from Cane Harvest Year 3

<table>
<thead>
<tr>
<th></th>
<th>Harvest Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenues</strong></td>
<td></td>
</tr>
<tr>
<td>Cane £/tonne</td>
<td>40.00</td>
</tr>
<tr>
<td>Yield tonnes/ha</td>
<td>3.876</td>
</tr>
<tr>
<td><strong>Total revenue (over 4ha)</strong></td>
<td>620.40</td>
</tr>
<tr>
<td><strong>Costs £/ha</strong></td>
<td></td>
</tr>
<tr>
<td>Baling Cost</td>
<td>37.00</td>
</tr>
<tr>
<td>Other (hire charges)*</td>
<td>9.25</td>
</tr>
<tr>
<td><strong>Total Cost (over 4ha)</strong></td>
<td>185.00</td>
</tr>
<tr>
<td><strong>Net Profit £/ha</strong></td>
<td>109.00</td>
</tr>
</tbody>
</table>

* 4WD telescopic forklift for loading, at average price £18.50/hr over two hours (SAC Farm Management Handbook 2007)
6.4 Case Study 3: Upland Arable Farm

A case study of an arable farm in South West England, which has chosen not to diversify into production of bioenergy crops.

6.4.1 Farm Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Farm Size:</td>
<td>137 ha</td>
</tr>
<tr>
<td>Land in Production:</td>
<td>135 ha</td>
</tr>
<tr>
<td>Potential Arable Production:</td>
<td>127 ha</td>
</tr>
<tr>
<td>Land in Bioenergy Crop Production:</td>
<td>0 ha</td>
</tr>
<tr>
<td>Contract:</td>
<td>N/A</td>
</tr>
</tbody>
</table>

6.4.2 Introduction to Farm Management

This arable farm currently produces a number of crops including winter wheat, winter oats and oil seed rape (OSR). Although in the past spring barley and spring beans have also been grown. The farm cultivates 127ha of land for arable production and lets out 8ha for sheep grazing through an annual grazing sale. Situated in South West England it is classified in the top 25% farms of the region based on farm performance, determined by yields of crop per hectare.

The farmer decided not to diversify into the production of bioenergy crops, but did consider the production options of both miscanthus and willow SRC. The farmer attended events for the promotion of bioenergy crops run by grower groups. However the performance of the farm and its ability to give high yields meant that the low returns from the cultivation of bioenergy crops were unattractive. The farm is able to produce consistent yields of 10tonnes/ha of wheat, considered as excellent in the industry. The farmer is also starting to consider retirement and was therefore discouraged by the long term nature of the contracts required in the production of bioenergy crops; normally a minimum 10years is expected in such a contract.
6.4.3 Farm Operations

The farm is divided into production of three main crops. These include winter wheat, winter oats and winter oil seed rape. The most attractive crop in terms of prices is wheat. The farm is however unable to produce wheat year in year out on the same land due to disease, principally *take-all* that would significantly reduce yields in the longer term. To avoid this problem the farm uses a break crop, growing an alternative crop on alternative years. Winter oats are used for this purpose as they provide an economically attractive break crop, well suited to the area. The added attractiveness of winter oats as a break crop may be seen in straw sales, with high local demand from a neighbouring racing stable, for equine bedding.
### Table 6.4.2.1 Current Operations – Arable – 1999-2006

<table>
<thead>
<tr>
<th>CROP</th>
<th>HARVEST YEAR</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winter Wheat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (ha)</td>
<td></td>
<td>44</td>
<td>43</td>
<td>44</td>
<td>51</td>
<td>51</td>
<td>63</td>
<td>51</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td></td>
<td>9.4</td>
<td>9.6</td>
<td>9.6</td>
<td>8.0</td>
<td>10.0</td>
<td>9.4</td>
<td>7.8</td>
<td>10.0</td>
<td>9.225</td>
</tr>
<tr>
<td>Price £/tonne</td>
<td></td>
<td>70.5</td>
<td>63.8</td>
<td>76.7</td>
<td>60</td>
<td>85.2</td>
<td>64.5</td>
<td>74.3</td>
<td>90.6</td>
<td>73.2</td>
</tr>
<tr>
<td>GO*</td>
<td></td>
<td>764</td>
<td>670</td>
<td>821</td>
<td>778</td>
<td>1113</td>
<td>625</td>
<td>667</td>
<td>1009</td>
<td></td>
</tr>
<tr>
<td>VC*</td>
<td></td>
<td>174</td>
<td>195</td>
<td>192</td>
<td>216</td>
<td>212</td>
<td>257</td>
<td>277</td>
<td>266</td>
<td></td>
</tr>
<tr>
<td>GM*</td>
<td></td>
<td>589</td>
<td>475</td>
<td>629</td>
<td>562</td>
<td>920</td>
<td>368</td>
<td>390</td>
<td>743</td>
<td>584.5</td>
</tr>
<tr>
<td><strong>Winter Oats</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (ha)</td>
<td></td>
<td>20</td>
<td>23</td>
<td>22</td>
<td>34</td>
<td>20</td>
<td>15</td>
<td>14</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td></td>
<td>8.0</td>
<td>7.4</td>
<td>7.5</td>
<td>6.1</td>
<td>6.6</td>
<td>5.6</td>
<td>5.3</td>
<td>7.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Price £/tonne</td>
<td></td>
<td>67.2</td>
<td>59.3</td>
<td>68.1</td>
<td>53.1</td>
<td>85</td>
<td>63.6</td>
<td>82.1</td>
<td>72.7</td>
<td>68.9</td>
</tr>
<tr>
<td>GO</td>
<td></td>
<td>606</td>
<td>509</td>
<td>581</td>
<td>622</td>
<td>862</td>
<td>452</td>
<td>529</td>
<td>624</td>
<td></td>
</tr>
<tr>
<td>VC</td>
<td></td>
<td>131</td>
<td>158</td>
<td>167</td>
<td>153</td>
<td>188</td>
<td>118</td>
<td>242</td>
<td>222</td>
<td></td>
</tr>
<tr>
<td>GM</td>
<td></td>
<td>475</td>
<td>351</td>
<td>414</td>
<td>469</td>
<td>674</td>
<td>333</td>
<td>287</td>
<td>402</td>
<td>425.6</td>
</tr>
<tr>
<td><strong>Winter OSR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area ((ha))</td>
<td></td>
<td>19</td>
<td>21</td>
<td>20</td>
<td>Not Grown</td>
<td>31</td>
<td>19</td>
<td>33</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td></td>
<td>3.3</td>
<td>2</td>
<td>4.2</td>
<td>4.2</td>
<td>3.9</td>
<td>3.1</td>
<td>3.1</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>Price £/tonne</td>
<td></td>
<td>99.4</td>
<td>104</td>
<td>151</td>
<td>177</td>
<td>135</td>
<td>188</td>
<td>180</td>
<td>147.7</td>
<td></td>
</tr>
<tr>
<td>GO</td>
<td></td>
<td>328</td>
<td>210</td>
<td>637</td>
<td>743</td>
<td>527</td>
<td>588</td>
<td>551</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC</td>
<td></td>
<td>154</td>
<td>196</td>
<td>189</td>
<td>249</td>
<td>205</td>
<td>243</td>
<td>241</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GM</td>
<td></td>
<td>174</td>
<td>14</td>
<td>448</td>
<td>494</td>
<td>322</td>
<td>345</td>
<td>310</td>
<td>301</td>
<td></td>
</tr>
</tbody>
</table>

Notes

1. Outputs do not include arable area payments.
2. Outputs include straw sales as well as grain sales

*GO* - gross output of the farm, i.e. revenues (figures may not correspond to prices if sold through pools at higher future price)

*VC* - variable costs

*GM* - gross margin (gross output less the variable costs)
The figures in the above table represent the farm operations over the period from 1999-2006 and includes the three principal crops grown. Other crops have been grown but on irregular patterns. For example, in 2002 oil seed rape (OSR) was not grown but replaced by spring beans (no data available).

It must be noted that the gross output for the sales of wheat do not correspond to the yield and market prices for the crop as this commodity is often sold through pools, whereby an intermediary creates a larger reserve of wheat in order to generate greater financial returns on the market. The higher returns are received by the farmer, with the intermediary taking a percentage commission.

6.4.4 Gross Margin Data

The tables below allow a comparison to be made of gross margins expected from the production of the three main crops grown in Case Study 3 and the discussed alternative option of miscanthus production. It is immediately clear that the gross margins, defined as the revenues earned after the deduction of all variable costs, are significantly more attractive across all the arable crops than with miscanthus.

The figures in the case study have taken average figures of the period 1999-2006 to give a more rounded view of the margins earned by the crops. The SAC figures on the other hand illustrate the potential current margins.

The difference in figures between the SAC gross margin data and the figures from Case Study 3 may be explained by the increase in price of all the crops over the last 8 years (see Appendix 7 for futures and trends in crop prices published in the Farmers Weekly March 2008).
Table 6.4.4.1 Gross Margin Data Comparison - Winter Wheat

<table>
<thead>
<tr>
<th>GROSS MARGIN DATA - Winter Wheat</th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Yield: tonnes/ha</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Straw Yield: tonnes/ha</td>
<td>3.9</td>
<td>5.2</td>
</tr>
</tbody>
</table>

**OUTPUT**

<table>
<thead>
<tr>
<th></th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain £/tonne</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>Straw £/tonne</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>

**VARIABLE COSTS (VC)**

<table>
<thead>
<tr>
<th></th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed@ £275/tonne</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>143</td>
<td>143</td>
</tr>
<tr>
<td>Sprays</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>308</td>
<td>312</td>
</tr>
</tbody>
</table>

**GROSS MARGIN**

<table>
<thead>
<tr>
<th></th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Yield: tonnes/ha</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Straw Yield: tonnes/ha</td>
<td>3.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Output Grain £/tonne</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>Output Straw £/tonne</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Output Total</td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>

* SAC DATA - sale price estimate for 2008 crop based on ex-farm spot price at 16% moisture content and average quality
* Case Study 3 - figures based on average yields, costs and revenues over the period 1999-2006

Table 6.4.4.2 Gross Margin Data Comparison – Winter Oats

<table>
<thead>
<tr>
<th>GROSS MARGIN DATA - Winter Oats</th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Yield: tonnes/ha</td>
<td>5</td>
<td>7.5</td>
</tr>
<tr>
<td>Straw Yield: tonnes/ha</td>
<td>4.3</td>
<td>6.4</td>
</tr>
</tbody>
</table>

**OUTPUT**

<table>
<thead>
<tr>
<th></th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain £/tonne</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>Straw £/tonne</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>

**VARIABLE COSTS (VC)**

<table>
<thead>
<tr>
<th></th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed@ £290/tonne</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Sprays</td>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>Other</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>223</td>
<td>229</td>
</tr>
</tbody>
</table>

**GROSS MARGIN**

<table>
<thead>
<tr>
<th></th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Yield: tonnes/ha</td>
<td>5</td>
<td>7.5</td>
</tr>
<tr>
<td>Straw Yield: tonnes/ha</td>
<td>4.3</td>
<td>6.4</td>
</tr>
<tr>
<td>Output Grain £/tonne</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>Output Straw £/tonne</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Output Total</td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>

* SAC DATA - sale price estimate for 2008 crop based on ex-farm spot price at 16% moisture content and average quality
* Case Study 3 - figures based on average yields, costs and revenues over the period 1999-2006
Table 6.4.4.3 Gross Margin Data Comparison – Oil Seed Rape

<table>
<thead>
<tr>
<th>GROSS MARGIN DATA - Oil Seed Rape</th>
<th>SAC DATA*</th>
<th>Case Study 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield: tonnes/ha</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>OUTPUT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed £/tonne</td>
<td>185</td>
<td>185</td>
</tr>
<tr>
<td><strong>VARIABLE COSTS (VC)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed@ £7.00/kg</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>127</td>
<td>127</td>
</tr>
<tr>
<td>Sprays</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td>Other</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td><strong>Total VC</strong></td>
<td>304</td>
<td>304</td>
</tr>
<tr>
<td><strong>GROSS MARGIN</strong></td>
<td>251</td>
<td>436</td>
</tr>
</tbody>
</table>

*SAC DATA - sale price estimate for 2008 crop based on ex-farm price
*Case Study 3 - figures based on average yields, costs and revenues over the period 1999-2006

Table 6.4.4.4 Gross Margin Data - Miscanthus

<table>
<thead>
<tr>
<th>GROSS MARGIN DATA</th>
<th>Miscanthus*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield: av. tonnes/ha</td>
<td>9.1</td>
</tr>
<tr>
<td><strong>OUTPUT</strong></td>
<td></td>
</tr>
<tr>
<td>Cane Sales £/odt</td>
<td>32</td>
</tr>
<tr>
<td><strong>VARIABLE COSTS (VC)</strong></td>
<td></td>
</tr>
<tr>
<td>Harvesting £/ha</td>
<td>110</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>LOW/NONE</td>
</tr>
<tr>
<td>Other</td>
<td>?</td>
</tr>
<tr>
<td><strong>Total VC</strong></td>
<td>110</td>
</tr>
<tr>
<td><strong>GROSS MARGIN</strong></td>
<td>180</td>
</tr>
</tbody>
</table>

*Miscanthus – figures taken as averages over a 10 year lifecycle from the information provided in the Investment Appraisal of Case Study 1 (originally sourced from BICAL contract information)
6.5 Conclusion

This chapter has illustrated three farm case studies in South West England. The first case study illustrates the farmer decision process involved in diversifying into miscanthus production from dairy farming and provides a detailed view of the costs of establishment and expected return. The second case study illustrates the process of diversification from mixed farming and small scale arable production into miscanthus for rhizome multiplication, and has recently harvested its first cane crop. Finally the third case study provides a good example of an arable producer in the South West that has considered diversification. The case provides for a comparison of gross margins across a number of arable crops and miscanthus as an alternative.
Chapter 7: Discussion

7.1 Introduction

This chapter discusses the results of the three case studies described in the previous section. The case studies cover a number of issues relevant to the diversification of farms into bioenergy crop production in terms of both qualitative and quantitative information.

The following will firstly discuss the farmer decision making process and look at an overview of the issues involved in the move to bioenergy crop production. This discussion will focus primarily on qualitative issues, based on farmers that have diversified into miscanthus. The discussion will then move on to look at establishment costs of miscanthus, as an important decision making criteria for the farmer and an important area for government policy makers. The economics of miscanthus will then be discussed in terms of potential revenues and gross margins in comparison to an array of arable crops. Finally the barriers to energy crop production are discussed.

The aim of this chapter is to illustrate how the theory and policy discussed in the literature review relate to the circumstances of these case studies, examining the links between the literature and findings. The discussion contributes to the wider debate surrounding bioenergy crop production in the UK and makes recommendations for improving farm diversification uptake levels.
7.2 Overview of Case Study Diversification

The links between specific decision factors and the choice to diversify into bioenergy crop production vary across these case studies. The degree to which the farmers chose to diversify also varied in terms of the amount of land committed, although it is fair to say that neither of the upland farms that chose to diversify relies on bioenergy crop production as their main source of farm income.

Due to the limited development of this market at present and the relatively low uptake of bioenergy crops, both case studies of diversification focused on miscanthus production. It would appear however that this is no coincidence, as this crop is far more versatile in the view of farmers in comparison to its alternative of SRC willow. SRC willow is thought to be more susceptible to disease and liable to cause land damage from deep-root structures. The water requirement for SRC is also higher, despite average yields being lower than miscanthus. Therefore the following discussion will apply principally to diversification of farms into miscanthus, although it may also be of use to those looking at the option of SRC willow and other bioenergy crops.

The decision to diversify in Case Study 1 was essentially the result of a forced exit from the dairy industry due to a case of TB. The decision to change operations on the farm was therefore in part due to necessity. In Case Study 2 on the other hand, the shift to miscanthus production was entirely voluntary and motivated by the economic incentive of relatively high revenues from a rhizome multiplication contract with BICAL. It should be noted here that such contracts are no longer available under such conditions (see Appendix 4).

A common factor in decision-making for diversification in Case Study 1 and Case Study 2 was the low maintenance requirements of the crop matching the life stage of the farmers, both of whom are coming up to the age of retirement. The low maintenance and low inputs of miscanthus production are noted in much of the literature to be a key attraction of this crop. With the exception of some fertiliser application in the first year, it is thought the crop needs very low inputs over its
lifecycle. This not only reduces cost but minimises the time involvement of farmers. The suitability of the land and climate were secondary factors allowing the diversification to go ahead. Reports submitted by agronomists on both accounts predicted average yields. It would however appear that actual yields off Case Study 2 in year 3 were below average, due mainly to ‘patchy’ growth.

‘Green’ or environmental motives for producing this crop are mentioned in both Case Study 1 and Case Study 2, with a desire to help contribute towards a reduction in climate change. The notion that farmers may diversify in part on the grounds of personal environmental ethics is both an interesting and encouraging phenomenon for the industry. Further research in this area would be beneficial to the industry as the planned levels of production in the UK require a far wider uptake of the crop, requiring significant farmer consultation, involvement and support. The willingness and recognition amongst farmers to recognise climate change may significantly enhance receptivity to new improved policies.

In the first case study all feasible land was converted to miscanthus production in a bid to maximise revenues. This amounted to a total 15.35ha of miscanthus, as a proportion of the land is poorly drained and therefore too wet for machinery to operate on during crop harvesting. A contract of higher value was offered for an increased level of diversification into miscanthus but had to be refused due to the constraints of topography. The remaining land is now let out for sheep grazing.

Diversification in Case Study 2 only committed to the minimum permissible level of production of 4ha, despite having 27ha of land suitable for arable crop production. There was concern over the commitment of government to support for this crop at the time and therefore some risk in the diversification decision, limited by the farmer by small scale diversification. This decision was made in 2004, prior to a significant number of publications made by the government signalling their intent to develop this resource into the long term. The implication of this for current practice now creates problems. Such a small commitment to the production of miscanthus has made the costs of harvesting and transport to BICAL too high, in comparison to other larger or more accessible producers. It is an uneconomically viable scale of production considering the likely yields of upland fields. It would therefore be recommended that
any bioenergy crop contract be subject to more concise minimum economic scales of production, dependant on location.

7.3 Discussion of Establishment Costs in Bioenergy Crop Production

There is no universal definition of establishment costs but usually included are all variable costs incurred in setting up the production of bioenergy crops in the first year. The discussion of these costs is of importance to policy, as the main grant scheme to farmers is derived as a proportion of these costs. The Establishment Cost Scheme (ECS) is available to all energy crops requiring a long term commitment in their establishment, subject to locational constraints with respect to the minimum distance to the point of end-use.

7.3.1 Case Study 1 – Expected Costs

The costs of establishment in Case Study 1 provide an up to-date set of figures for comparison against the recently released NFU figures on costs of establishment. This allows for useful comment on an actual case in South West England and thus wider implications for UK farming.

The costs of establishment in the case study would appear to be generally consistent with the figures proposed by the other organisations listed (see Graph 6.2.3.2). These organisations have published figures on the costs of establishment of miscanthus in varying levels of depth and accuracy. The most comprehensive set of figures in this discussion are those from the SAC/Cambridge and BICAL (see Table 6.2.3.1). SAC/Cambridge is of particular importance as the standard cost scenario is used to base government grant scheme financial subsidy thresholds. BICAL is of significance as it provides a full set of figures and should be directly comparable to Case Study 1, a current BICAL contract.

The overall cost of establishment in the case was £1,969.00, higher than the standard cost in the SAC/Cambridge forecast £1,691.00 and less than the BICAL figure £2104.00 in Table 6.2.3.1. The reason for the higher than average cost (taking the
SAC/Cambridge scenario as average) is mainly due to higher planting densities of 15,000 to 20,000 rhizomes per hectare, averaged in the table at 17,500 rhizomes/ha. This elevates the costs of plants to £1,675.00 in the case study and is supported by the identical figure that BICAL proposes. Although this is higher than the average proposed planting cost (SAC/Cambridge), there is no planting charge, which in most cases would be in the region of £250-349/ha (see Tables 6.2.3.1, 6.2.3.2 and 6.2.3.3).

The cost of cultivations (ploughing) has been the topic of much debate in discussions around appropriate costs of establishment, from which to determine grant support. The SAC/Cambridge figure of £117/ha (£118/ha for BICAL) is thought to be too low and should be increased by £10-15/ha to account for recent inflation. The figure from WINBEG of £83/ha is particularly low and is thought to have been calculated on a marginal cost basis using previously owned farm equipment and on-farm labour (see Table 6.2.3.3). The figure of £86/ha in Case Study 1 is therefore also likely to have been calculated in a similar manner and is not to be considered representative of standard industry cost to the farmer.

Case Study 1 topped the crop in Year 1, which according to initial Defra guidance is unnecessary as the growth is not sufficient for harvest and the stems may be left in the field until the following season (Defra, 2001). However Defra in a draft report have suggested that topping in Year 1 may become necessary before land is sprayed for weed control to prevent crop uptake. The cost of topping in the case is £20/ha, which is a standard industry cost level. Although only BICAL suggests this cost should be included in determining costs of establishment for farms across the UK, it is clear that this is a likely requirement in the first year, as demonstrated by the case study. BICAL is also responsible for most contracts across the UK and is the largest producer of miscanthus in Europe. It would therefore be recommended that an allowance for the cost of topping be included in the ECS.

The cost of herbicide applications in the case is of £147/ha which is above the expected £56/ha proposed by the SAC/Cambridge figure. This average figure would appear nevertheless to be particularly low and unrealistic. The figure in the case is however high compared to the BICAL figure of £70/ha. It would therefore seem that the figure proposed by BICAL, as a compromise, would be an appropriate cost level
requiring a minimum £14/ha increase in cost. Further research on the actual costs of herbicide application in line with price increases (see Graph 6.3.3.2) would be recommended in order to establish an appropriate figure for the ECS over the next five years or more.

Both the application of fertiliser and the installation of temporary vermin control measures (rabbit fencing) in the case study were not considered necessary. There is however significant debate around these issues in the literature. Fertiliser application is in general perceived as unnecessary as the crop requires very low inputs once established, although it should be recognised that not all land is of equal soil quality. The need for vermin control presents a significant cost increase as illustrated in the case of BICAL at £200/ha (see Table 6.2.3.1). The main concern is rabbit damage to crops and although location specific is becoming a more commonly accepted concern for farmers. It is likely that farmer experience over time will allow greater insight into this issue to be understood and the most effective means of controlling vermin established.

7.3.2 Case Study 1 - Discussion of Grant Support

The role of the establishment grant subsidy for the farmer in Case Study 1 was critical to the decision to diversify into miscanthus. The grant under the Energy Crops Scheme (run up until late 2006) was set at £920.00/ha for miscanthus (see Table 6.2.4.1). This scheme has recently re-opened under the Rural Development Plan for England and will no longer be based upon a fixed rate of payment, but a proportion of the actual costs of establishment. For miscanthus this has been set at 40% of actual costs of establishment. Hypothetically, 40% of the actual costs for Case Study 1 of establishment would have been £788.00/ha, therefore receiving circa 16% less in terms of subsidy support.

The impact of this change in policy is yet to be seen, but it is fair to say that if such an approach reduces on average the amount of subsidy payment for establishment, it is unlikely that farmers will be attracted to an already marginal crop. On the other hand such an approach may improve equity ensuring that those farmers facing higher costs
of establishment receive appropriate subsidisation. At present there does not however appear to be evidence of levels in cost variation significant enough to justify this approach, at least on the evidence of these case studies.

Discussion of EU Energy Crop Scheme payments has been limited as the proposed €45/ha is a theoretical figure scaled back with total European production of energy crops (RPA, 2007). The impact of which has been that in some years, the scheme is of marginal value in terms of payments received in the UK. This has been due to much greater uptake of energy crops across Europe. There is also a total national and EC modulation rate of 17% (RPA, 2007).

7.3.3 Case Study 2 – Expected Costs

The costs of establishment in Case Study 2 are not directly comparable to the figures proposed by the organisations as discussed in the previous section. The lapse in time between 2004 and 2007 has meant changes in costs to the farmer in establishing miscanthus (see Graph 6.3.3.1).

The most notable difference in this case is the significantly higher cost of planting at £2,700/ha compared to the SAC/Cambridge (2007) estimate of £1,169/ha. Case Study 2 is unlikely however to be based on the same planting density to the recent BICAL figures (Carver, 2008). According to discussions with BICAL it is likely that planting densities would have been in the region of 20,000 rhizomes/ha (see Table 6.3.3.1 and Appendix 4). The cost information for the cultivations of the land prior to planting were not available although it is expected they would be in line with the figures proposed by BICAL, after taking into account the rate of inflation.

The crop on this farm was topped in the first year as was recommended by BICAL to avoid the crop taking up the herbicide applied. Figures for this were not available from the farmer, as it was carried out using farm-owned machinery. The cost was therefore drawn from the SAC Farm Management Handbook (2007) and is consistent with those figures proposed by BICAL at £20/ha.
The application of herbicide to the crop was at a higher cost than stated by the SAC/Cambridge or BICAL estimates, although this work was contracted and could therefore have been subject to other contractual costs.

### 7.3.4 Case Study 2 - Discussion of Grant Support

The case study could not have received a grant for subsidy of the establishment cost of this crop as running a rhizome multiplication contract would contravene the Energy Crops Scheme; although significant revenues were expected from rhizome sales at the end of the second year (see Table 6.3.4.1). The farm does however currently receive the EU Energy Crops Scheme payment.

### 7.4 Discussion of Bioenergy Crop Economics

In this section the investment appraisal of miscanthus will be discussed before moving on to discuss the economics of miscanthus in comparison to an array of arable crops produced.

#### 7.4.1 Investment Appraisal of Miscanthus Production

The initial investment appraisal carried out in Case Study 1 covered the 10 year contract period and is based upon a number of variables (see Table 6.2.4.2). The yield of the crop increases incrementally over a period of 6 years, before reaching a maximum yield of 140t/ha. It is important to note that in the economics of bioenergy crop production no revenues are earned in the first two years, emphasising the significance of establishment grants. The revenues are based upon a guaranteed minimum ex-farm price per tonne of £32.00 and then take into account the costs of harvesting the crop/ha. The rate of discounting used by the farmer to establish the NPV of the crop was 8% (based on farmer value judgement). This is quite high and means that the crop is likely to just break even over the period once the costs of establishment are taken into account. The profit is £19/ha under these circumstances. However with a more balanced 4% discounting rate the profit over the ten years increases to £352/ha (see Table 6.4.2.3). This is still a very low return for any farm
(see below), but is considered by farmers as a guaranteed and secure positive farm income.

From Case Study 2 it is possible to assess the current performance of a miscanthus plantation in the UK (see Table 6.3.5.1). The yield from this upland farm in the first harvest was slightly below the expected value of 5 tonnes/ha at 3.9 tonnes/ha, although the price paid per tonne was more than expected at an ex-farm price of £40/odt. The farmers in both case studies hope to attain prices higher than the minimum guaranteed price, particularly as climate change mitigation becomes a more important issue in the UK economy.

### 7.4.2 Comparison of Gross Margin Data

The gross margin for miscanthus over a single year is not representative as the yields increase incrementally. An average yield was therefore had to be calculated for the crop in Table 6.4.4.4 and the harvesting costs and sales prices also taken as an average over a 10 year contract period (data from Case Study 1). A gross margin of £180.00/ha was calculated for the production of miscanthus. This figure is an average gross margin and should not be taken as an annualised figure in future research. This figure compares poorly across a number of alternative arable crops produced in Case Study 3.

Case Study 3 did not diversify into the production of bioenergy crops, due to its ability to produce high yields from a number of cereal and seed crops. Figures for Case Study 3 have been taken from average figures of the period 1999-2006 to give a rounded view of the margins earned by the crops. The average gross margin on wheat on the farm over the period 1999-2006 was £584.50/ha. The farm is able to consistently produce yields of almost 10 tonnes/ha, an industry upper ceiling, as illustrated by the SAC data. The gross margin of wheat is currently (2007) in the region of £998.00/ha at 10 tonne/ha yields, due to the high prices of wheat, brought about by world grain shortages.
It would appear the costs of harvesting in the case study are lower than the estimated costs put forward in the SAC data scenarios, although they are not significantly different.

The average gross margin on the production of winter oats for Case Study 3 over the 8-year period is £425.60/ha, which again is below the SAC data but is based upon the last 8-year average and not current inflated prices (see Table 6.4.4.2). The benefit of oats to the farm in this case study is the convenient sales of straw to the neighbouring horse racing stable. The farmer is able to attain prices of between £25-30/tonne for this commodity in a local market. The yields are not as high as with wheat but the average costs of harvest are still low, compared to SAC data. The crop is a clearly more economically attractive option than miscanthus.

Oil seed rape has been grown on the farm in most years although in 2002 the crop was replaced by spring beans (see Table 6.4.2.1). Oil seed rape has produced an average margin of £301/ha over the period 1999-2006 yielding 3.4 tonnes/ha, a slightly below average margin considering the yield of this crop according to SAC data (see Table 6.4.4.3). The current gross margin for a farm producing OSR yields of 3.4 tonnes/ha should be in the region of £351/ha, although costs of harvest are again lower in the case study.

The overall implication of this comparison highlights a significant gap in performance between alternative arable crops and miscanthus production in the UK based on the potential gross margins. Therefore miscanthus remains for the foreseeable future an unsuitable crop for productive arable farms across the UK. It would seem prudent to conduct further research into the economics of miscanthus in the UK if there is to be a wider uptake of its production. The crop may not need to compete with highly productive farms such as that in Case Study 3, but at present even the lower levels of productivity illustrated in this research suggest that gross margins on arable crops are still more attractive.
7.5 Barriers to Miscanthus Production

The third case study based on an arable farm in the South West provides a useful insight into the reasons for productive arable farms not to diversify into bioenergy crops. There are a significant number of barriers to the production of bioenergy crops highlighted by this case:

- Low financial returns of the crop (discussed in Section 7.4).
- Long term nature of contracts
- Concern over the commitment of government to policy and subsidy support
- Costs of re-instatement of land after bioenergy crop production (particularly with willow SRC on drainage systems)
- High productivity of land being inappropriate for such crops

Long term contracts for the production of bioenergy crops are generally perceived to be an attractive proposition, guaranteeing a minimum price for the crop over longer periods. Suggestions have been made to increase the standard 10 year contract to 16 years, more accurately reflecting the lifecycle of a crop such as miscanthus and giving greater security of demand to the farmer (for lifecycles see Table 6.2.3.1). However when compared to the flexibility of arable crop production, there is significantly less opportunity for change in cropping patterns. This has become a more important issue in recent years as certain cereal crop values have reached record values and are therefore significantly more attractive for cultivation over that period (see Appendix 7 for future crop prices).

It could however then be suggested that from the perspective of the farmer in Case Study 3 shorter contracts would be more attractive. However with a perennial crop such as miscanthus taking three years for establishment, this is unlikely to be a practical or economic proposition.

The costs of reinstating land to its prior use after the production of bioenergy crops such as willow SRC or indeed miscanthus are currently largely unknown. The UK is at a relatively early stage of development in bioenergy crops and there are few cases
to illustrate the extent of impact caused by these deep rooted crops. Little has been published on this end of the production lifecycle as most attention is currently focused on costs of establishment of the crops and suitable levels of subsidy support. Perhaps future research should begin to look into the effects of SRC willow and miscanthus as the two dominant crops in the UK and the impacts on land use in the longer term i.e. costs of re-establishing drainage systems where necessary.

Finally it is clear that bioenergy crops are not suited to all farms across the UK. Land of high productivity leading to consistently high cereal crop yields is unlikely ever to be considered as an appropriate location for the production of biomass for bioenergy. The opportunity cost of not using such land in the production of cereal and other arable crops is too great. Case Study 3 is a clear illustration of this issue in determining appropriate locations.

These barriers to production are recognised to some extent in reports written to government (see literature review) and are being or have been addressed in policy documentation. However much of this policy including the directives of the Biomass Strategy (2007), is not being implemented to breakdown the barriers. They remain a set of ideological objectives.

### 7.7 Conclusion

This chapter has discussed three farm case studies across South West England and analysed a wide a range of issues related to the diversification of farms into bioenergy crops, notably miscanthus. A number of links may be drawn between the decision to diversify and the context of the cases.

It would appear that neither farm that diversified became reliant on miscanthus as their principal source of farm income (see Appendix 5). Miscanthus is considered a low maintenance crop giving low but guaranteed levels of income, providing a use for land otherwise redundant. There is a further motive of environmental ethics and a concern for climate change amongst farmers, although this is hard to quantify and so it is unclear how important such criteria can be considered. The role of establishment
grants played an important part for the first case study and makes significant contributions towards the high costs of establishing miscanthus. The value of this grant scheme is discussed in depth with regards to its component parts and recent changes in policy. A number of issues for further research have been recommended.

The financial value of miscanthus production is compared against the farm outputs of the third case study and more recent values from the SAC. The gross margin of miscanthus leaves a lot to be desired in comparison to all three arable crops considered. However miscanthus is not intended to replace high value agricultural crops and so should be considered on alternative land. Financial performance was considered as an important barrier to entry into the production of bioenergy crops although other concerns were also identified. These included the long term commitment to production, uncertainty of government support and costs of land reinstatement at the end of crop lifecycles. All these issues must be addressed to a greater extent over the coming decade if the UK is to meet its emissions targets through biomass production.
Chapter 8: Conclusions

8.1 Introduction

The main aim of this dissertation has been to review the current context of the bioenergy and biomass resource in the UK and to shed light on the involvement of the agricultural sector in the provision of energy crops, assessing to what extent government targets and policy is achieving the desired outcomes for farm diversification. Through the use of three case studies this research has been able to analyse the decision processes and current performance of a selection of farms in South West England both in the production of miscanthus and other traditional arable crops. In addition the dissertation has provided a literature review in chapters 1, 2, 3 and 4 setting the background for the research, enabling the reader to gain a clear understanding of the current context for bioenergy production. This addresses the key issues related to bioenergy and biomass in the UK, on the level of policy and production.

Chapter 6 sets out the case studies from across South West England and illustrates a number of factors related to the decision and physical processes of diversification into bioenergy crop production. The case studies focus on the discussion of miscanthus production as willow SRC is currently perceived as less desirable by these farmers. An in depth discussion of farm diversification and the financial implications can be seen in Chapter 7. The results were in brief:

- the establishment costs of miscanthus require further investigation in order to establish appropriate levels of grant;
- the gross margins of miscanthus production appear to be unattractively low considering agricultural alternatives for production;
- and there remain substantial barriers to production of bioenergy crops.

Each case study provided a rich set of information which has enabled this level of analysis and a set of further recommendations to be proposed for the development of this resource.
8.2 The Literature Review

As mentioned above, Chapters 1, 2, 3 and 4 provide the background to the research and cover a number of issues relevant to the discussion of the bioenergy and biomass resource. Chapter 1 was important in outlining the precise aims and objectives of the research and also in explaining the current context of the UK agricultural sector. The information in this section becomes vital to understanding the role of bioenergy crop production in the UK in light of the current patterns of production in agriculture. Chapter 1 also provides an introduction to the climate change debate and sustainability, two key themes that underpin the need for the development of a sustainable biomass resource.

Chapter 2 is arguably the most detailed and an important part of the literature review looking at the policy and regulatory context. This is a vast and complex area to cover integrating both European and UK policies. The result of which allows the reader to understand the mechanisms that are driving the development of the bioenergy resource on the side of the energy generator and those that provide the biomass resource inputs. The importance of clear policy and procedures is clearly shown through the example of supply chain development in biomass.

Chapter 3 provides an overview of the principal sources of biomass including the two main bioenergy crops, miscanthus and SRC willow. This chapter also reviews two other important sources of biomass, notably the forestry resource and municipal waste. The costs and availability of these resources vary. There are also considerations to be made of the calorific energy content of each type biomass type for the process of combustion for heat and electricity. In summary the chapter looks at the available resource quantities in the UK and current government targets for biomass.

The final chapter of the literature review discusses the conversion technologies available for the generation of electricity and heat only, or combined heat and power (CHP). Diagrams are provided to illustrate clearly to the reader the processes involved and in particular highlight the more advanced technological processes of pyrolysis.
and gasification. This chapter builds on the previous chapter covering the issue of conversion efficiencies of the biomass resource.

The literature review, although thorough in its findings, could have benefited from a greater number of academic sources that are at present not available due in part to the very recent development of bioenergy in the UK. The literature review would also possibly have been improved by discussing in more detail the contribution of bioenergy to the global climate challenge or looking at this resource on a European scale, particularly as the Scandinavian nations seem to have made significant progress with this renewable energy source. This was not possible for the reasons of a lack of time and resources.

8.3 Research and Findings

Chapters 5, 6 and 7 focused on the empirical content and design of the research. Chapter 5 provides an introduction to the methodology for the research. A case study approach is adopted using multiple points of data, relying most importantly on the use of guided discussions as an interviewing technique. The weaknesses of the case study approach to research are recognised and multiple case studies used to minimise their impacts. The research is largely deductive and looks to make a number of inferences regarding farm diversification into bioenergy crop production.

Chapter 6 presents the results in a case-by-case format introducing general farm management matters before outlining the financial and soft decision making factors. Although some discussion of the case study occurs in this chapter through a need to clarify concepts for the reader, the main discussion of results is reserved for the following chapter. Chapter 7 provides an in depth discussion of all three case studies and outlines the implication of the findings. The main conclusions were that:

- In no case had the production of miscanthus become the main source of income for the farm after diversification.
- The decision to produce the crop was based upon two common criteria, including a concern for climate change and the low resource input requirements for the production of miscanthus.
• The role of a grant or a significant financial inflow to support the high costs of establishment is critical to the diversification decision.
• The gross margin of miscanthus production is low and compares poorly to a wide array of alternative arable crops even at lower levels of productivity.
• A number of barriers to diversification exist including an unknown financial cost of exit in land reinstatement.

A potential criticism of the research may be that only farms diversifying into miscanthus production were selected. This was due to the overall low uptake of bioenergy crops in the UK limiting choice and current low uptake of SRC willow due to poor perceptions of the crop, with high disease risks and greater impacts on agricultural land. The results may however be of value in understanding the farmer decision making process of diversifying into bioenergy crops, broadly applicable to any crop.

8.4 Recommendations

The research highlights a number of recommendations for the development of the biomass resource through improved levels of farm diversification. These include a focus on farmer interest in support for climate change initiatives that may open up greater opportunities for consultation and willingness to consider the production of bioenergy crops. Secondly more precise minimum scales of production to be developed relative to closeness of the end producer or processing facility, so as to avoid circumstances whereby small scale productions of bioenergy crop become uneconomically viable and thus disregarded.

A further revision of the figures for costs of establishment of miscanthus used by Defra would also be beneficial to the industry. The costs of establishment are an important factor in the Energy Crops Scheme grant and should be well understood, despite grants now being based on actual costs. A better understanding of the real costs would enable Defra to determine what will be considered reasonable costs of establishment to be reimbursed under the new system. Aspects to be considered under this include notably the cost of topping, cultivations and herbicide. Vermin control
costs may also require consideration in the future for the purposes of inclusion or exclusion in the grant scheme.

From the initial findings of this research it would seem prudent to undertake a careful assessment of the establishment grant mechanism based on 40% of actual costs. There is little evidence for significant variation in the costs of establishment across farms; the scheme would therefore appear to have the sole effect of reducing average levels of grant support. The establishment grant scheme is considered a critical part of the decision to diversify and has been vital to the support of an economically unattractive crop. The impact of this change in policy should therefore be carefully considered and monitored over the coming months.

Finally, higher than current minimum guaranteed prices on miscanthus cane production should be ensured through subsidisation of the crop at higher levels than €45/ha under the current EU Energy Crops Scheme. It is thought that this scheme will be extended from 1.5million hectares across Europe to 2million hectares, however even the full grant subsidy would not render gross margins on miscanthus economically attractive compared to other crops. Increased subsidisation or higher prices are recommended for the support of the development of miscanthus into the longer term. Figures are not suggested in this research as a wider farmer consultation would be required to determine appropriate financial thresholds.

8.5 Future Research

This study has highlighted a number of areas for future research. Due to the lack of current academic or other coverage of the bioenergy and biomass resource there is much scope for further research. This piece of research looked at the process of farmer diversification across three case studies and made inferences about the critical influences to this decision, but does not provide a framework for the process of diversification or make specific quantitative recommendations. It would however clearly be beneficial for future research to look at a wider process of farmer consultation and establish a more in depth understanding of prices and gross margins that miscanthus would need to attain in order for a certain proportion of farmers to consider diversification attractive.
Research into the costs of exit from the production of bioenergy crops would also be beneficial as these costs are largely unknown at present and may, if significant, require attention and assignment of resources in order to reduce their impact on the decision to diversify. The barriers to the production of bioenergy crops must be understood for the resource to develop, overcoming or addressing any such practical challenges.

This research has focused largely on the production of miscanthus and therefore would be well complemented by a similar study on SRC willow production in the UK. It would appear that more research is available on this crop from the Scandinavian nations, therefore facilitating this future research.

8.6 Conclusion

This chapter has provided an overview of the research as a whole, providing an outline of the research covered with respect to the aims and objectives of this dissertation. It has provided an outline of the issues covered in the literature review that provide the background for the subsequent research and findings discussed in the latter chapters. The research is briefly overviewed and the main conclusions presented for the reader as a summary of the case study analysis. The research is also criticised in this chapter, acknowledging areas for improvement or aspects that were limited by the amount of time and resources.

Finally, the chapter has also provided a set of recommendations for the development of the bioenergy crop resource in the agricultural sector, which may be of significance to producer groups and to wider development of government policy. Also highlighted were a number of areas for future research into this resource.
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Other Sources Consulted


Appendix 1: Case Study 1 Selective Interview Transcript

What initiated your first interests in biomass as a crop for your farm?

Demise of the dairy enterprise in November 2005 then had the situation of an area of low quality grassland production potential fairly low and most arable options not very attractive due to topography and rainfall. Beef and sheep options were not very attractive at all particular on their scale of farming profitability too low.

So biomass seemed to fit the bill with the farm with high rainfall and soil type ok and infrequent harvesting avoids harvesting. The problem with alternative arable crops was too frequent harvesting on steep slopes causing erosion.

What were the key factors in your reasoning process for diversifying?

Once decided it was just a matter or SRC or miscanthus. Fairly easy decision to make as SRC was not attractive, harvesting not able to do themselves, probably heavy machinery and disease problems. Even more severe disease problems than thought.

And actual mechanics of handling the product, miscanthus big bales can be handled by conventional farming machinery. Straw baling as normal until heavier going as the crop matures. They will be baling and contractor in for big baling thereafter.

Miscanthus slightly more favourable in harvesting early spring rather than early winter with SRC but avoids issue of harvesting on wetter grounds.

Good time of year for although poultry works on own cycle but not really an issue. Some arable farms may clash though.

Very low on inputs which goes well for the farm running style. Certainly no intention for next few years to add anything to the land. The crop was sprayed in first year for weeds.
Other crops would have been cereals and have been done in the past on the farm but all would have to be contracted and on such a small scale no point and can get a very wet climate and leads to high fungicide bills too.

Unless cows had gone he would not have considered it. TB the sole reason and control of this problem in the UK has not improved so pointless going back in.

**How was the transition into biomass production – infrastructural/administrative?**

Not really a problem. Establishment grant is vital for the economics of it, without this it would not be worth it.

Slow and tedious application process. Long delay in the application and response. For arable farmers this went well past the point of planting winter wheat so had he been in arable would not have waited.

1st June deadline and got application in April 6weeks before and no response until late December. He knows a lot of people who gave up and put into winter wheat as could not afford to wait.

December is far too late anyway as should be spraying off grassland in October! Now suffering as the spray was applied too late in December as could not spray off until got approval. Less effective spray off than could have and was against recommendations on the spray packaging should not spray in frosty conditions. Had to spray as the crop had to be growing.

**What barriers/difficulties did you meet in the process of deciding to diversify?**

- financial
- technical
- social

Crop and planting very straightforward, although a barrier was the process of application. Main barrier was the financial one as it is not particularly attractive – best of worst options. Did costing on the sale price and will not make any money in the next ten years but break even so is a long term decision
But now wheat has gone so high can’t see why anyone would move into it – big risks as from point of cash flow a large outlay in first three years and the income is a long way out in the future. Costing found at this point. First two years no sales at all. Over full ten years getting a profit of 19 pounds per hectare but this is far more than beef and sheep at the moment. At least is a guaranteed minimum price but not very attractive.

“Least worst option”. Not a very good situation to be in. He expects the price to be above the guaranteed minimum and price rises with inflation.

Presumes when the grant was set they picked a figure that would only tempt the odd few. Social issues:

Had to have an inspection from a member of forestry commission to assess environmental impacts and SSI’s in the area and visual impacts but no problems at all.

**Were their ecological considerations to be made regarding the conversion of land uses (conversion of permanent pasture being previously a dairy farm)?**

If it had have been species rich as defined by European directive then would have had to get permission to plough it but as was mainly grazing and just rye and clover mix there was no problem with ploughing it up.

**How does biomass production contribute to the farms operations (is it significant relative to the amount of land used)?**

Not much in way of an earner but is using the land in a productive way and agrees with the idea in principal yet investment appraisal not very good. His hope is that the price will increase quite significantly and if it is the right thing to do (morally for the environment in which we live) then eventually the market will reward that.
Looking at twenty year time frame that will tie in with his working life and that there will be big changes in the energy market in this time and hopes this will go in the right direction and trying to make a stab at predicting this change.

Because of early weighting of cost of establishment and payback period have to take a long term view and cannot afford to plough up in the short term.

Energy producer contract – initial interest to burn onsite for chicken houses in farm so did not get a contract but too costly to set up the boilers so sought a later contract with supplier. This was supported and the contract offered by the company that did the planting which was done by BICAL.

Facilitate the supply of the crop between end user and the crop and harvesting and transport and provide pelleting service if required later on. Most now involved with BICAL are growing rhizomes for sale.

No need to look at the performance the farm as a whole but would it be possible to determine the revenues from the crop/hectare?

Taken from BICAL as standard figures (see investment appraisal).

At what stage of diversification are you currently at (percentage landtake)? Would it be possible or desirable to increase levels of production in the short/long term?

See farm plans in the appendices. Coming up to end of year 1 so first sales will be 2009.
Agronomist has confirmed the crop will be average so the figures are accurate.
Percentage of land take is 40%. Largely because all the suitable land taken if not would have put in more.

Other information
Have been offered a better price if they did plant more but even so as an arable farmer would not grow more but in his situation he would have done it if feasible.

Fairly negative but to his mind it is a great mystery why people are in beef and sheep and dairying for that matter as reasoning is not altogether rational and people tend to then stick at it regardless of whether they are making a loss or not.

15.35 hectares under production. Rhizome mat should hold the machinery in wet weather but some land very wet or steep. SRC discounted initially because of the yield being at 10 not 14 tonnes per hectare as a big negative from the start and then disease so no figures considered. Also miscanthus has uses in paper production and bedding so more potential alternative uses. Has not looked at these alternatives in much detail but will look at after the ten years to see what the market is like.

Beauty of the contract is that BICAL will provide entire service so can sit back and let them do it all. Great if you are approaching retirement.

No option of farming the rhizomes as tied into the grant and would have to harvest them in first three years before they lose vigour so not really an option.

**Annex to Interview**

**With regards to the original plans for use of the miscanthus to heat the chicken sheds the problems/barriers were quite clear and simple.**

1. The cost of the boilers was too high and there was no grant support available. It turned out after three and a half months that although the Carbon savings Trust initially said it was possible after a lot of mixed messages and dishonesty it turned out under EU regulation the farm would not qualify under doubling up off grant support schemes.

2. The operation of fitting up the heating tubes overhead in the sheds was not feasible from the point of view physical layout.

**How were the baling charges calculated in the investment appraisal?**
The charges for baling increase incrementally whilst there is a fixed element for the cost of mowing. The build up of the crop and therefore these costs depends very much on the success of the growth in the establishment period. For the moment much of the calculation is guess work as there is little industry information available.

**How was the 8% discounting rate selected for the investment appraisal?**

The discounting rate was founded on the base rate plus a couple of points. It was based on a personal judgement.

**How important is the EU subsidy scheme, was it an important factor to your decision of diversification?**

It was not a factor to be considered. The figure is purely theoretical and is substantially scaled back. EU wide uptake affects the level of subsidy and due to wider uptake of energy crops across the EU this payment may be significantly less. It is based on total European and includes all energy crops including biofuel.

**Have you established an end contract with an energy generator?**

Yes. A contract has been set up with Aberthaw Power Station in south Wales which is less than thirty miles away as the crow flies.

**What contribution does miscanthus make to farm incomes?**

At peak production miscanthus will contribute approximately 8% of farm income, with the remaining 92% coming from the chicken units.
**Appendix 2: Case Study 2 Selective Interview Transcript**

What initiated your first interests in biomass as a crop for your farm?

First interests initiated by the fact that it was a biofuel and the fact that barley prices had gone down meant they had wanted an alternative. They also wanted to do something green and wanted to maintain some arable crops on the farm.

In April 2004 the miscanthus was started on the farm through a contract with BICAL. At the time barley prices were low and this was the crop previously grown on the land so looked for an alternative.

**What were the key factors in your reasoning process for diversifying?**

The crop was appealing as it is relatively low maintenance and low hassle and requires very low inputs. No application of fertiliser, the leaves seem to drop off in the winter and mulch in. Due to the high initial costs to setting up they had to go for rhizome multiplication to make it worth it and get payback. So the key factor in the decision was the ability to get the rhizome multiplication contract and get the money back.

But now wheat and barley have become viable as crops – relate to the final question later.

They now own the rhizomes and when asked about the nature of the contract they are on it seems BICAL have agreed to a seven year contract for the harvesting of the cane.

With regards to my interest in how they managed to get the option of rhizome multiplication it would seem that today prices of rhizomes have decreased to 2/3 of the price back when they were harvesting – so decrease in demand.

**How was the transition into biomass production – infrastructural/administrative?**
The transition into miscanthus production was smooth with the land being previously arable and used for barley production. BICAL came in and supplied the rhizomes for planting. After the agronomy was informed by BICAL regarding spraying requirements and the need to top the crop in the first year.

Prior to miscanthus production the land was used for barley production which was run by the farmer with contractors in for the machinery needs. The crop was taken to a neighbouring farm with drying facilities where the farmer bought the commodity. This facilitated transport in a hard to access area and removed need to invest in own capital equipment.

Administration was relatively simple and so no barriers as such met in this area of operation. There was however no grant application.

Minor social barrier as a member of the public has voiced his opinion against the brown jungle along the fields by a road – visual eye sore.

**How does biomass production contribute to the farms operations (is it significant relative to the amount of land used)?**

It was possible to plant miscanthus for rhizome multiplication and as there was no financial sense in doing miscanthus without this possibility they took up the production on the minimum level contract of 10 acres (4 hectares).

The contribution of miscanthus to other farm operations – can run 35 acres of arable. Grass let out for sheep grazing with total farm acreage at 185 acres or 75 hectares. Currently set aside on the farm at too higher level as half a field of miscanthus has been left with cropping on one half only.

They were offered a guaranteed minimum price for the rhizomes but now may sell to somebody else if they so wish. £40/tonne for cane production.
No need to look at the performance the farm as a whole but would it be possible to determine the revenues from the crop/hectare?

The costs of the rhizomes initially came to £2700/hectare with an additional cost of a potato planting contractor at a total cost of £540 to put in the rhizomes.

The growth seems to have been a bit hit and miss with some areas of growth a little sparse and patchy. In 2005 the crop was topped by the farmer and sprayed by a contractor with herbicide to knock back the weeds before the miscanthus shooted again. In late 2005 the canopy was high with a good growth.

In 2006 BICAL were supposed to come and harvest the crop although they did not turn up and the crop was left until early 2007. The reason for BICAL not arriving was purely down to lack of time although perhaps the size of the plantation was too small to be of significant economic importance.

In 2007 the 4 hectares were cut in approximately 50 minutes by a large specialised machine and then baled in large square bales all within 1 hour. A machine had to be hired to get the bales on to the transport by the farmer (minimal but still a cost).

Baling costs 2007 – £148.05
BICAL paid 2007 – £620.40 (ex farm) (15.51 times 40)
Profit - £118/hectare in 2007 (check this figure)

In fact they had to pay for the harvesting and baling cost and received an ex farm figure of £40/tonne. The yield in 2007 was 15.51 tonnes in total.

The rhizome multiplication went to plan through BICAL and they were paid for the rhizomes. This amounted to £15,643.55 for the rhizomes.

So considering the cost outlay of £11,600 in the set up phase (add up costs of rhizomes, planting and spraying at £560) the farmer made a profit of approximately £1000/hectare for the three years. They did not receive a planting grant under the UK
scheme back in 2004 although are receiving payments under the EU single farm payments scheme for the land and the biomass fields at 45 Euros/acre so £88/hectare. A modulation fee is taken away from this by the UK at 12% amounting to £17.50 and a further 4% goes to the EU. This is apparently not the case in France but goes on in the UK and is a cause for disgruntlement for the farmer.

What are the expected and actual yields from the crop on the farm? To what extent did soil fertility and farm location affect your earlier decision on viability to produce miscanthus?

In terms of the expected they were told to expect a higher figure however they were fully aware that this was the case and are satisfied with the actual despite a higher estimate. 2007 yield – 3.88 tonnes/hectare.

At what stage of diversification are you currently at (percentage land take)? Would it be possible or desirable to increase levels of production in the short/long term?

In light of the proposition of increasing production of miscanthus on the farm the response was negative as it would make more economic sense to go into barley and wheat again with the rise in prices. Miscanthus is fine if you can get the money back with the rhizomes.

Coming back to this at the point of planting BICAL were keen to put 25-30 acres worth of miscanthus in but the farmer wanted to wait and see how things went. The concept of avoiding a monoculture for them was important in case of change in agricultural prices (markets can be volatile).
Appendix 3: Case Study 3 Selective Interview Transcript

Referring to the information given on the data sheets.
Three major crops grown at the moment winter wheat, winter oats and oil seed rape, although other crops have been grown during this period include spring beans and spring barley. Not really relevant to the ongoing cropping on the farm but does explain why during one winter there was no oil seed rape.

Figures extracted from Exeter University anonymously. Slightly different as tax not shown. It is however very useful as it allows the farm to be compared to the top 25% farms in the south west region on performance, very useful tool for the farmer. This is broken down in farm sizes and farm types and gets similar farms. Outputs do not include area payments and subsidies as these continually change. Although you have yield and price this does not necessarily add up to gross output – basically how much you sell. Not included are the fixed costs of insurance, machinery, and equipment.

The prices for winter wheat and oats do however include the revenue from straw. Quite a valuable commodity at £20-30/acre in the area. Used for a neighbours racing stables. Oat straw used there and wheat straw to cattle farmers. Not used for biomass as is a bulky commodity and difficult to access. Although artics can access the farm.

What initiated your interests in biomass as a crop?

Initial interests stimulated from the press and then looked into at BICAL event seeing the multiplication of rhizomes for selling on. Eastern Europeans doing this manually.

Interested to see it but put off by the idea of it being a longer term decision at a 5-10 year plan and wanted to make things easier rather than more complicated. Did not think the certainty of it going ahead at that time was that clear so it was a bit of a risk as subsidy arrangements have been changed in the past. An example of this was Linseed whereby subsidies were available and then withdrawn by government. It was therefore a concern.
What were the key factors in your reasoning process for not diversifying?

The figures were also not that attractive taking into consideration the risks and concerns mentioned. Also looking at the figures you will see that this is a good arable farm capable of producing or getting on for 4tonne/acre of wheat and it is unlikely you will see a farm of this productivity going into bioenergy crops.

More useful on less productive land. Problem when talking about the product itself rather than the rhizomes is the issue of it being a bulky crop to then transport from the farm. So these are the main reasons for not diversifying.

Would you consider the land on your farm to be suitable for the production of bioenergy crops?

It is not a suitable farm for growing energy crops, although he could grow them. Looking at £60-70 per tonne for wheat in 2005, to more than double that now so if he had committed at the time he would have been rather sorry.

He is not sure that permanent pasture is a problem. It is put into an annual grazing sale for the summer and paid a reasonable amount for it. He could plough them up, particularly with zero set a side rates but he likes to see them there and is a good access for machinery to the other fields.

Would ecological considerations regarding the conversion of land uses be of importance to any decision making (conversion of permanent pasture)?

Yes particularly when considering getting rid of it at the end and putting land back to other use. Concern for ruining draining systems particularly for SRC, perhaps less of a concern for miscanthus.
No need to look at the performance of the farm as a whole but would it be possible to determine the revenues from crops/hectare in order to act as a comparison to a hypothetical situation of bioenergy crop production?

No figures for the bioenergy crop but could access at BICAL. Cannot however grow wheat after wheat in the area principally due to take-all, so have to have a break crop. In the past has been spring barley, peas but the best has been oil seed rape (as more reliable and potentially more profitable) and oats is a break with the advantage of being a straw crop which he can sell.

If set aside varies does not impact too much as there is a bank which is north facing and steep, only able to put linseed to claim area payments. Would not be suitable for biomass anyhow. Usually just uses areas of fields to meet requirements.

It would have to have been substantially better to attract him into bioenergy crop production because at this point in life (nearing retirement) he is looking to make things easier not more complicated through such a change.

Other information.

Current procedure on the farm is contracting out. In the second year of this now but does not affect the figures. Paid a fixed sum for that and then a percentage of the profits given over for the work.

Can understand if small arable areas exist on a cattle farm then they would arrange a contract with BICAL rather than work with a contractor who is unlikely to be interested in small scale contracts and are unlikely to do in a timely fashion. There are often farms in this situation with a small amount of arable land to be used in some way. It is a niche thing.

By in large farmers will go into anything very quickly if the price is right, and the government has control of this with subsidy. It is pity to be chasing subsidies but that is the way it is set up, although most farmers would probably rather have a decent market for the crop.
Would never consider it in the future and has written off re-consideration as changes so unlikely to happen and arable crops going up in price. Of course could grow wheat and rape for biofuel anyhow. So could grow either way even if changed direction to biofuels.

In the data, be careful of one off low yields that affect averages significantly. Oil seed rape hit badly by weather one year.

2006 was a very good year. 4tonne/acre average which is very good for a farm. Yield then went down and the price went down so has an impact on the bottom line.

2007, not yet any figures, as not all sold so not sure. Prices not as high as spoken about as some of it sold forward. Pooling of wheat practiced to get a better than average price, but if had held onto could possibly have improved on the £120 to around £170/tonne. This was part of the reason as much of the wheat had been sold at this point so an issue of supply and demand. Very much a global issue too, Australian droughts etc.
Appendix 4: Selective Interview Transcript with Paul Carver at BICAL

The following discussion relates to information on the topic of rhizome multiplication contracts and the cost of rhizomes. Paul Carver is the head of Research and Development at BICAL ltd, Europe’s largest grower group of miscanthus.

In a case study conducted in my dissertation research it appears that in 2003/2004 the price of rhizomes was considerably higher than they are currently in 2007/2008. Have miscanthus rhizomes been subject to significant price change over the past five years or are there other possible factors to consider?

There has in fact been no particular increase in the price of rhizomes. It is all to do with the planting density and any variation is most likely due to this factor. Although prices have gone up, these have not been substantial enough to create a particular trend.

Are rhizomes sourced in the UK and contracts for rhizome multiplication still offered?

Yes we are still sourcing in the UK although these contracts are carefully managed and assigned and tend to be awarded to areas in the production of potatoes (higher yields). There is a higher value return from rhizome multiplication contracts but it also requires higher value land (potato farming areas). Under the rhizome multiplication contracts a farm is not eligible for the Energy Crops Scheme, this would be a contravention of the terms. In the past anyone was used for the contracts, but they are now based more on cropping and land suitability.
Appendix 5: Selective Interview Transcript with Patricia Thornley at the Tyndall Centre for Climate Change Research

Willow SRC seems to be perceived by farmers (or at least in the three case studies in my dissertation) as a crop that is less attractive in terms of financial returns, yield and susceptibility to disease, compared to miscanthus as the alternative biomass crop. If this is the case, are there conditions under which SRC is appropriate as an agricultural crop?

As the case study was conducted in the southwest the primary reason for the focus being on miscanthus is the new power plant at Eccles Hall, which is entirely, miscanthus fuelled. Its grant funding is based on the use of miscanthus so there has been a large amount of miscanthus promotion. This is similar to the failed plant Arbre in which grant funding was based upon SRC willow and a large uptake of the crop was seen in Yorkshire. The plant subsequently failed but the bioenergy crop grown is now primarily used at Drax.

The current status of bioenergy in the UK stands as follows (SRC is certainly not an ungrown or inappropriate crop in the UK):

Mid 1990s - 1500ha planted for the Arbre project.
Currently - 1180ha SRC willow (including 5ha SRC poplar).

3358ha miscanthus (mainly for co-firing or small to medium scale dedicated plant – figures not yet published)

It is thought that the main driver for this increase in the last couple of years has been largely due to the development of the Eccles Hall Power Plant. So miscanthus largely all was planted in one year. Originally however miscanthus was not eligible for the establishment grant or qualification for ROCs. This is clearly not the case today. The allowance of miscanthus under the ROC has seen significant demand put on this crop by energy generators. It is highly likely that the 2000ha or more planted in 2006 is found mainly in the South West.
With regards to the financial returns from SRC willow it would appear the main barrier is the 3-year growing cycle, seen as a major obstacle by farmers. In most cases the farms that have diversified into willow SRC are not depending on the crop for their income, it is a marginal activity that allows land to be used, operations to be contracted out and requires very low inputs. The yield from willow SRC is lower than that of miscanthus, but miscanthus is a harder crop to deal with in terms of processing. It is far harder to sell miscanthus to the local market due to a more complicated processing of the crop. This however is of concern depending on the market as large energy generators have the facilities in place to process.

The issue of disease in the UK is not a concern commonly expressed by the farming community and there have been few problems with disease in the UK such as willow rust. Not a dominant trend/problem.

The gross margin for miscanthus (averaged at £180/ha in the dissertation research) appears to be much lower than a wide array of other arable crops. Are there any specific reasons for the low market value of this crop? Could you possibly suggest any means of rendering this crop a more attractive proposition to farmers? I have considered subsidisation but would this be effective on a UK scale?

The figure of £180/ha is consistent with what has been reported in research on this crop. The issue is that today the price of wheat is particularly high and that 5 years ago crops such as wheat would have been earning a similar gross margin/ha as miscanthus offers. The prices of OSR have also increased significantly under the Biofuels Directive.

The reason for the low market value of bioenergy crops is based on what people are able to pay. So as oil prices rise ($100/barrel) so the price of bioenergy crops will be able to increase. Roughly speaking the energy value of woodchip £/GJ is not far off the value of oil for domestic heating in £/GJ. It is possible that in the long term woodchip will become more economically attractive and eventually price rises seen. It is important not to view it as the value of the crop, but in terms of a unit of heat.
The key problem is the irregularity of the income and the significant cost outlay for establishment of £800-900/ha (with the establishment grant). This a large barrier as you do not know the future of the crop and at present the prices of wheat are very high and may be a better source of economic return. If the grant for establishment equalled the cost it would be a much more attractive option and require less consideration. At present however it does not, so it relies upon the confidence of the farmer to go ahead with the bioenergy crop.

There is discussion (review) going ahead on the RO as the main driver in electricity production. It is being suggested that the ROC be subject to a system of banding under which the previous 1MW of renewable energy = 1 ROC be changed. It is proposed that 1MW of renewable energy (from bioenergy crops) = 2 ROCs. This would favour bioenergy crops and reduce the amount of burning of demolition (waste) wood etc.

There is of course still the EU Energy Crops Scheme subsidy at €45/ha based on the 2million ha maximum grant area. The figure of £375/ha put forward in a 1998 report is not necessarily representative as it depends on the farmer’s motivation. Often the farmer is growing the crop for other reasons.

**Considering the relatively low uptake of biomass production to date in the UK, other than the new establishment costs scheme (ERDP) are there likely to be any changes in policy?**

The recent policy developments have essentially been covered in the previous section looking at the banding of renewables under the RO. It is however also important to consider the RTFO biofuels obligation that the UK must meet by 2010 (binding targets set by the EU). This places an emphasis on the provision of biodiesel, mainly through the production of oil seed rape. This will provide a new source of land competition, as the value of this crop is likely to increase in the coming years.
Finally the development of markets for heat seem to be slow despite the clear links between the use of bioenergy and heat generation, is this likely to have been due to RDAs not pushing the development of biomass centres, lack of a heat ROC or any other reason I have not considered?

The issue is more generally a lack of support than an ROC. The ROC is just one method and there are other ways. The production of heat takes up a lot of space and the economic viability of heat generation from biomass is not attractive. On the domestic scale the cost of a domestic wood fuel burner installation is £4000 and the Carbon Trust are offering approximately £400 in support. The issue again is the upfront costs of establishment.

There are three main issues with heat on the domestic scale:
1. The requirement of space
2. Flexibility of the system
3. Reliability of supply (of wood chip in the long term unknown)

With regards to larger scale production there is a fundamental challenge of load factors. The domestic market has an average load factor of 50%, that is heat energy is only required during the winter months. Therefore industrial uses for heat must be present for such heat system to be a viable consideration. Therefore a heat ROC would not help the upfront costs of any system but would help the long-term reliability of supply.

The role of the RDA is not really relevant to this policy. There is a lack of sensible information here as the role of the RDA is to provide a biomass coordinator to help those wishing to set up small-scale use of bioenergy. It is the Carbon Trust and the larger organisations whose role should be considered in the development of bioenergy in the UK.
Appendix 6: Selective Interview Transcript with Ruth Digby at NFU Biofuels

To what extent and in what ways is the RTFO likely to impact upon the production of biomass in the UK? Is this perceived as a potential problem for UK agriculture in terms of land competition?

The RTFO comes into action on the 15th April 2008 and will set binding targets for UK production. The target has been set at 5% (a staged system of a rising target). It is important to note that these targets refer to the production of fuel and are not based on energy production.

It is unlikely this will have any impact upon the production of biomass for bioenergy. The UK currently has more than enough resources to satisfy the obligations of the RTFO. In reality most of the fuel will be imported from mainland Europe, as the infrastructure for production does not currently exist in the UK. We are also currently a net exporter of wheat, exporting some 2.8million tonnes between 2003-2005. This wheat could serve to almost meet our targets in bioethanol production.

It is however clear that in comparison to biomass production, biofuels do not require a lengthy 3 year establishment and there is greater flexibility in production, and so may appear more attractive. The production of wheat may be seen as more flexible as there are two markets for the commodity, either feed or biofuel and the farmer may choose which market he supplies.

Biomass is however suited to more marginal land. It is a different business decision. The most significant impact of biofuel (or biodiesel) production has been an additional end use to wheat and oil seed rape crops that are produced in the UK.
Appendix 7: Agricultural Markets taken from Farmers Weekly