NNFCC

The Bioeconomy Consultants

Report Title: Domestic Energy Crops; Potential and Constraints Review

Project Number: 12-021

April 2012

A report for DECC

URN: 12D/081

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Disclaimer

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1 Executive Summary

This study considers domestically produced non-food crops grown specifically for energy generation. These include both established perennial crops such as *Miscanthus* and short rotation coppice (SRC) willow, and novel species like switchgrass and reed canary grass. The study does not cover annually cultivated crops also used for food or feed which may be used in other technologies, for example maize used in anaerobic digestion or grains and oilseeds for use in transport fuels.

The benefits of these energy crops include not only their use for biomass heat and electricity but also their ability to store carbon, benefit industrial landscapes, prevent erosion, improve biodiversity in the right location and ensure fuel security. However, the planted area of energy crops remains small in the UK and, although there is no single reliable source of data, the most accurate information we have (1) suggests 10,114 hectares (ha) have been supported by the Energy Crops Scheme, see figure 1, and we understand 1,500 ha of SRC was planted pre-Energy Crops Scheme in around 1996.

We are aware that some of these crops have been removed at the end of the live grant agreement, due to economic or productivity issues. We estimate, based on discussions with industry and Natural England that less than 10,000 ha may remain in production. The potential for scale up is currently restricted by our planting and harvesting capacity, grower acceptance, economics and technology compatibility. There is also social resistance around energy crops that needs to be approached sensitively, especially where perennial energy crops are proposed and long-term land use change is likely.

The theoretical maximum area of land available in England and Wales for growing *Miscanthus* and SRC, not impinging on food production, has been modelled to be between 0.93 and 3.63 M ha. If we assume planting would not take place below a gross margin of £526/ha for *Miscanthus* (at £60/odt) then research suggests the maximum area of land available will be 0.72-2.80 M ha. Alternatively, if we assume a gross margin of £241/ha for SRC (at £60/odt) this figure decreases to 0.62-2.43 M ha.

But *Miscanthus* and SRC remain novel crops and there is an associated risk with growing them; despite these prices being available to some growers in the current market we have not seen anything like this level of uptake. Without education, training and improved contract security uptake could be as low as 0.007-0.05 M ha in England and Wales. These ranges must be interpreted with care as the underlying assumptions have a large degree of potential error but offer an estimate based on our best knowledge and understanding.

If we were to carry on with business as usual, perennial energy crops would remain marginal. If we increase the area of plantings by 20% every year, by 2020 we would have around 0.04 M ha in the ground. This falls around the middle of our lowest range of potential and hence it remains feasible to exceed this, but only if planting rates were to increase at a dramatic rate. This clearly shows we have much to do to come close to the potential offered by energy crops and also does not take into account the delay in achieving harvestable biomass or other capacity constraints.

Domestic supplies of perennial energy crops often offer superior greenhouse gas (GHG) balances and more needs to be done to encourage the development of a domestic energy crop market. This could include: full effective promotion of the existing ring fenced Energy Crops Scheme, its extension and communication to agriculture and biomass sectors beyond 2013, and robust support for the production of sustainable biomass on non-prime arable land that is inefficient for food production. Addressing all the barriers to deployment will require further action both from Government and Industry.

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2 Introduction

2.1 Background

The Renewable Energy Directive has set ambitious targets for renewable energy generation by 2020. Biomass has been identified as a major contributor to the delivery of the 2020 targets for electricity and particularly for heat and transport fuels.

Provided local markets exist, biomass energy crops such as *Miscanthus* and short rotation coppice (SRC) willow offer growers the chance to diversify into non-food crops, generate renewable energy, reduce greenhouse gas (GHG) emissions, enhance biological diversity and stimulate the rural economy.

However, a workable bioenergy sector is dependent upon a secure supply of biomass feedstocks from a range of sources. Lack of feedstock is said by developers to be the main barrier to deployment, as without guaranteed long-term feedstock supply finance will not be made available.

Indigenous feedstocks like energy crops and 'waste' biomass are currently underutilised but offer significant potential that could help mitigate the pressures on the supply of biomass, offering opportunities for diversifying domestic supplies that could benefit both the electricity and heat market.

2.2 Project aim and scope

The aim of this paper is to review the evidence relating to the potential deployment opportunities of domestic energy crops. It will primarily cover an estimation of potential production from energy crops in the England and Wales, but will also appraise the associated environmental considerations and other possible constraints to take up.

NB: This study considers domestically produced non-food crops grown specifically for energy generation. These include both established perennial crops such as *Miscanthus* and SRC willow, and novel species such as switchgrass and reed canary grass. The study does not cover annually cultivated crops also used for food or feed which may be used in other technologies, for example maize used in anaerobic digestion or grains and oilseeds for use in transport fuels.

3 The Energy Crops Industry

3.1 History

Dedicated energy crops have been grown commercially in the UK since spring 1996 when the first biomass power station was planned, known as ARBRE (a 40MWe project which was developed with the intention of using 100% energy crops and which signed contracts with a number of farmers). The first grant programme to support energy crop establishment (ECS1 [1]) was launched in 2000, offering a fixed rate payment per hectare for *Miscanthus* and SRC plantings in England [2]. Uptake was initially very slow, however, as there was almost no bioenergy market at the time and the grants were deemed to be too low to encourage uptake. Unfortunately the ARBRE project was unsuccessful and was decommissioned not long after it initially began operation. This left a number of growers with crops for which they had no end market.

In 2008 the second phase of the Energy Crops Scheme (ECS2) was launched, delayed from 2006, this time with slightly higher grant rates (initially 40%, then increased to 50% of actual establishment costs). This, combined with increased demand from the bioenergy sectors and early promotion of the scheme by Natural England, led to a gradual increase in energy crops production in the UK. In particular, 'hubs' of activity occurred in the vicinity of two key energy crop users of Drax in Yorkshire and Eccleshall in Staffordshire. In addition to the ECS available in England, some support was also available through the 'Energy Aid Payment Scheme', which paid a flat rate of €45/ha for all crops grown on non-set aside land intended for fuel or energy use. This programme was run directly by the EU and opened in 2004, but due to budgetary constraints payments ended and the scheme closed in 2009.

Development of the industry was severely stunted during the years 2006-2008, as for a period of 17 months there was no support scheme for the crops between the closure of ECS1 and the beginning of ECS2. This shattered confidence in the energy crops market and purportedly contributed to the demise of some key players in the industry. However, the market did begin to recover, and the period 2008-2010 showed a gradual increase in energy crop production in the UK coupled with an increased demand for the crops from bioenergy generators. Unfortunately deployment in recent years has slowed significantly, due to poor economics and other barriers which are preventing establishment of the crops (see section 4). New plantings are now mainly restricted to farmers wanting to produce fuel for their own usage, and very little additional material is being fed into biomass supply chains.

3.2 Current status

Energy crops plantings remain small in the UK and, although there is no single reliable source of data, the most accurate information we have (1) suggests that around 10,000 ha were planted as a consequence of ECS1 and ECS2. A further 1,500 ha was also established pre-ECS1 intended for the ARBRE plant in Yorkshire. However, the consensus within industry is that a proportion of this area will have been removed

[1] Energy Crops Scheme 1, England Rural Development Programme (2000 – 2006)
[2] There have been no grant schemes for energy crops in Wales, hence current production in Wales is negligible.

either due to productivity or economic issues, and hence further research and collection of primary data is needed to establish exactly how much of land is still cultivating energy crops.

Figure 1: Summary of area under live Energy Crop Scheme agreements (1)

	Total area planted under ECS1 (2000-2006)		Total area planted under ECS2 (2006-2012)	
Region	*Miscanthus* (ha)	SRC (ha)	*Miscanthus* (ha)	SRC (ha)
East Midlands	1890	609	333	264
East of England	381	76	93	40
North East	0	228	0	0
North West	63	125	0	0
South East	305	257	95	18
South West	1036	31	387	11
West Midlands	859	27	374	0
Yorkshire and Humber	1843	464	216	89
Subtotal	**6377**	**1817**	**1498**	**422**
TOTAL		**10,114**		

Similarly data collated by Ofgem, as part of sustainability requirements in the Renewables Obligation, shows that only approximately 45,000 tonnes of energy crops were used in biomass power stations [3] between 2010 and 2011 (see Figure 2).

Figure 2: Domestic energy crop usage under the Renewables Obligation, 2010-11 (2)

Biomass Type	Biomass Form	Mass (tonnes)	Country of Origin
Short Rotation Coppice willow	Willow granules	1,848.06	England
Short Rotation Coppice	Wood chips	2,133.32	UK
	SRC willow SUBTOTAL	***3,981.38***	
Miscanthus and Cereal	Pellets	4,478.48	UK
Miscanthus	Pellets	2828.08	UK
Wood and *Miscanthus*	Dust	7,387.52	UK
Miscanthus	'*Miscanthus* grown as an energy crop'	25,343	UK
Miscanthus with biomass binders: 90% *Miscanthus*, 10% cereal residues	Pellets	542.62	UK
	Miscanthus SUBTOTAL	***40,579.70***	
	TOTAL	**44,561.08**	

[3] In England and Wales

However, a number of companies[4] are operating in the energy crops industry, which have made a clear commitment to energy crops and a significant financial investment in planting, harvesting, processing and transport equipment.

3.3 Future Opportunities

The potential for scale up is currently restricted by our planting and harvesting capacity, grower acceptance and technology compatibility. There is also social resistance around energy crops that needs to be approached sensitively, especially where perennial energy crops are proposed and long-term land use change is likely.

The Biomass Strategy (3) suggested 350,000 ha of perennial energy crops could potentially be planted by 2020, however because energy crop plantings have been slower than expected and there are more pressures on land availability than ever before it is likely we will fall some way short of this figure.

However, a realistic target for the potential uptake of energy crops remains elusive and there is a clear need to identify what this is likely to be in deciding subsidy support and future resource planning. It is especially clear that long-term planning is needed to create a secure and sustainable platform for growth and remove uncertainty.

Perennial energy crops grown as a domestic feedstock also provide wider benefits, creating and sustaining jobs and value to the rural economy, for example. NNFCC recently compiled data and evidence on jobs in the bioenergy sector on behalf of DECC. The Biosynergy Integrated Project (4), led by ECN in the Netherlands concluded the labour required in order to produce 1 oven dry tonne of Miscanthus is 0.000852 FTE and of SRC is 0.000945 FTE. This is employment that would not be offered by other non-biomass low carbon technologies.

If we increase the amount of plantings we have by 20% every year, by 2020 we would have around 0.04 M ha in the ground, supporting around 250 jobs in feedstock supply. This is a conservative estimate and hence it remains feasible to exceed this, but only if planting rates were to increase at a dramatic rate. This clearly shows we have much to do to come close to the potential offered by energy crops and also does not take into account the delay in achieving harvestable biomass or other capacity constraints.

4 Review

In order to assess the potential and constraints of growing perennial crops for energy production in the UK we must undertake a full literature review of the social,

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[4] Including (but not limited to): *Miscanthus* Growers Ltd, Regro, International Energy Crops, Crops4Energy, Coppice Resources, Strawsons Energy, etc.

environmental and economic barriers and opportunities. This should include data collated from scientific analysis in previous studies on energy crops, including impacts on:

a) Social and environmental:
    i. Food production
    ii. Biodiversity
    iii. Water use
    iv. GHG emissions
    v. Educational
b) Economic
c) Legislative
d) Technical

Scenarios of likely or potential uptake can then be developed on this basis.

4.1 Review of social and environmental barriers and opportunities

4.1.1 Food production

- The impact of bioenergy on food production is less direct than the impact of biofuels on food production because bioenergy typically does not use food crops. Instead it uses non-edible crops like *Miscanthus* and SRC willow. In addition, by using idle and marginal lands in the UK for energy crop production we can mitigate the conflict with areas of food production and make better use of otherwise unproductive land.
- However, planting energy crops may result in land use change. As biomass becomes more competitive with fossil fuels more land may be planted with energy crops, conversely the amount of land available for food would decrease. This has raised concerns that food prices will rise as a result.
- Some studies have attributed the increasing price of food to the growth in bioenergy and in particular biofuels (5; 6; 7; 8). Other studies (9; 10) downplay the role of bioenergy and biofuels in inflating food prices, instead attributing higher than expected food costs to a combination of poor food crop yields, market speculation, increasing demand from China for livestock feed, increasing cost of agricultural inputs and the decline in the value of the dollar, in addition to bioenergy and biofuel growth.
- There also remains a large area of available land for bioenergy that does not compromise food security; an outlook published in 2009 (11) suggests that current cropland could be more than doubled by adding 1.6 billion hectares – mostly from Latin America and Africa – without impinging on land needed for forests, protected areas or urbanisation. However, much of this available land is far from agricultural infrastructure and significant investment would be needed to realistically make this land available for growing energy crops. In

addition, the study doesn't account for rural communities' use of land, e.g. for unstructured cattle grazing, firewood collection etc.

4.1.2 Biodiversity

- In general, *Miscanthus* and SRC support a wider abundance and diversity of wildlife (both flora and fauna) when compared to conventional arable agriculture but this may decrease if energy crops are used to replace grasslands or woodlands, which is not recommended and often restricted.
- There remains a lack of evidence on the biodiversity impacts of planting energy crops on idle land; most of the work completed to date has made the comparison with arable production and in many cases annual crops.
- *Miscanthus* provides a habitat which encourages a greater number and diversity of species than winter sown cereal crops, particularly earthworms and spiders. Defra also report that one study (12) showed that the *Miscanthus* crop had five times more mammal species and four times more bird species than a control crop of wheat.
- Research by the Game & Wildlife Conservation Trust (13) found that in both summer and winter there tended to be slightly more bird species in *Miscanthus* fields compared with the arable control fields. But according to the Organisation for Economic Cooperation and Development (14) the structure of *Miscanthus* is unlikely to provide a suitable nesting habitat for open-field, ground-nesting birds, because crop growth in Spring may be so rapid that the vegetation becomes impenetrable for the chicks to fledge.
- In addition, varieties of *Miscanthus* currently being promoted for bioenergy are non-seeding, so the crop will not provide any seed food resource itself. Therefore the value of *Miscanthus* as a foraging area for seed-eating species in winter is likely to be low.
- SRC willow, for example, provides a more stable, less intensive environment in which species of plants, invertebrates and small mammals which are uncommon in cultivated arable land can persist (15; 16; 17). In particular wasps, bees and ants are common in SRC and provide essential ecosystem processes, such as plant pollination or pest control.
- As edge habitats support higher densities of birds than the interior it is important to retain headlands, rides and open areas within the plantations to increase the overall conservation value. Commercial SRC plots also provide shelter and warmth favourable to butterfly species, it is therefore important to retain suitable headlands to support these species (15).
- Incorporating improved plantation design (e.g. including a ride) and management can enhance biodiversity. However, when planted under Defra's energy crop grant scheme, *Miscanthus* and SRC willow are currently largely excluded from Environmental Stewardship (ES). Within the area for which establishment grant is applied, up to 10% can be left as open ground where this is used for management or environmental purposes. The wildlife value of this crop could be increased by the inclusion of rides and headlands

to increase the number and species of flora and fauna and there is scope for well-researched plantation design and management protocols to be included in ES to improve the crop's value to wildlife.

4.1.3 Water use

- During summer in the UK, water use from mature SRC willow exceeds that of all other vegetation and on an annual basis is second only to coniferous forest (18). This is due to high transpiration rates and interception losses, as a result of large leaf areas (19; 20; 21).
- *Miscanthus* yields are known to be affected by soil water content and as this drops so too will the productivity of the energy crop (22; 23; 24).
- C3 photosynthesising crops (e.g. poplar and willow) use water less efficiently than C4 species (e.g. *Miscanthus* and switchgrass). For example, Hall (25) found annual water use in *Miscanthus* was 40-100 mm less, on a per unit area basis, than that of SRC.
- There is a perception amongst farmers that the deep, coarse roots typical of these species can affect drainage ditches and be difficult and expensive to remove from the field (26) although this is not supported by scientific evidence and due to the fast growing nature and frequency of harvest of the crops much of the plants energy is used to maximise above ground biomass thus not allowing deep or thick roots to become established
- SRC willow is a riparian species, meaning it thrives in areas prone to flooding. Planting energy crops on areas prone to flooding has been identified as one solution to mitigating the long-term impact of high water use in SRC energy crops and the conflict with food producing land but there is still a lack of evidence to determine the wider impacts on water tables and catchments. This also makes mechanical harvesting more problematic during winter.

4.1.4 GHG emissions

- While it is true that in general energy crops reduce GHG emissions, studies show that the species grown, its energy conversion route and the land use it displaces, play important roles in determining the speed at which GHG savings are seen (relative to fossil fuels).
- St. Clair *et al.* (27)found that *Miscanthus* and SRC grown for power and electricity abated more GHG emissions than either grasslands or traditional crop systems, as a consequence of decreased fossil fuel inputs and increased carbon sequestration. However, the converse was true when these crops were used to replace broadleaf woodland. Again, there remains a lack of evidence on the impacts of growing perennial bioenergy crops on idle or otherwise uncropped land.
- Limitations: Studies are often based on modelling which has a large degree of potential error. GHG emissions are also dependent on the efficiency of

conversion to energy; converting biomass to electricity without heat recovery will decrease the GHG mitigation potential of the crop.

4.1.5 Review of educational barriers and opportunities

- Awareness of the Energy Crop Scheme subsidy for crop establishment is very poor; there is little or no promotion of the scheme.
- *Miscanthus* and in particular SRC willow are a change to the normal range of crops planted by farmers; they involve a break from traditional agronomy practices, supply chains and harvesting routines. This can be a daunting prospect for many farmers and training and education is still needed to move development from energy entrepreneurs to more typical arable farmers/landowners.
- Most farmers have a poor understanding of correct establishment and management practises for perennial energy crops.
- Forestry Commission (and other bodies) have supported and promoted uptake of woodfuel, but there is no similar push for energy crops. Need clear government support and a 'champion' to promote energy crops. Need an effective group to lobby for energy crops and an opportunity to share views.
- Needs to be more promotion of the environmental and biodiversity benefits of energy crops in order to raise their profile and public/industry perception.

4.2 Review of economic, legislative and technical barriers and opportunities

NNFCC engages regularly with stakeholders in the bioenergy industries in order to gather market information relating to the economic, legislative and technical barriers to deployment.

Recent NNFCC discussions with key players in the energy crops industry have revealed some useful insights into the current status of the sector and industries views on barriers to deployment of energy crops. The following comments are direct quotes from companies in the field.

Relating to *Miscanthus*:

- We see strong demand for biomass from energy crops - both on a large scale for co firing etc. and for local use; both for pellet and straw with good contracts and prices.
- We see a remarkable improvement in planting and crop establishment.
- We see much better knowledge and understanding of the benefits of the crop in farming situations, biodiversity and for meeting government policy on carbon reduction and fuel security as part of a package.
- BUT delivery is failing to take off due almost entirely to lack of a clear and consistent government message and poor delivery by the various agencies.

There is also a lack of promotion of ECS and a complete lack of knowledge or priority by assessors; the fact that *Miscanthus* is not included in any options compounds this.

- Farmers can be criticised as being traditionally reluctant to try something new but many are independent and entrepreneurial business men who care about UK plc. and the environment.
- Having said that – a period of rising fuel prices, increased publicity about the benefits of *Miscanthus* and stability in the supply chain together with excellent new planting results has seen a maturing of the industry and we are defiantly seeing a slowly gaining confidence.
- The main barrier to expansion of energy crop production in the UK is the lack of a clear message and a trustworthy and stable policy/financial package around the ECS and the RHI, FIT etc. Lack of joined up thinking of SFP and ELS/HLS and a general unwillingness by government, Natural England and DECC to help promote the new developments under one umbrella.
- After a lot of hard work those that support *Miscanthus* now have a VERY good, strong story to promote on all fronts, be it economic, environmental, farming enterprise, biodiversity, food/fuel, carbon reduction, handling and burning etc. Those who have had the opportunity to see the current planting of the past two years and the results it produces have shown enthusiasm way beyond that of 2 years ago. Strong arable margins (albeit under current SFP levels which will reduce) inevitably make people lazy about exploring other options, however, as costs rise and support falls, interest is growing. Much of the current planting is relatively small blocks for new growers. And this slow expansion will not help government reach its own targets.
- Government MUST ensure a new scheme is set up and ready to go when the current one expires. Unless this is done all the hard work in confidence building, R&D in planting, and the new markets opening up will disappear overnight as it did before.

Relating to SRC willow:

- We would say that the energy crops industry is pretty stale at the moment and showing little, if any, growth. From our own group's point of view, we have a very small area of SRC to plant this spring but are also seeing crops planted in the mid to late '90s coming out after harvest and not being replaced.
- Demand for energy crops from heat/power users has remained fairly static over the past couple of years. We have been asked to tender for supply into new biomass installations but have found that at the moment we cannot compete with other woody biomass steams i.e. waste wood, forestry waste etc. in terms of both price and specification. We do think that RHI may stimulate growth in energy crops, but it will be very slow. We would be pleased to see a more "joined up" approach to biomass installations with

more consideration given to the specification, delivery and storage of a bulky fuel in the early stages of the project.

- We would like to think that the future for perennial energy crops in the UK is positive, but would have to say that currently that future is underpinned by demand from the major power generators. We are seeing a steady flow of farmers/growers/landowners planting SRC for use in their own biomass boilers in building conversions, holiday lets, glasshouses etc. and we think that this will continue to grow steadily with the introduction of RHI and a domestic tariff later.
- The main barrier to expansion of energy crop production (unless grown for own use) in the UK remains financial. Growers are reluctant to finance up front a crop from which they will receive no return for four years and for which the return, whilst not subject to the fluctuations of the commodity markets, is perceived to be moderate. The uncertainty over the funding (if any) post 2013 is not boosting confidence.
- The main reason for farmers/growers have chosen to plant SRC over the past few years has predominantly been for own use in biomass boilers as noted earlier. We have seen little planting of SRC from farmers choosing to grow the crop for the crops sake.

NNFCC market analysis and engagement with the biomass industry has highlighted the following economic, legislative and technical barriers to successful deployment of domestic energy crops.

Economic:

- Cash flow issues between planting and the first harvest are critical and support during this time is needed, it would give not only financial security but also confidence in the market.
- Small margins for the grower at present mean there is little room for error and if the grower has an unexpected additional cost then they may be left with no profit at all and possibly even a deficit.
- The energy sector offers a great opportunity for diversification in the agricultural sector but at the moment prices are too low to make it attractive to farmers.
- Farmers themselves are often not willing to contract long term, even if financial gains significant.
- Finance is available towards the planting of energy crops, but there is no funding for contractors/other stakeholders to provide support and advice to the sector.
- Need more support for growers to access end users and secure off-take contracts. Including helping farmers to supply into local markets, which may make them more willing to plant energy crops (due to higher price and benefit to local communities).

Legislative:

- Need to make it easier for new innovative crops (e.g. switchgrass) to be classified as an energy crop under the Renewables Obligation (RO) – previous legislation meant they were eligible but was very difficult to document, new proposals may exclude similar innovations currently.
- Need to allow farmers to get Entry Level Stewardship benefits from the actual energy crop and open ground within the crop for which the grant is also payable.
- RO energy crop uplift needs to be grandfathered to give confidence to the market and enable access to finance for energy crop supply chains and infrastructure.
- Grandfathering of the uplift may also stimulate increased demand from generators and provide a more stable market for energy crops, encouraging more farmers to plant.

Technical:

- Biomass boilers are not always compatible with *Miscanthus* (due to ash alkalinity and melting temperature) and SRC (sometimes, due to high moisture content or high chlorine content); additional advice about boilers that suit *Miscanthus*/SRC would be very useful.
- Further support needed towards infrastructure, especially processing and pelleting equipment.
- Need pellet mills local to farmers so that can transport material economically over longer distances.
- There is a lack of specialist planting/harvesting equipment, which prevents significant expansion of the sector.

4.3 Summary of barriers and opportunities

Despite Government investment in some of the key areas identified above, the production of energy crops is being severely constrained by the lack of promotion of the Energy Crops Scheme to potential growers, agents, consultants or advisors. These players could offer a secure supply of sustainable indigenous biomass but they are cautious about a new venture and lack knowledge and information about the potential opportunities of energy crops and the bioenergy market. Conflicts of organisational objectives within Natural England make it very difficult for them to actively promote energy crops, and so the industry would welcome a reappraisal of the structure of this scheme, including consideration of transferring the management to an independent non-conflicting authority. If this is not addressed there is a real danger that the £27 million funding available to enable planting of these crops could fail to realise the objectives set.

The issues and barriers surrounding energy crops constitute a complex problem requiring a multi-faceted solution, which requires further time and research to answer fully. The benefits of energy crops include not only their use for biomass heat and electricity but also their ability to store carbon, benefit industrial landscapes, prevent erosion, improve biodiversity in the right location and ensure fuel security.

The table below sets out the key barriers identified from our discussions with industry representatives and the potential mitigating actions from Government and Industry.

Figure 3: Summary of the most severe barriers to energy crops

Barrier	Impact	Government mitigation	Industry mitigation
Lack of specialist planting/harvesting equipment.	Severe - will restrict ability to increase planting or harvesting rate.	Long term support is required to encourage machinery suppliers to invest in specialist equipment development.	Invest in development of specialist equipment, when long term support is guaranteed.
Poor understanding of correct establishment and management practices by growers.	Will hamper confidence and delay uptake, but not severe.	Update best practice guidance for planting and establishment; previous version is dated. Support trial work on planting and management techniques, i.e. precision planting.	Establish trials to consider alternative planting and management techniques and communicate the findings; Masstock Energy SMART Farms are a start.
Not economically viable for farmers.	Reduced feedstock availability. Missed opportunity for UK agriculture.	Energy Crops Scheme currently supports *Miscanthus* and SRC; list of energy crops in RO Consultation is somewhat longer. Need long term guaranteed support, to encourage uptake.	Investigate cost reduction innovations.
High up front establishment costs.	Reduced feedstock availability. Missed opportunity for UK agriculture.	Energy Crops Scheme supports 50% of planting and establishment costs, not guaranteed post-2013. Consider restructuring scheme to cover issue of no income for first 2 - 3 years post-planting.	Investigate cost reduction innovations and new crops (i.e. novel energy grasses).
Lack of promotion of the Energy Crops Scheme to potential growers,	Severe - likely to be very little or no production of these fuels.	Natural England administer the scheme but do not promote it, nor does any other authority. Promotional activity is required to generate	Need to establish a fixed programme of meetings and activities, promoted through farming organisations such as NFU, CLA.

agents, consultants or advisors.		interest and encourage applications. Promotion should be carried out by an independent organisation with technical knowledge and a strong interest, such as NNFCC.	
'Standard' biomass boilers are not compatible with energy crops (*Miscanthus* specifically).	If no compatible systems are installed then there will be more demand for other woody feedstocks, and energy crops may be diverted to lower value use for power generation.	Develop educational programme about compatibility of fuels and boilers. Communicate good matches through BEC/NNFCC/CT/EST etc.	Continue to develop and promote fuel-flexible boilers. State ash melting temperature compatibility in boiler specs. Conduct more trials on non-woody fuels. Promote the energy crop boiler guide established by NNFCC.
Lack of specialist local supply infrastructure.	Imperfect supply mechanisms may be used (e.g. tractor and trailer) and this may restrict number of installations.	Provide support for supply chain infrastructure.	Invest in equipment and infrastructure.

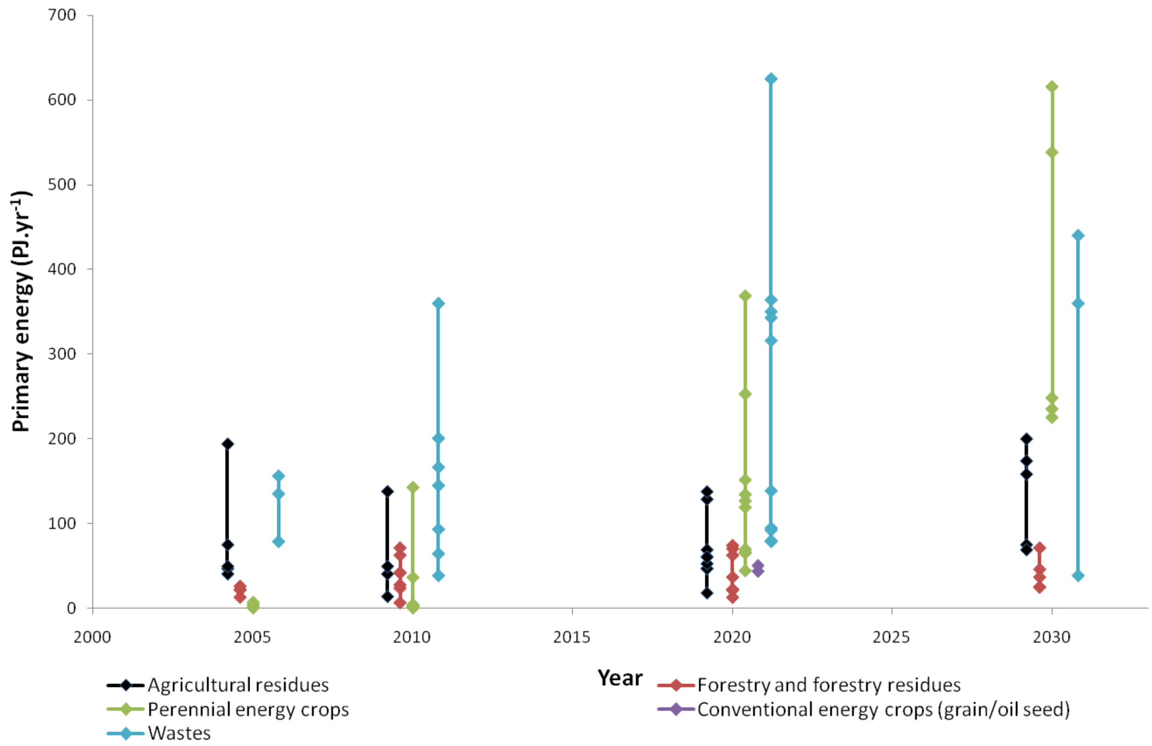
5 Scenario development for energy crop deployment

Potential biomass supply scenarios were developed on the broad assumptions that energy crops should only be planted where they:

- Do not conflict with food production;
- Do not impact on ecosystem services;
- Do not displace alternative land uses that offer greater GHG savings;
- Return a profit.

According to research from the UK Energy Research Centre (28)the biomass feedstocks offering greatest potential for growth are perennial energy crops and wastes. For energy crops, growth comes from the allocation of land to a variety of perennial crops. However, for agricultural residues, growth comes from increased utilisation, but the fundamental resource does not change markedly; Fischer (29) predicts that the resource from agricultural residues will decrease as perennial crops encroach onto agricultural land. If technological improvements increased crop yields, or population decreased, or diets changed and the consumption of meat was reduced, then at least in theory, surplus land would become available.

Figure 4: Range of predictions for the contribution to UK primary energy from domestically source biomass feedstocks (28)



5.1 Maximum theoretical potential

UK modelling approaches largely focus on using expert judgement rather than the top-down approach common in Europe-wide models (30; 31; 29). The EEA (31) report evaluates land availability using a partial equilibrium land use model (CAPSIM) to derive an estimate that between 0.8 M ha (in 2010) to 3.4 M ha (in 2030) could be released in the UK as a result of reform to the common agricultural policy (CAP).

Approximately half of the land released would be former grassland [5]. The Fischer (29) report uses assumptions about the rate of technical advances in crop yields, food demand (considered to be a function of population and diet) and livestock intensity to estimate land available for energy crops in member states. Stipulating that maintaining the current level of self-sufficiency for food should be a fundamental constraint, this report estimates that up to 1.1 M ha could be made available for energy crops in the UK, split between different land classes. The deWit (30) report adopts a similar approach, calculating that the area freed up in the UK will be 0-

[5] This is not recommended in terms of reducing greenhouse gas emissions (36) and may also impact biodiversity

6.5% in East England, 6.5-17% across most of the rest of the UK, and up to 31% in South West England; however, estimates of the actual area are not given.

Results of research on *Miscanthus* yield and land availability by Rothamsted Research and the University of East Anglia (32) concluded that: (i) regional contrasts occur in the importance of different factors affecting biomass planting; (ii) areas with the highest biomass yields co-locate with food producing areas on high grade land, and; (iii) when land use is restricted to grade 3 or 4 agricultural land only excluding environmentally sensitive landscapes and grasslands (3.12 M ha), then the total yield across England is 38.9 M odt (an average of 12.5 odt ha^{-1}). This paper does not include Scotland or Wales because of a lack of data.

Using a similar approach for SRC, researchers at the University of Southampton and the Forestry Commission found that 0.8 M ha of land for SRC is realistically available in England and could be grown almost entirely on poor quality marginal lands (agricultural grades 4 and 5) (33). With an average yield of 9.4 oven dried tonnes per hectare (odt ha^{-1}) such production would produce 7.5 M odt of biomass. This figure could be greatly increased if more favourable agricultural land were used to grow energy crops. This paper is based on upscaled field trial data from the UK national SRC field trials network but upscaling does not include Scotland or Wales because of a lack of supplementary data.

If we follow the restraint criteria identified earlier in this chapter and make assumptions[6] based on the work of Lovett *et al.* (32) and Aylott *et al.* (33), we can estimate the maximum likely availability of land in England and Wales at **between 0.93 and 3.63 M ha may be available to energy crops**.

5.2 Likely farmer uptake based on gross margins

However, this does not take into account likely uptake by farmers. Sherrington *et al*. (34) suggests this will be closely linked to gross margins. SRC currently achieves between £45-60/odt on energy crop contracts with power stations. This would deliver a gross margin of between £116/ha and £241/ha, respectively – based on 8.3 odt/ha (35).

Miscanthus, on the other hand, can attain higher gross margins due to higher productivity. Contract prices can be as low as £45/odt – which would give a gross margin of around £306/ha (at 14.0 odt/ha) – or as high as £75/odt which would give a gross margin closer to £736/ha. If we assume £60/odt is a typical price for a current contract then a gross margin of £526/ha is achievable (35).

[6] Wales has 1.53 M hectares of agricultural land. England has 9.34 M ha of agricultural land. If we assume that between 8.6 and 33.4 per cent of the agricultural land in England could realistically be available to perennial energy crops and apply this to Wales then 0.13 and 0.51 M ha of land may be suitable for energy crops in Wales, however not all of this will be available economically.

A comparative gross margin for winter oilseed rape is £714/ha (based on £340/tonne), winter wheat is £673/ha (based on £140/tonne) and winter barley is £532/ha (based on £135/tonne) (35). Growing conventional crops typically exceeds the gross margins achievable from growing energy crops but a 2005 University of Cambridge study found that uptake of energy crops occurs at levels of gross margin lower than would be expected given the gross margins of conventional crops. This is related to the fact that the energy crop gross margins include the costs of machinery and labour as most work is undertaken through contract. But if farmers use on-farm machinery and labour, then the gross margin will improve.

If we assume a gross margin of £526/ha for *Miscanthus* then uptake amongst landowners is predicted to be around 77% based purely on financial costs (34). This would indicate that a uptake based on gross margins would be **between 0.72-2.80 M ha** based on £526/ha and using our assumptions from the work of Lovett *et al.* (32) and Aylott *et al.* (33) [7]. However, if we assume a gross margin of £241/ha for SRC then uptake amongst landowners is predicted to be around 67%, based purely on financial costs (34). This would indicate that an uptake based on gross margins would be **between 0.62-2.43 M ha** based on £241/ha and using our assumptions from the work of Lovett *et al.* (32) and Aylott *et al.* (33) [8].

5.3 Likely farmer uptake based on social factors

The actual supply response of UK farmers to perennial energy crops, given the current energy and agricultural policy environment, is clearly going to be different from the modelled supply response.

A 2008 survey of arable farmers by Sherrington *et al.* (26) found that around 1.5% of respondents to the question "Are you intending to plant *Miscanthus* on your farm in the next five years?" said probably or certainly (n=133), while a further 15.8% were unsure. Similarly, when asked "Are you intending to plant SRC willow on your farm in the next five years?" 0.8% said probably or certainly (n=131), while a further 10.7% were unsure.

Farmers perceive these novel crops to present a greater risk than conventional annual crops, for numerous reasons outlined above, and will not simply switch to them when the predicted gross margin is slightly higher than for an existing activity. For most farmers, there should, however, come a point when the price offered for

[7] These numbers are calculated by multiplying the maximum theoretical potential (derived from Lovett *et al.* (32) and Aylott *et al.* (33)) by the potential landowner uptake identified by Sherrington *et al.* (34) which are based on gross margins (0.93 M ha * 0.77 and 3.63 M ha * 0.77 for £526/ha margins).

[8] These numbers are calculated by multiplying the maximum theoretical potential (derived from Lovett *et al.* (32) and Aylott *et al.* (33)) by the potential landowner uptake identified by Sherrington *et al.* (34) which are based on gross margins (0.93 M ha * 0.67 and 3.63 M ha * 0.67 for £241/ha margins).

Miscanthus or SRC willow is sufficiently high to overcome these other concerns. When this occurs, in effect, payment will accurately reflect the premium for the risk that individual farmers believe they are taking.

There is a clear need for education, training and improved contract security to reassure farmers that there are grounds for the investment of capital and time. Without which, based on these numbers and the work of Lovett *et al.* (32) and Aylott *et al.* (33) [9], uptake **could be as low as 0.007-0.05 M ha** in England and Wales.

6 Conclusions

The theoretical maximum available land for *Miscanthus* and SRC has been modelled at between 0.93 and 3.63 M ha. If we assume planting would not take place below a gross margin of £526/ha for Miscanthus (at £60/odt) then research suggests the maximum area of land available will be 0.72-2.80 M ha. Alternatively, if we assume a gross margin of £241/ha for SRC (at £60/odt) this figure decreases to 0.62-2.43 M ha.

But *Miscanthus* and SRC remain novel crops and there is an associated risk with growing them. Without education, training and improved contract security uptake could be as low as 0.007-0.05 M ha in England and Wales. These ranges must be interpreted with care as the underlying assumptions have a large degree of potential error but offer an estimate based on our best knowledge and understanding.

The production of energy crops is being severely constrained by the lack of promotion of the Energy Crops Scheme to potential growers, agents, consultants or advisors. These players could offer a secure supply of sustainable biomass but they are cautious and lack knowledge and information about potential opportunities of energy crops and the bioenergy market.

If we were to carry on business as usual, perennial energy crops will remain marginal. As current plantations come to the end of their 15-20 year productive life and are scrubbed up, with no real incentive to replant, the planted area could even decline. If we increase the amount of plantings [10] we have every year between now and 2020 by 20% this will mean by 2020 we have approximately 0.04 M ha in the ground, which falls around the middle of our lowest range. This clearly shows we have much to do to come close to the potential offered by energy crops and also does not take into account the delay in achieving harvestable biomass. Having a crop in the

[9] These numbers are calculated by multiplying the maximum theoretical potential (derived from Lovett *et al.* (32) and Aylott *et al.* (33)) by the potential landowner uptake identified by Sherrington *et al.* (26) which are based on farmer interest (0.93 M ha * 0.008 and 3.63 M ha * 0.015).

[10] The latest figures we have access to suggest ~10k ha has been planted through the ECS to date (Natural England, 2011). An additional 1,500 ha of SRC is understood to have been planted pre-ECS for the ARBRE project.

ground does not mean it will be readily available for energy, *Miscanthus* can take between two and three years to establish and be harvested and SRC willow takes three to five years to mature before it can be harvested.

The benefits of energy crops include not only their use for biomass heat and electricity but also their ability to store carbon, benefit industrial landscapes, prevent erosion, improve biodiversity in the right location and ensure fuel security.

Domestic supplies of perennial energy crops often have superior GHG balances and more needs to be done to encourage their development. This could include full effective promotion of the existing ring fenced Energy Crops Scheme, its extension and communication to agriculture and biomass sectors beyond 2013 and robust support for the production of sustainable biomass on non-prime arable land that is inefficient for food production. Addressing all the barriers to deployment will require further action both from Government and Industry.

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