WPI ECONOMICS

Realising the potential of perennial energy crops in the UK

Supporting jobs, levelling up and negative emissions

April 2022

A WPI Economics report for Drax

Cover Image: Terravesta

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About this report

WPI Economics has authored this report on 'Realising the potential of perennial energy crops in the UK' with supporting analysis from Carter Jonas. This report was commissioned by Drax, and features photographs and a case study kindly supplied by Terravesta.

drax

About Drax

Drax Group's purpose is to enable a zero carbon, lower cost energy future and in 2019 announced a world-leading ambition to be carbon negative by 2030, using Bioenergy with Carbon Capture and Storage (BECCS) technology.

Drax's around 3,000 employees operate across three principal areas of activity – electricity generation, electricity sales to business customers and compressed wood pellet production and supply to third parties. For more information visit www.drax.com

Carter Jonas
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About Carter Jonas

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Foreword

The events witnessed in Ukraine over the last month have been horrifying to many across the world. As well as being a tragedy to those living there, the impact of this invasion has been to further amplify the economic instability which increasingly characterises the world economy. Driving this in particular has been the increasing cost of energy and food – and secure access to both is crucial to any functioning and prosperous society.

Farmers are a prominent group who bear the brunt of these instabilities. The increased costs and uncertainties of doing business will no doubt be worrying to many within UK agriculture especially at this time of radical change and transition within the sector. This vital industry needs to be suitably supported across the entire production supply chain to ensure that it can ride out these near term pressures, the agricultural transition in the medium term, and assume its vital longer term role in attaining our shared net zero goal.

It is also important to plan for the long-term future, and the central role farmers and landowners will play in building a low carbon economy over the next 30 years. This report addresses how we can ensure the farming sector can deliver ‘food, fuel and fibre’ in the future, backed up by policy which supports well informed decisions on land use and nature.

In particular, energy crops can play an important role in supporting jobs, levelling up rural communities, helping nature recover and improving biodiversity, as well as delivering crucial negative emissions through BECCS and soil carbon sequestration.

This report represents a call to action for all those concerned with how UK farming can survive in order to thrive over the longer term, maximising its contribution to our economy, society and the environment.

Executive summary

Meeting the goal of net zero carbon emissions by 2050 is perhaps the UK's greatest policy challenge over the coming decades. In order to achieve this target, the UK needs to successfully deliver full or near full mitigation of carbon emissions across a range of sectors including homes and buildings, surface transport, and the power system. However, significant residual emissions will remain in some sectors, particularly industry, aviation, and agriculture in 2050 according to the Climate Change Committee (CCC).[1]

That is why the Government's strategy for delivering net zero – along with modelling from the CCC, Energy Systems Catapult, and National Grid – makes clear that technologies and approaches that allow us to achieve negative emissions will be vital if the UK is to reach its climate goals. One such negative emissions technology is Bioenergy with Carbon Capture and Storage (BECCS). In particular, the CCC has highlighted the important role that BECCS can play in potentially delivering 45-95 $MtCO_2$ a year of negative CO_2e emissions by 2050.[2]

But for BECCS to deliver on its potential to help meet the UK's ambition for negative emissions, an increasing amount of feedstock for BECCS will need to be drawn from a range of sustainable domestic and imported sources. Types of domestically grown agricultural crops which can be used for bioenergy (and BECCS) include Short Rotation Coppice (SRC) willow and Miscanthus. However, only 0.2% of arable land in the UK is dedicated to these crops at present.[3] This report shows how, alongside sustainable imports, development of a sustainable supply of UK based energy crops can support our climate ambitions, whilst simultaneously delivering a whole range of wider strategic benefits to the UK including:

- **Strengthening the rural economy** – new economic analysis for this report shows that completing the UK's leadership in bioenergy by establishing a thriving energy crops sector can create around 500 specialist jobs in rural communities across the country. Furthermore, it could have a net positive impact on Farming Business Income (FBI), offering a crucial long-term source of replacement income for farmers. The bioeconomy more widely – of which energy crops are a component – is a key part of the UK's green economy of the future.

- **Levelling up rural communities** – the Levelling Up White Paper sets out the Government's mission to "end the geographical inequality which is such a striking feature of the UK" by "improving economic dynamism and innovation to drive growth across the whole country".[4] To be effective, levelling up must consider the importance of cities, towns, and rural communities alike. Because Miscanthus and SRC can be produced on the vast majority of agricultural land in England and Wales,[5] scaling up their production is a levelling up opportunity which can benefit rural communities across the country. A decentralised model of UK energy crop production would allow farmers to supply local power plants with biomass feedstocks to produce power. Furthermore, the use of local hubs provides the potential opportunity to reduce supply chain emissions for biomass power and BECCS over time.

- **Developing the UK as a hub for energy crop innovation** – the UK's Innovation Strategy is a central element of the Government's programme to build back better following the pandemic, deliver on a vision of Global Britain post leaving the EU, and tackle macro challenges including climate change.[6] In the area of energy crops specifically, Government has rightly recognised the potential through previous scientific funding schemes and more recently its Biomass Feedstocks Innovation Programme.[7] In addition to these bespoke schemes for funding specific trials, a larger domestic sector for producing energy crops would position the UK in a much better place to continue building a research and knowledge base to drive innovation, working alongside the UK's world-leading research institutions in the form of our universities and the Catapult network.

Underpinning all of these potential benefits is the need to ensure that scaling up the production of energy crops in the UK is delivered in the most sustainable way. Here, it is critical that well-informed decisions on land use are made, and this report argues for a land use strategy which will be an important driver of best practice outcomes from a sustainability perspective. There are significant benefits attributable to perennial crops in soil carbon sequestration when compared to rotational annual crops,[8] alongside potential for a positive biodiversity impact linked with second generation energy crops such as Miscanthus and SRC where these are integrated into mainstream farming.[9] Planting could be targeted around specific rural communities that would benefit from the potential for increased flood mitigation and biodiversity benefits that perennial energy crops support.

Whilst there are clear benefits to supporting UK biomass/energy crops, there are also significant barriers to ensuring the sustainable growth of the energy crop sector in the UK. In order to fully realise these benefits, while managing the growth in a sustainable and balanced way, Government now needs to urgently address five key policy barriers to unlock the sector:

Our policy recommendations to Government are the following:

1. **Create certainty in demand for energy crops to encourage take up** - at present, there is little assurance for the farming and landowner communities that there will be demand and thus end users of energy crops. Changing this means certainty for the upstream business models which will generate the most demand for energy crops in the future, chiefly BECCS. To deliver this, clear signals from Government on BECCS and bioenergy must be matched by clear policy decisions which place a value on negative emissions and provide a long-term business model.

2. **Provide financial support for farmers -** there are significant economic, environmental, and social benefits attached to a growing energy crops sector in the UK. As a result, there is a case for a policy mechanism which either directly supports farmers to plant energy crops, or incentivises planting by rewarding farmers for the additional environmental benefits they provide as part of the Environmental Land Management Scheme (ELMS)

3. **Publish a rural land use strategy –** to support land use decisions by farmers and landowners over time, there is a need for a rural land use strategy which reinforces both our food and energy security, sequestering carbon in the short term (soil carbon sequestration) and the medium to long term (BECCS). This land use strategy should be developed in parallel with points 1 and 2 to ensure the farming sector can deliver food, fuel and fibre for the UK. To provide certainty to farmers, all three measures should be expedited.

4. **Provide clarity on criteria and standards for energy crops –** there is a need for a set of clear and ambitious sustainability standards - alongside updated guidance - to ensure robust checks and balances exist for energy crops, and that these support a growing sector.

5. **Contribute to the development of more accurate and robust information and guidance –** for farmers to have greater confidence in planting energy crops, improved resources need to be readily available for them to encourage best practice, for example around growing techniques. Organisations such as the National Farmers Union (NFU), particularly local NFU networks, have a key role to play in developing and sharing information and guidance.

This report draws on a wealth of primary and secondary data to make the case that – if these challenges are addressed – the UK and the world can reap the economic, social and environmental benefits of a growing and thriving domestic energy crop sector.

CHAPTER 1 Introduction and context

COP26 and the agreements created therein aimed to keep 1.5°C global warming alive. The challenge now is to ensure that the commitments made become a reality through economic, social, technological and policy change.

This report looks at one crucial element of this; the role of energy crops in helping the UK reach its targets for negative emissions and delivering a green economy. Bioenergy with Carbon Capture and Storage (BECCS) is where sustainably sourced biomass is used to generate power, and any carbon emissions created in this process are captured and permanently stored. BECCS has already been identified as a vital tool in delivering a net zero-carbon economy:

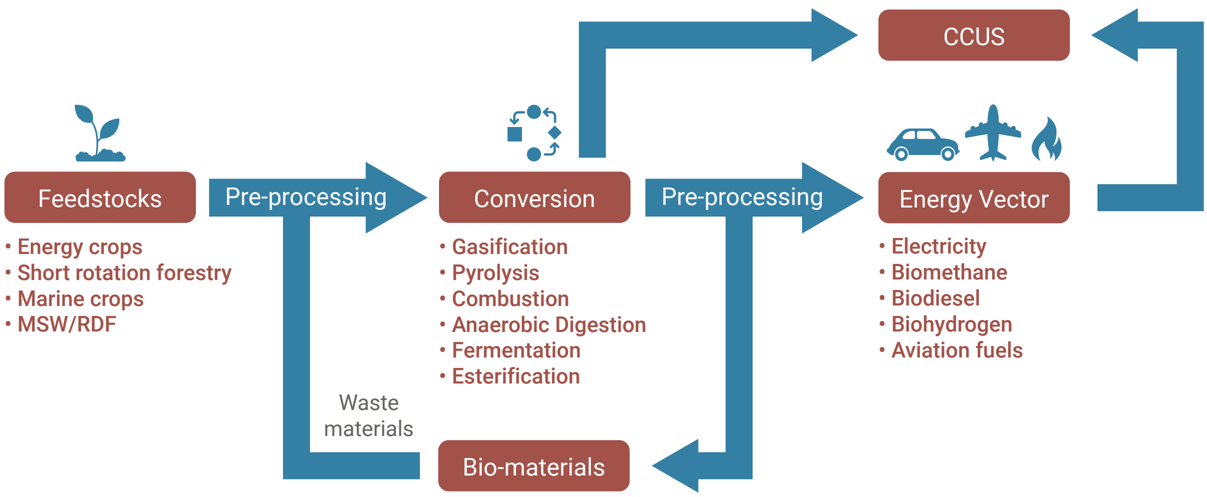
- The Climate Change Committee (CCC) has set out the potential for between 20 and 65 $MtCO_2e$ a year to be sequestered through BECCS in the UK by 2050.[10] All five scenarios in the CCC's Sixth Carbon Budget which reach net zero include a role for BECCS in delivering negative emissions.[11]
- Modelling from the Energy Systems Catapult suggesting that the UK will miss its net zero target by 40 $MtCO_2e$ a year in 2050 without negative emissions delivered through BECCS.[12]
- BECCs plays a role in delivering negative emissions in all National Grid Future Energy Scenarios that reach net zero.[13]

BECCS deployment in the first instance is projected to take place in the power sector from the late 2020s. Beyond this, there is scope for BECCS to be integrated into the production of clean hydrogen, which, like power, provides a low carbon vector for the energy created in the process. It could also be deployed in industrial processes, particularly where biomass is already used as a fuel, such as in paper and cement production.[14] Furthermore, BECCS is also projected to provide 5GW of capacity in the power sector in 2050 by the CCC, providing a valuable source of dispatchable generation.[15]

In addition, bioenergy plays an important role in delivering fuel solutions in hard to abate sectors. Sustainable Aviation Fuel (SAF) in particular, produced from biomass, could play a role in reducing aviation emissions.[16] Although, unlike other countries establishing SAF mandates, the Department for Transport currently recognise only waste-derived bioenergy feedstocks.[17]

The UK's leadership in this space can already be seen in its domestic actions and ambitions, such as the government's ambition to deliver 5 Mt of negative emissions per year by 2030 using BECCS and DACS. The Government has also taken a lead with recent policy announcements included in the Net Zero Strategy and the Biomass Policy Statement, as well as its commitment to support four CCUS clusters by 2030 at the latest. The Government has committed to setting out the role for BECCS and biomass in meeting UK climate targets in the forthcoming Biomass Strategy due later in 2022.

Figure 1: Scope of the forthcoming Biomass Strategy



Source: BEIS

Biomass Feedstocks in the UK

Currently, feedstocks for bioenergy are drawn from a range of sources, including biogenic wastes and residues from agriculture. One of the biggest sources of biomass feedstock in the UK is imported wood pellets, which are largely made up of the by-products of using timber in manufacturing and residues from Sustainable Forest Management.[18]

One emerging opportunity – as highlighted by the Biomass Policy Statement[19] – is to complement imports by sustainably scaling up the production of domestic biomass sources. Energy crops have been highlighted by the CCC and others as crucial in ensuring a diversified, sustainable feedstock for BECCS and bioenergy over the coming decades, although at the moment they play a very small but important role in comparison to imported feedstocks.[20] The key crops for the UK context are Miscanthus, SRC (often referred to as second generation, [21] or perennial, energy crops) and Short Rotation Forestry. A box summarising both these crops can be found below.

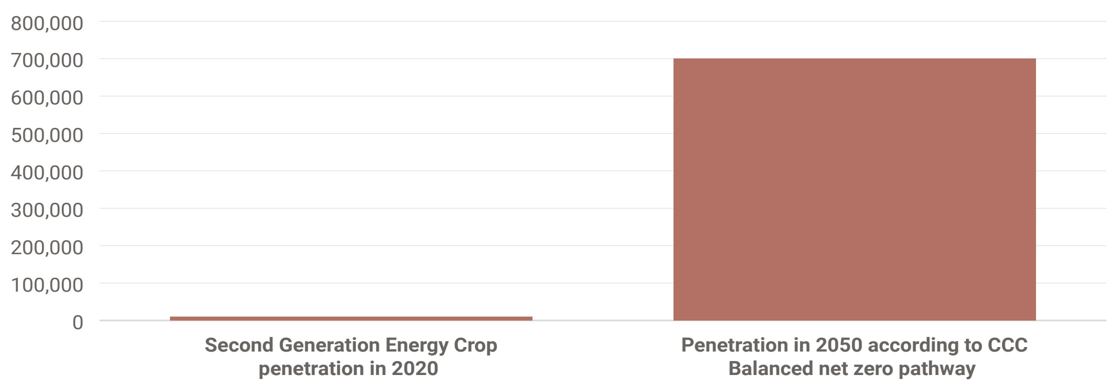
Table 1: Second generation energy crops in the UK

Crop	Description	Current size
Short Rotation Coppice (SRC)	In the UK, this is usually a willow or poplar that is harvested at three-year intervals for up to 10 harvests.	Less than 0.1% of arable land in England, around 2,032 hectares in 2020
Miscanthus	Miscanthus is a genus of perennial grasses that grows woody canes like bamboo and is not native to the UK. Crops are produced using both sterile hybrid Miscanthus x giganteus and other cultivars, also known as elephant grass.	Grown on around 0.1% of arable land in England, around 8,286 hectares in June 2020
Short Rotation Forestry (SRF)	The production of trees in a rotation of 15-20 years, and usually without the thinning that is practiced in typical long-rotation forestry. Species can be coniferous (e.g. Sitka spruce, Douglas fir) or broadleaved (e.g. silver birch, downy birch, sycamore). Potential for imported Eucalyptus and Paulownia.	Experimental crop

Source: Defra[22]

Farmers have an important dual role as providers of both food and energy, two crucial elements for any prosperous society. The CCC has highlighted the potential for a significant scaling up of energy crops in the UK, as a means of increasing and diversifying the supply of sustainable biomass feedstocks for BECCS and other uses. In its balanced net zero pathway it identifies the potential for 0.7 million hectares of energy crops to be planted across the UK.[23]

Chart 1: Scaling up energy crops in the UK (Hectares)



Source: CCC Sixth Carbon Budget[24]

CHAPTER 2 Rationale for scaling up domestic energy crop production

Bioenergy and BECCS are essential components in delivering the UK's net zero target, in delivering renewable low carbon energy and negative emissions, both made necessary by hard to decarbonise sectors. BECCS could also generate low carbon fuel for aviation. In scaling up bioenergy and BECCS, the UK should also identify how best to capture the co-benefits that can be realised in terms of jobs, growth, increased productivity, as well as wider sustainability aims such as biodiversity protection and enhancement.

This chapter considers the opportunities for securing co-benefits by scaling up domestic energy crop production, especially in the context of the UK's wider missions to Build Back Better from the Coronavirus pandemic, levelling up the country to reduce regional inequalities, and fundamentally reforming our approach to supporting farming post Brexit.

Encouraging a strong bioeconomy

Debates about achieving net zero at present tend to highlight the costs attached to the UK reaching its climate targets. However, the UK Government has rightly highlighted as part of the Net Zero Strategy that there are substantial opportunities available to the UK in demonstrating leadership in green technologies, as these can help deliver jobs and growth, and strengthen productivity.[25]

There is a clear economic opportunity for the UK in terms of bioenergy, BECCS, and the wider Bioeconomy. Some specific examples include the East Coast Cluster (ECC), which aims to be a world leading CCS cluster and includes the UK's first BECCS project at Drax power station, which will directly support 25,000 jobs on average per year to 2050. In addition, there is significant economic opportunity across the country from Sustainable Aviation Fuel (SAF) which by 2035 could add £32.7 billion in GVA to the UK economy, 5,200 jobs at SAF plants, with 13,600 further jobs in innovation and exports.[26]

There would be further economic benefits attached to scaling up of domestic energy crops. British farming has a vital role to play in the coming decades, particularly as geopolitical instability and broader factors highlight the importance of food security The opportunities for the farming sector in supplementing their income through the growing and supplying of energy crops for bioenergy are also significant. This is particularly true due to the versatility of the crops – Miscanthus can be planted on the vast majority of the UK's lowland agricultural land. As a result, it is attractive to farmers looking to generate greater revenue from land that is otherwise unsuitable for food crops or less productive. This means energy crops do not have to compete directly with food crop production, which uses the highest quality land. A number of farmers spoken to by Carter Jonas as part of research for this report who already grow Miscanthus confirmed this as being a key contributor to their decision to grow the crop.[27] Case studies gathered by the Energy Technologies Institute (ETI) suggest similar motivations, with one respondent stating:

"We've tried growing a variety of different crops on my awkward fields, but they actually became a cost to the farm business because they were so inefficient. The fields were making a loss, so we were bold and tried Miscanthus and haven't looked back"

David Sargent, Norfolk farmer

New economic modelling for this report sets out the potential economic benefits of scaling up the production of energy crops (see methodology in Annex 1). This modelling considers the economic effects of the three different scenarios for hectares of energy crop planting by 2050 that are given in the CCC's Sixth carbon budget, as well as a further scenario which considers the impact of 5,000 ha being planted a year to 2050. Using farm economics, it considers the impact of these scenarios on Farm Business Income (FBI) and number of jobs. It finds that, by 2050, there is the opportunity for 500 direct specialist jobs in this sector to be supported in farming across the country. Furthermore, there is a net positive impact on FBI in all scenarios, when displacement of either arable land, or a mix of arable and grassland, is taken into account.

Figure 2: Miscanthus margin to farmers annually in the four scenarios by 2050

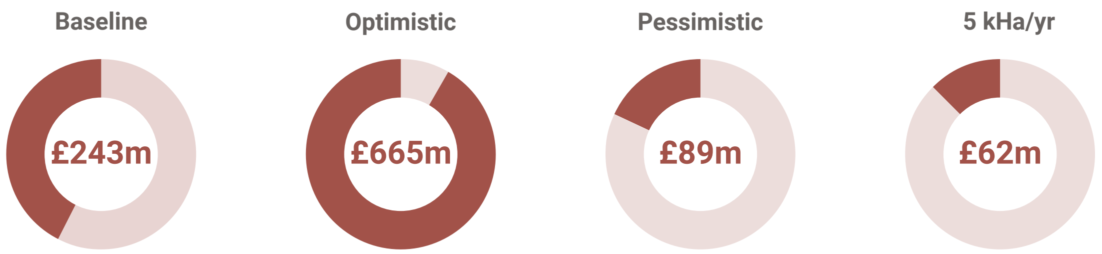


Table 2: Miscanthus margin to farmers annually in 2050, after displacement effect (million)

	Baseline	Optimistic	Pessimistic	5k ha a year
Farm level profit improvement – displacement of arable land	£90	£333	£25	£17
Farm level profit improvement – displacement of arable and grassland	£131	£422	£42	£29

In addition to these direct economic benefits, scaling up domestic sourcing of energy crops allows the UK to accelerate its vision of a strong domestic bioeconomy, by allowing power stations, SAF plants and other users of biomass the opportunity to diversify their sources of feedstocks.

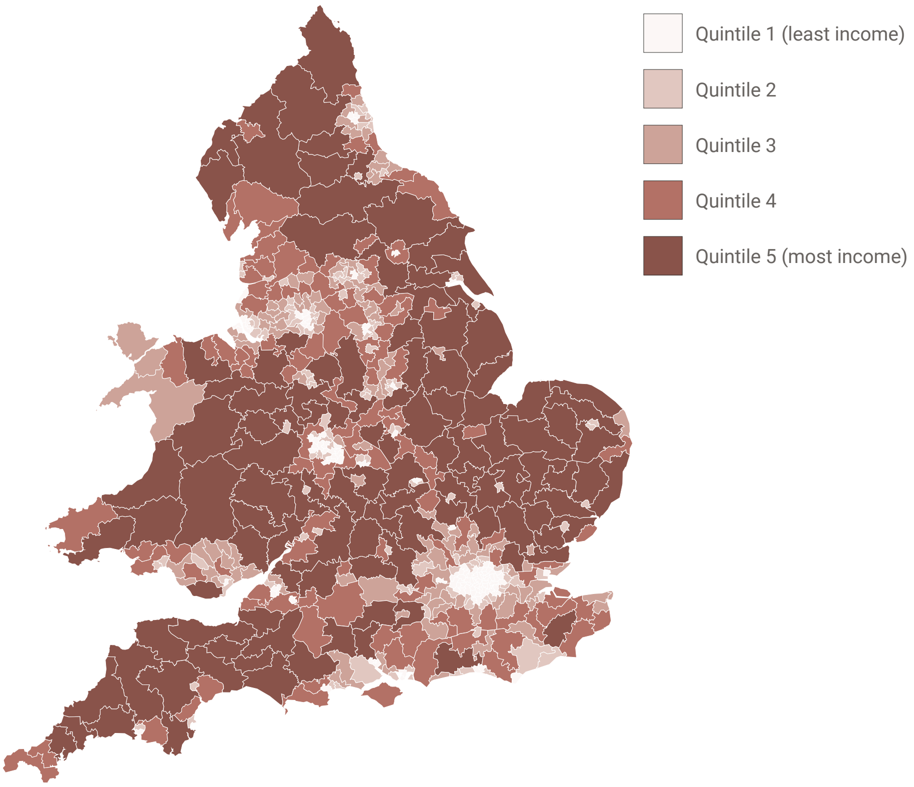
Source: Terravesta

Energy crops for levelling up

Levelling up is a central mission of the current administration. The Government has set out a series of missions around improving pay and employment, restoring pride of place, and improving education and skills.[28] Successfully achieving these missions requires progress not just in towns and cities, but in rural communities, too, and this demands policies to support agricultural economies.

Energy crops can play an important role in levelling up, due to their nature as an inclusive crop which can be grown on the majority of lowland agricultural land across the UK. The mapping in Figure [3] demonstrates how rural communities across the country stand to benefit from scaling up Miscanthus production in line with the plans by the CCC to 2050. The mapping in Figure [4] shows the breadth of power stations potentially producing power from biomass (and power BECCS over the longer term), as well as nearby areas which are suitable for the growth of Miscanthus and SRC.[29]

Figure 3: Farm Business Income by 2050 by constituency



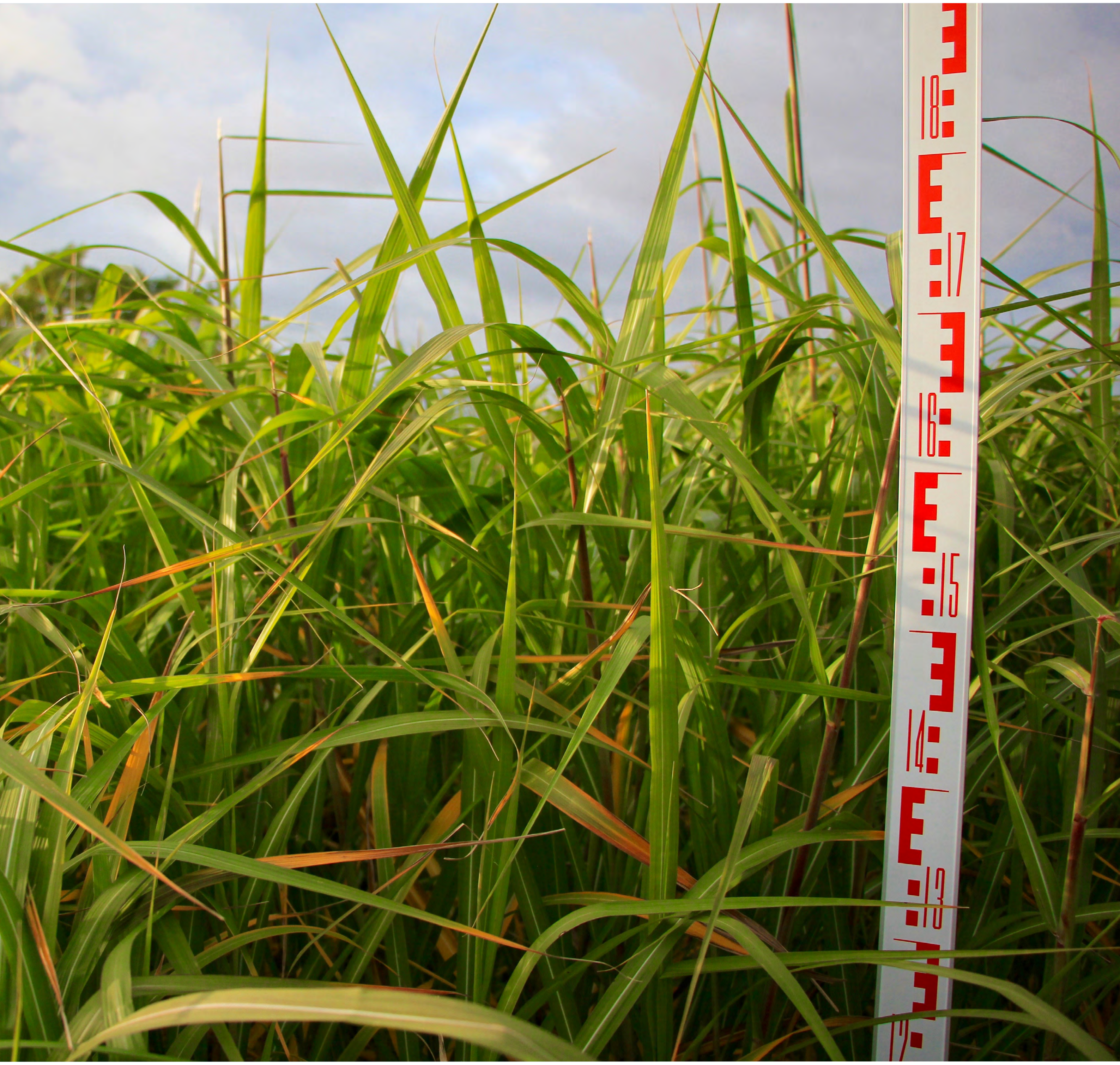
Source: WPI Economics mapping of modelling by Terravost

This demonstrates that rural areas across the whole of the UK are able to benefit from the potential growth in domestic biomass production.

As Figure [4] shows, there is a remarkable amount of viable land in the UK for growing energy crops, the majority of which is close to a number of biomass-using sites. There is therefore an opportunity to create local distribution hubs serving nearby power stations and other offtakers.

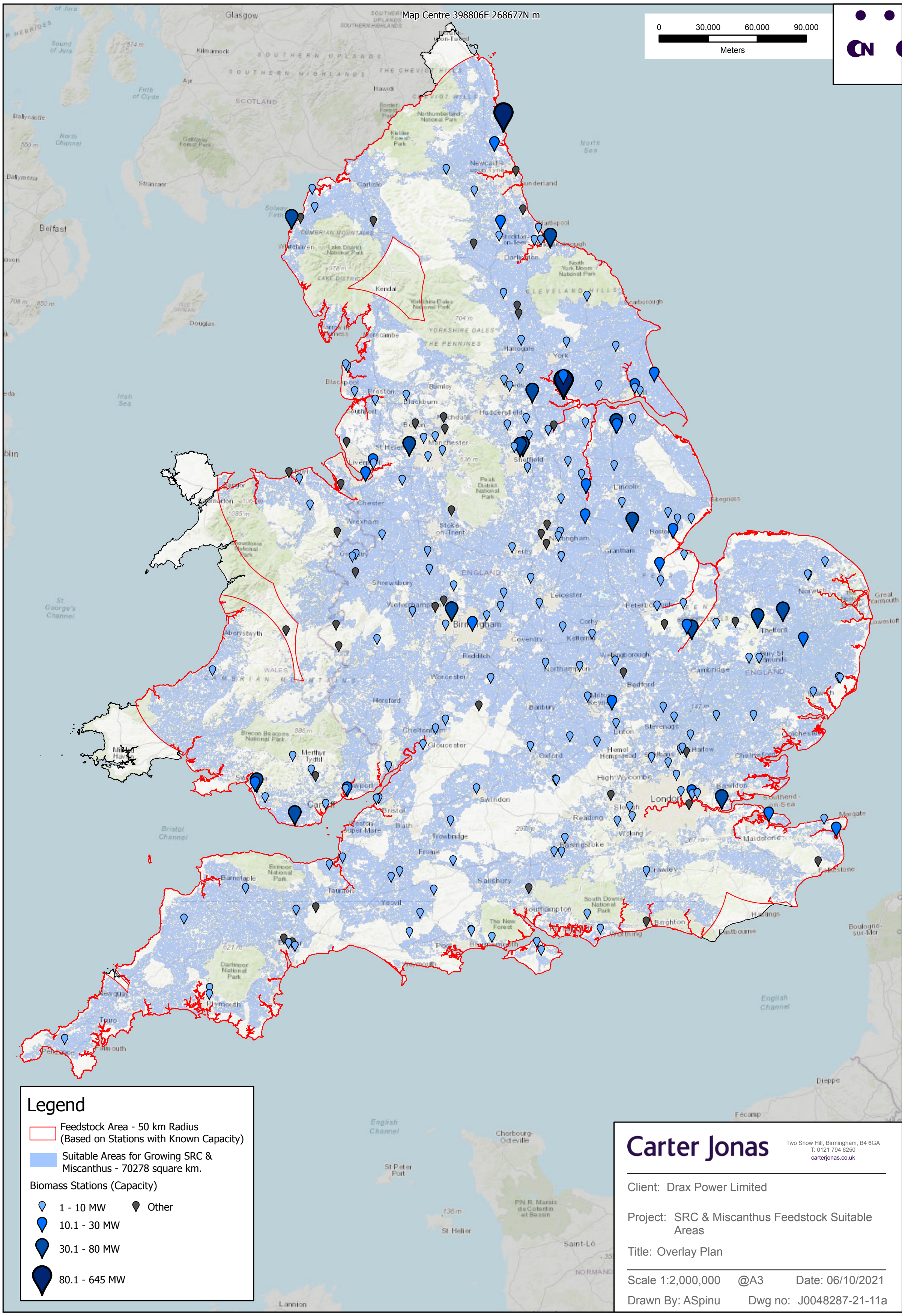
Following establishment, the major costs associated with biomass systems are harvesting, storage and transport. All three elements could be assisted by the creation of local networks providing economies of scale and facilitation of continuation of supply to these locations. Furthermore, the creation of distribution hubs could also assist with minimising the distance travelled by biomass products, which is economically efficient and could help to reduce supply chain emissions over time.

This decentralised model of local networks of supply and end use directly maps across to the government's levelling up agenda, and could create a range of opportunities to the landowners, farmers and off takers within these areas.



Source: Terravesta

Figure 4: SRC and Miscanthus feedstock suitable areas



Seizing the crop innovation opportunity

While not a panacea, innovation can play an important role in improving economic performance. Recent work by David Sainsbury, former Minister for Science and Innovation, highlights innovation as being central to an economy's international competitiveness.[30] The UK's unequal and relatively low rate of R&D intensity has been highlighted as an important factor to address, particularly to strengthen the economic performance of regions outside London and the South East. This is underpinned by international evidence looking at how the benefits of R&D spill over into local economies.[31]

In addition, innovation will play an important role in delivering the UK's net zero targets. The Energy Systems Catapult has highlighted the potential contribution of innovation across a range of areas, such as smart systems, small modular nuclear reactors, as well as bioenergy and BECCS. It describes the need for innovation across the whole system – technology, land use, and behaviour change.[32]

The UK Innovation strategy seeks to bring these various strands together – highlighting the importance of raising the UK's overall R&D spending in terms of building back better from the pandemic, levelling up and delivering macro-challenges such as tackling net zero. It sets out a number of focusses of UK innovation, such as AI and advanced manufacturing, tying these into the delivery of a series of Innovation Missions.[33]

Energy crops present a key innovation opportunity for the UK in this context. Further crop innovation can maximise the potential economic and environmental benefits of bioenergy and BECCS that are set out in this report. While Miscanthus and SRC can already be grown on otherwise unproductive and unprofitable land, there is potential to go further in improving overall global yield potential, and further optimising land use in the coming decades. Innovation can support this. The Government's Biomass Feedstocks Innovation Programme aims to deliver commercially viable innovations in biomass production by supporting innovative projects, sharing lessons learned, disseminating knowledge to farmers and helping develop business models that ensure further commercialisation. For example, the Miscanspeed initiative at Aberystwyth University is aimed at improving the yield and resilience of the crop.[34]

Bespoke initiatives such as this are one crucial element of an approach to innovating energy crops. A bigger domestic source of biomass will further support the UK to build a research and knowledge base to improve the production of this crop. A thriving agricultural sector growing these energy crops could work together with our world leading research institutions, in the form of the universities and the Catapult network, by providing a clear route to test and scale innovative techniques.

This could both help the UK to deliver on its emissions targets, as well as support other countries to tackle climate change by sharing this technology globally, representing an important example of UK climate leadership. This prize from seizing the opportunity around innovation further highlights the importance of the UK taking the key policy decisions which allow it to join up its ambitious plans for BECCS with a growing energy crops sector and its world leading research base.

CHAPTER 3 Sustainability and energy crops

As set out, there are socioeconomic benefits involved in scaling up the production of energy crops domestically in terms of the economic impact, levelling up, and driving innovation. In addition to this, there are a series of sustainability benefits, ecosystem services, and risk mitigation - such as carbon sequestration, biodiversity, flood management and water quality improvements - that are associated with energy crops if their establishment and production is managed appropriately.

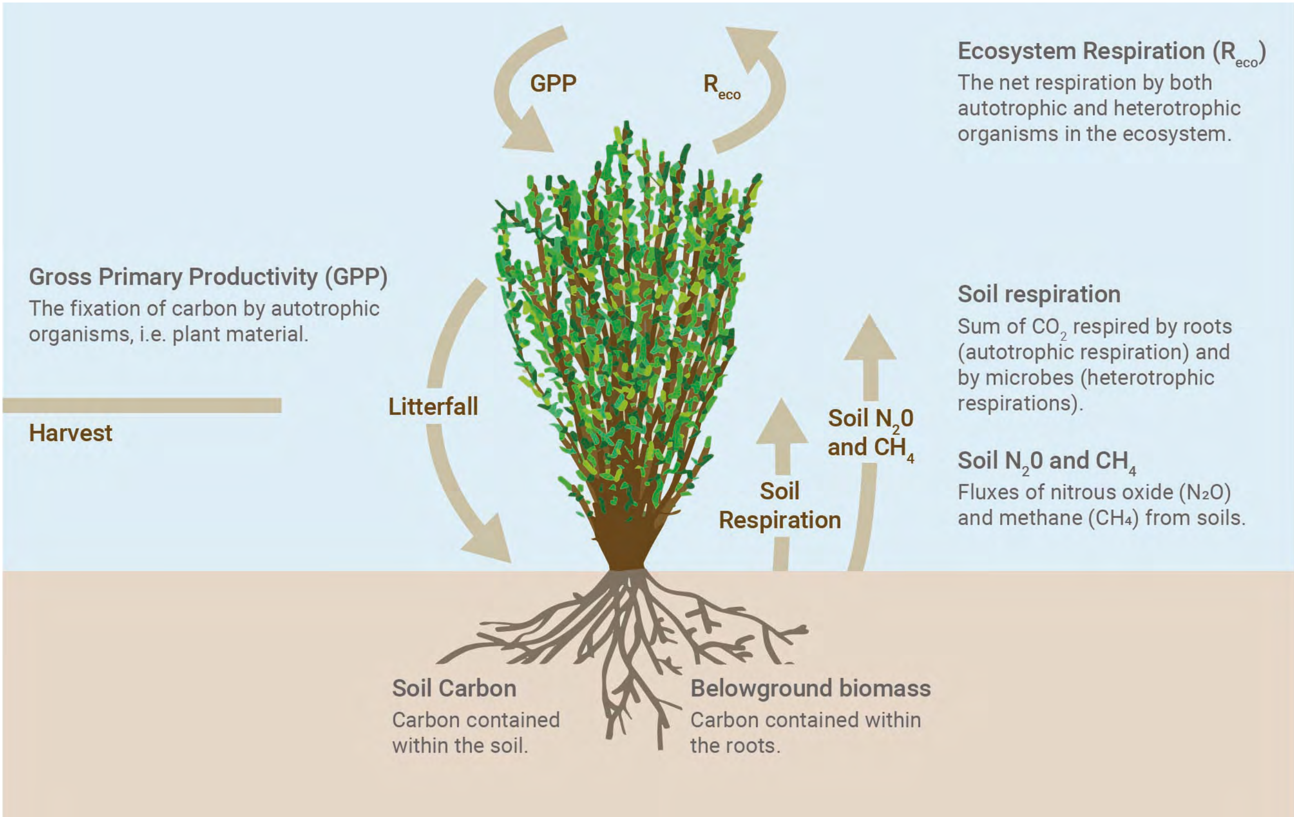
As discussed in chapter 1, the CCC has set out the importance of biomass in delivering net zero through negative emissions, generating power, and potentially producing fuels such as SAF. The CCC has also detailed some key criteria in relation to how we approach feedstock sourcing. These chiefly revolve around direct and indirect land use change, and resulting impacts on soil carbon, biodiversity, as well as competition with other land uses. We explore some of these sustainability vectors below.

On-farm carbon sequestration

Agriculture is regarded by most as one of the hardest to abate sectors, and faces a range of challenges in relation to addressing its emissions.[35] The NFU and others have set out various ways in which farmers can contribute to delivering the UK's climate targets, such as improving overall farm productivity. Another key activity which can reduce emissions is by increasing the level of on farm carbon sequestration.[36] This can be supported by a range of activities such as planting and restoring hedgerows and practices to encourage improved soil carbon storage.

Miscanthus and SRC are perennial crops, meaning they are not replanted annually but regrow. This means that they provide the opportunity to improve overall levels of soil carbon sequestration in farmland over time. Research suggests that, when replacing rotational crops, a reduction in cumulative greenhouse gas emissions into the atmosphere can be achieved. Over 35 years, 76.4 tCO_2e/ha is saved by planting Miscanthus, and 37.7 tCO_2e/ha saving by planting SRC.[37]

Figure 5: Soil carbon sequestration



Source: Harris et al 2016[56]

Notably, these effects are not always observed if these crops are used to replace grassland or forest. Indeed, there is a risk this will result in an initial loss in soil carbon stocks according to some research.[38] However, other research suggests that carbon lost through cultivation of grassland is recovered through the life of the Miscanthus crop.[39] A land use strategy alongside guidance on carbon management would support farmers to make decisions which contribute to tackling agricultural sector emissions.

Furthermore, there are synergies between second generation energy crops and novel kinds of soil amendments for on farm carbon sequestration. For example, biomass crops can be used to produce biochar, a high-carbon form of charcoal that is produced by heating organic matter, in the absence of oxygen, which can further support on farm soil carbon stores.[40] Working to join up synergies such as this underlines the need for guidance from government on land use.

Biodiversity

The protection and promotion of biodiversity is another important goal in the coming decades, one that is often complementary to reducing carbon emissions. Government has set out a number of policy tools to deliver on this goal through the Environment Bill, which aims to halt species decline by 2030 through, for example, the new Local Nature Recovery Strategies which aim to bring together a range of public, private and third sector stakeholders to drive nature recovery and provide additional benefits.[41]

Second generation energy crops do have the potential to complement the delivery of UK Government objectives around biodiversity, particularly if they are integrated into mainstream farming.

A summary of the evidence on biodiversity benefits of Miscanthus and SRC conducted in 2010 found that:

"Second generation biomass crops are perceived as being beneficial for biodiversity compared with cultivated areas of arable food crops because, in general, biomass crops have longer rotation periods, low fertilizer and pesticide requirements, provide better soil protection, a greater richness of spatial structures, are exposed to fewer disturbances during the growing period, and harvesting is carried out in winter or can be done after the breeding period of birds, which again causes less disturbance"[42]

and further that:

"…integration of biomass crops into agricultural landscapes could stimulate rural economy, thus counteracting negative impacts of farm abandonment or supporting restoration of degraded land, resulting in improved biodiversity values."[43]

A more recent meta-analysis (Donnison et al., 2021) supported by UK Energy Research Centre (UKERC) suggests strong benefits attached to second generation bioenergy crops in agricultural landscapes, including bird abundance, bird species richness, arthropod abundance, microbial biomass, and plant species richness.[44]

In addition to this academic evidence, case study interviews for this report also reveal that, anecdotally, several farmers already growing the crops have observed biodiversity benefits following their planting.[45] Case studies from farmers spoken to by the Energy Technologies Institute observed similar effects.[46] Furthermore, the CCC suggests in analysis of the sector that there is evidence that Miscanthus and SRC are largely positive for biodiversity in the UK.[47]

The biodiversity gains that could be realised by energy crops are, however, diminished if planting these crops is done on the basis of large monocultures, rather than a 'mosaic' of cropping across a larger landscape [48] A future land use strategy should take all of these factors into account in order to strike an appropriate balance.

Land use allocation

For the UK to meet its climate change targets, the use of land across the country will need to change in the coming decades to 2050.[49] Factors such as a reduction in on and off farm food waste, innovation and improved productivity have the potential to lead to a reduction in the amount of land needed to produce food.[50] The UK government has set out a target to increase tree cover in England to 12% by the mid-century, to sequester carbon, improve biodiversity and deliver a range of social benefits.[51] In addition, land will be needed to enable nature recovery and provide space for power generation too (wind farms, solar panels). At the same time, land will be needed for energy crops, in order to deliver the UK's climate targets and deliver several of the benefits set out in this report. The CCC sets out, based on research from the Energy Technologies Institute, the potential for up to 1.4 million Ha of land to be dedicated to perennial crops by 2050.[52] A rural land use strategy which acknowledges the multiple land use opportunities in the UK on a level playing field will be critical and could be a useful catalyst to address land use competition concerns. This strategy should not seek to dictate land use on a top down basis, rather it should seek to support farmers and landowners to deliver public goods alongside food, fuel and fibre.

As discussed, a key benefit of second-generation energy crops is that they could be scaled in a way that does not necessarily impact on food systems.[53] This is because they can be grown on land that is less suitable or productive in the context of food production. Furthermore, there is evidence that the small number of farmers in the UK who do grow these crops are motivated by improving the income they draw from less suitable or productive land.[54] This suggests an alignment between the economic and environmental objectives in relation to using land to produce energy crops.

There is considerable uncertainty around how land use will evolve over time, in the context of wider challenges around a growing global population and uncertainty around how our diets will change. The nature of perennial crops allows them to be scaled in a way that does not necessarily compete with more productive agricultural land. Furthermore, energy crops for BECCS likely offer a valuable opportunity for carbon sequestration on a per hectare basis when compared with other solutions.[55]

The right policy environment which balances land use, and also supports greater innovation in crop practices, can help to deliver a future in which land meets the UK's needs for food, fuel, fibre, and nature recovery in the coming decades. In addition, flood risk mitigation is a further particular benefit of planting Miscanthus on certain farms, which will be of significant value in addressing the additional challenge of adapting to the effects of climate change.

Case study 1: Record wheat yields and added income from high-performing Miscanthus

North Shropshire farmer, Jim Mullock, has been growing Terravesta AthenaTM Miscanthus as part of the farm's net zero strategy.

"When deciding to grow Miscanthus we were mindful of the 'net zero' ambitions of agriculture and the need for every farm business to take an honest look at its carbon footprint, so with the crop's carbon sequestration potential and undeniable wildlife benefits, the investment was justifiable," explains Jim.

"Having discussed the merits of growing Miscanthus with my agronomist we agreed it was a good opportunity to 'put something back'," he says.

"The 36 ha we planted in spring 2020 is part of a larger traditional arable rotation, and with the increased challenges of growing oil seed rape, Miscanthus should bring a lot of positives to the business," says Jim.

Jim recently removed a 16-year-old Miscanthus crop and has seen improvements in the soil. "We were pleased to see how fertile the two difficult fields have become. As you might expect, the organic matter readings are now high and the soil is alive again."

Jim explains that the new Terravesta Athena™ crop looks better than his previous Miscanthus giganteus planted in 2005. "Having had previous experience of growing the crop on heavy clay ground 16 years ago it was clear this last spring just how much the planting process and varieties have improved."

"I do believe the cane has further end-use potential, and I hope that farmers will be rewarded for storing carbon on their farms, with added potential for carbon trading in future," adds Jim.

Source: Case study kindly provided by Terravesta

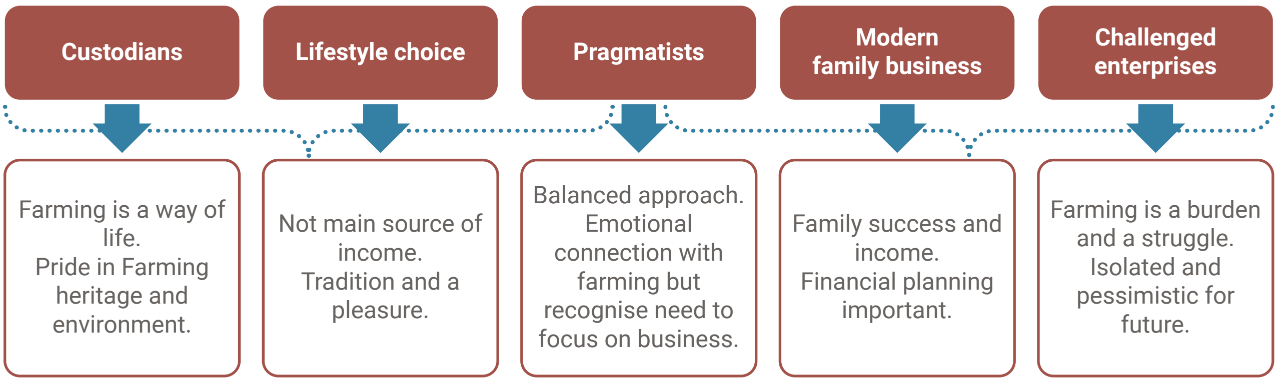
CHAPTER 4

Realising the benefits of energy crops for the UK

Delivering on the potential of UK energy crops requires us to understand the motivations of farmers and the existing barriers to scaling up domestically sourced energy crops.

The modelling in the previous sections quantifies the economic potential of farmers across the country, over the long term, to generate net positive farm business income from the production of this crop. However, as with other small, often family run businesses, a simple rational self-interest strategy is limited in fully accounting for how policy can support environmental best practice in farming. Research for Defra (Figure [6]) has set out to develop a taxonomy of different types of farm businesses, and their mindsets, approaches, and behaviours.

Figure 6: Farmer taxonomy



Source: Pike et al[57]

This means that to realise these potential benefits of a scaled-up domestic energy crop sector, policymakers need both to look to a range of other motivations, and how these all collectively feed into the barriers to scaling up domestic production of energy crops.

Drawing on research for this report, as well as research carried out for the CCC's Biomass in a Low Carbon Economy report,[58] there are a number of barriers that farmers face in scaling up energy crops domestically:

- **Economic barriers** – there is a noteworthy timing gap between planting and harvesting for perennial crops, and therefore in realising returns. As planting is the most expensive part of the process, this is likely to be prohibitive to many farmers, particularly when combined with a real or perceived lack of demand for these crops by end users. Furthermore, typical commercial arrangements for energy crops can challenge some farmers' desire for flexibility in how they change the use of land over time.

- **Policy barriers** – at present, policy fails to provide farmers with any confidence or certainty that they should begin planting the energy crops the UK needs to reach its environmental targets. This is true in that there is both a lack of confidence in consistent upstream demand (decisions pending on BECCS) or how the planting of these crops (or various other non-food crops) could be rewarded under post Brexit payment schemes , such as the Environmental Land Management Scheme (ELMS), as well as wider agriculture and land use policies. This kind of uncertainty is particularly damaging where, as discussed, this crop is sold on the basis of a multi-year relationship. There is a clear opportunity to align the environmental policy being developed by Defra with energy and decarbonisation policy being developed by BEIS, such that they reinforce each other. Energy crops in particular would benefit from this approach.

- **Cultural barriers** – some farmers prioritise non-economic objectives and may not switch to energy crops to realise the financial benefits as a result. Furthermore, they may have difficulty in shifting the perception of themselves from producers of food to producers of fibre for energy.
- **Knowledge/technical barriers** – significant steps forward have been identified and achieved over the past two decades both in selection and performance of cultivars and agronomic practices that need to be disseminated so that decision making is not based on 'old knowledge'. However, the energy crops sector is fairly nascent in the UK, and so there may be a view among farmers that they are not fully appraised of 'best practice' techniques which will allow them to take full advantage of planting these crops. The informal networks that we know are an important source of information for farmers are also underdeveloped as a result. In addition, more formal guidance on growing also contains significant gaps with regard to energy crops. One key example is the RB209 Fertilizer Manual, which currently does not cover several key aspects in relation to growing these crops, although it does over fertilizer and soil pH adjustments. The guidance document acknowledges it can only provide preliminary information based on a lack of reliable data.[59]
- **Contractual legal barriers** – affecting the ability of tenant farmers to grow perennial crops due to restrictive covenants and conventional lease durations that are shorter than a typical perennial crop growth and harvest cycle.

In addition to addressing these barriers to drive scale in domestic energy crop production, there is also a need to do this in a way which carries the greatest likelihood of fully capturing the sustainability benefits as explored in Chapter 3. This issue needs to be addressed by policy, too. Annex 2 looks at the history of previous policy to support the development of biomass feedstocks for energy production in the UK.

Policy recommendations

Creating certainty in energy crops demand to encourage take up

At present, there is little assurance for the farming and landowner communities that there will be demand and thus end users of energy crops. Strong demand signals are needed to overcome this, which can be significantly aided by clear policy decision-making from government. The existing bioenergy sector and associated supply chain would also benefit from a clear policy direction which ensures ongoing demand and new offtake contracts which support further development of BECCS.

Therefore, one key element of missing policy is the need for certainty in BECCS business models. This is crucial because, as set out in this report, BECCS will underpin the major growth in demand for biomass feedstocks in the UK. Without a predictable level of feedstock demand, farmers cannot make financial and other investments needed to begin planting energy crops. As such, a clear roadmap for the support available to BECCS in delivering negative emissions in the UK is required to provide the appropriate signals to farmers.

In this respect, a key concern is that there is currently no proper commercial support for BECCS in pricing in negative emissions, which as stated are essential to delivering net zero. This is rightly recognised by Government in the Biomass Policy Statement, which states: "existing models are not designed to value the negative emissions of BECCS projects in the power sector. The need to define the revenue mechanisms that will be used to reward CO_2 removals was also expressed by multiple stakeholders in response to our call for evidence."[60]

Given energy crops are a long-term commitment for farmers, Government needs to set clear signals in good time to support the resource and other investments needed, and so arriving at a decision and implementation on commercial models for BECCS swiftly is important in this respect. This is especially true given a scale up in planting needs to begin quickly.[61] The Government should therefore urgently address this matter.

Furthermore, while BECCS is likely to make up the majority of demand for energy crops in the future, consideration also needs to be given to other potential end uses of the crop which are crucial to enabling decarbonisation, and how their business models can be supported. For example, policy decisions on supporting SAF production later in 2022[62], and encouraging energy crop use across the bioeconomy.

Financial support for farmers

Crop planting is the most expensive activity when considering switching to energy crops - there's a gap of several years between planting and harvesting, and therefore expenditure and return. At present, unlike for forestry, there is no financial support available for farmers to facilitate the upfront investment needed to begin planting, since the previous government backed energy crop scheme closed in 2013.[63] Realising the various benefits that have been set out requires support to farmers that can bridge the gap they face between investment and return.

The Environmental Land Management Scheme (ELMS) has been highlighted as a potential route by which farmers can be supported with the upfront costs of energy crops. ELMS is founded on the principle of "public money for public goods", meaning that ELMS will provide farmers, foresters and other land managers with an opportunity to secure financial reward in return for delivering environmental benefits. As a result, ELMS could provide a route for delivering support for the co-benefits of planting energy crops and in doing so, incentivize their scale up.

In a similar vein, a bespoke payment which is separate to ELMS could be identified as the best route to incentivising the production of this crop. Whilst policy solutions are still being identified, it will be important for Defra to work with the sector and interested stakeholders to ensure a feasible approach is chosen – importantly, such a policy strategy must work in tandem with incentives or support for the end users, and must be operational for sustained periods of time (to mirror the longer-term harvesting cycle of perennial energy crops). In addition, this route must deliver the necessary carbon savings and on farm carbon sequestration in the coming years and decades. The objective should be to mainstream these crops within UK agriculture in order to maximise the potential benefits and provide long term and credible policy support to enable their sustainable scale up.

Need for a rural land use strategy

Survey information collected for this report anecdotally suggests that farmers already growing energy crops such as Miscanthus or SRC broadly do so in order to optimise the economic value of less suitable or productive land. Case studies collected by the Energy Technologies Institute reinforce this perspective. This aligns with the objectives of the CCC in its modelling for scaling up the planting of these energy crops.[64] This identifies a clear potential synergy in land allocation between the interests of farmers themselves and wider carbon and nature goals with respect to energy crops.

Land needs to deliver a number of different economic, social and environmental objectives over the coming years. Delivering food security is essential, alongside the restoration of nature in order to meet the Government's biodiversity targets. Alongside this, energy crops and BECCS provide a great opportunity for delivering negative emissions.[65]

Other organisations have set out the need for a strategy to support landowners to make decisions about the right use of land for the right purpose.[66] Alongside development of the Biomass Strategy, we believe a rural Land Use Strategy should be developed on land use in the UK, to help provide certainty to landowners, end users and investors. This strategy should not seek to dictate land use on a top down basis, rather it should seek to support farmers and landowners to deliver public goods alongside food, fuel and fibre.

Need for clear sustainability standards for energy crops and clarity in terms of criteria

In order to maximise the potential for negative emissions, robust, comprehensive and comparable sustainability standards are required for both domestic and imported biomass feedstocks. Effective sustainability criteria need to ensure that all feedstocks fully take into account lifecycle greenhouse gas emissions, land use change, biodiversity impacts, water quality, soil health, as well as socioeconomic criteria.[67]

The UK Biomass Policy Statement rightly calls for an approach to ensure that the UK's – already world-leading – sustainability standards for biomass continue to reflect best practice.[68] This means building on what already exists in current legislation and regulation (such as the Renewables Obligation) which regulates woody and non woody biomass used in the power sector.[69]

In addition, there is a need to deliver clarity and certainty to support expanding the production of domestic energy crops. Due to the barriers highlighted in this report, long term certainty around standards – as well as commercial drivers – are a key prerequisite for behaviour change.

Furthermore, the UK's updated standards must be accompanied by new and clear guidance to ensure effective implementation. While this is currently reflected in standards for forestry, there also needs to be a similar approach for energy crops. In order to avoid any duplication of effort and resource, updated standards should be clearly linked to any new financial support scheme.

Lack of information and support

The technical and cultural barriers identified are likely to contribute to an overall inertia in encouraging farmers to move, for example, from annual to perennial energy crops, at the required scale. If farmers cannot be confident in establishing energy crops on their land using best available techniques, then they are unlikely to move away from crops they know and feel familiar with.

Organisations such as the National Farmers Union (NFU), local NFU groups, and others (agronomists and land agents) have a key role to play in strengthening the information and support available to farmers in order to facilitate a mindset and behaviour change which can integrate energy crops into mainstream farming.

Conclusion

The significant public good attached to perennial energy crops for the UK is clear, particularly in the context of the macro challenges the country faces to renew its society and economy after the Coronavirus pandemic, whilst still tackling climate change. At present, this nascent sector requires support from industry and decision makers alike so that the full benefits can be realised. The solutions, however, are in our gift, and this report sets out a roadmap for policy decisions which can seize the energy crops opportunity in the 2020s and beyond.

Source: Terravesta

Annex 1: Approach to modelling

Energy crop modelling: Technical annex – (*All information correct as of October 2021*)

An initial exercise was undertaken by the Carter Jonas geospatial team to screen potentially eligible land for biomass crop production in England and Wales. All land was included with the exception of the following:

- Developed in any way (buildings, roads, hardstanding)
- Woodland
- Water (Rivers and Ponds)
- Roadside verges etc.
- Slope – Anything that has a slope more than 25%
- ALC land classification Grade 1 or Grade 5 – on the basis of Grade 1 land being too valuable to convert to energy cropping and Grade 5 land too poor to convert to energy cropping
- Any land within the boundaries of a National Park or Area of Outstanding Natural Beauty (AONB)

Land above an elevation of 300 metres was excluded for Miscanthus and SRC production but included for SRF production. The potential land area for SRF is thus slightly higher than it is for the other crops.

The total area of land identified in England and Wales using the above criteria is just over 7 million hectares of land – 7.03 million hectares for SRC and Miscanthus and 7.21 million hectares for SRF.

Biomass Crop Uptake / Penetration Rate

The CCC developed five scenarios for their Sixth Carbon Budget[70] that explore a range of ways to achieve Net Zero, by 2050 at the latest.

The base case scenario is called the **Balanced Net Zero Scenario** which assumes 700,000 ha of biomass crops in the UK by 2050. There are then four further scenarios:

- In the **Headwinds** scenario, they have assumed that policies only manage to bring forward societal and behavioural change and innovation at the lesser end of the scale of possible outcomes. This also assumes 700,000 ha of biomass crops in the UK by 2050.
- In the **Widespread Engagement** scenario, they assume higher levels of societal and behavioural changes. People and businesses are willing to make more changes to their behaviour. This reduces the need for biomass crops to 245,000 ha in the UK by 2050.
- In the **Widespread Innovation** scenario, they assume greater success in reducing the costs of low-carbon technologies. This allows more widespread electrification, a more resource and energy-efficient economy, and more cost-effective technologies to remove CO_2 from the atmosphere. This scenario has a more ambitious biomass crop target of 1.4 million ha by 2050.
- They also constructed a further exploratory scenario ('**Tailwinds**') that assumes considerable success on both innovation and societal / behavioural change and goes beyond the Balanced Pathway to achieve Net Zero before 2050. This scenario also has the more ambitious biomass crop target of 1.4 million ha by 2050.

The CCC further note with respect to their biomass crop assumptions:

We assume an immediate scaling up of the industry would be required from the mid-2020s in order to deliver the rates in our scenarios: 10,000, 30,000 or 60,000 hectares being added annually by 2035. This results in a total planted area of 0.2 million, 0.7 million or 1.4 million hectares by 2050. The lower level corresponds to a scenario where there is low BECCs capacity, while the middle and upper levels correspond to work by the Energy Technology Institute (ETI)[71].

Translating these UK areas into England and Wales only targets gives us the following[72]:

Baseline (700k UK)			Pessimistic (245k UK)			Optimistic (1400k UK)			5k Per Year Strategy		
	Area	Increase		**Area**	Increase		**Area**	Increase		**Area**	Increase
2020			2020			2020			2020		
2021			2021			2021			2021		
2022	**1,000**	1,000	2022	**0**	0	2022	**1,000**	1,000	2022	**5,000**	5,000
2023	**3,000**	2,000	2023	**1,000**	1,000	2023	**3,000**	2,000	2023	**10,000**	5,000
2024	**6,000**	3,000	2024	**3,000**	2,000	2024	**7,000**	4,000	2024	**15,000**	5,000
2025	**11,000**	5,000	2025	**5,000**	2,000	2025	**15,000**	8,000	2025	**20,000**	5,000
2026	**17,000**	6,000	2026	**8,000**	3,000	2026	**28,000**	13,000	2026	**25,000**	5,000
2027	**27,000**	10,000	2027	**12,000**	4,000	2027	**48,000**	20,000	2027	**30,000**	5,000
2028	**40,000**	13,000	2028	**17,000**	5,000	2028	**76,000**	28,000	2028	**35,000**	5,000
2029	**56,000**	16,000	2029	**23,000**	6,000	2029	**111,000**	35,000	2029	**40,000**	5,000
2030	**75,000**	19,000	2030	**30,000**	7,000	2030	**153,000**	42,000	2030	**45,000**	5,000
2031	**96,000**	21,000	2031	**39,000**	9,000	2031	**199,000**	46,000	2031	**50,000**	5,000
2032	**117,000**	21,000	2032	**48,000**	9,000	2032	**245,000**	46,000	2032	**55,000**	5,000
2033	**138,000**	21,000	2033	**57,000**	9,000	2033	**291,000**	46,000	2033	**60,000**	5,000
2034	**159,000**	21,000	2034	**66,000**	9,000	2034	**337,000**	46,000	2034	**65,000**	5,000
2035	**180,000**	21,000	2035	**75,000**	9,000	2035	**383,000**	46,000	2035	**70,000**	5,000
2036	**201,000**	21,000	2036	**84,000**	9,000	2036	**429,000**	46,000	2036	**75,000**	5,000
2037	**222,000**	21,000	2037	**93,000**	9,000	2037	**475,000**	46,000	2037	**80,000**	5,000
2038	**243,000**	21,000	2038	**102,000**	9,000	2038	**521,000**	46,000	2038	**85,000**	5,000
2039	**264,000**	21,000	2039	**111,000**	9,000	2039	**567,000**	46,000	2039	**90,000**	5,000
2040	**285,000**	21,000	2040	**120,000**	9,000	2040	**613,000**	46,000	2040	**95,000**	5,000
2041	**306,000**	21,000	2041	**129,000**	9,000	2041	**659,000**	46,000	2041	**100,000**	5,000
2042	**327,000**	21,000	2042	**138,000**	9,000	2042	**705,000**	46,000	2042	**105,000**	5,000
2043	**348,000**	21,000	2043	**147,000**	9,000	2043	**751,000**	46,000	2043	**110,000**	5,000
2044	**369,000**	21,000	2044	**156,000**	9,000	2044	**797,000**	46,000	2044	**115,000**	5,000
2045	**390,000**	21,000	2045	**165,000**	9,000	2045	**843,000**	46,000	2045	**120,000**	5,000
2046	**411,000**	21,000	2046	**174,000**	9,000	2046	**889,000**	46,000	2046	**125,000**	5,000
2047	**432,000**	21,000	2047	**183,000**	9,000	2047	**935,000**	46,000	2047	**130,000**	5,000
2048	**453,000**	21,000	2048	**192,000**	9,000	2048	**981,000**	46,000	2048	**135,000**	5,000
2049	**474,000**	21,000	2049	**201,000**	9,000	2049	**1,027,000**	46,000	2049	**140,000**	5,000
2050	**495,000**	21,000	2050	**210,000**	9,000	2050	**1,073,000**	46,000	2050	**145,000**	5,000
Average		17,069	Average		7,241	Average		37,000	Average		5,000

Table 1 – Biomass Crop Areas in England and Wales

Crop Choice

The different crops provide different economic and environmental benefits but some of the crops are more established than others.

From a farmer uptake perspective, **miscanthus** would be the obvious crop of choice – it is the dominant crop currently (75% of energy crop area) and is the most flexible in terms of management and, crucially, remediation. It can be harvested using a modified forage harvester annually and baled and the land remediated using ordinary cultivation equipment at the end of its life (15-20 years).

Currently SRC does not appear to offer substantial yield or economic performance benefits over miscanthus though it may have a longer life span (c. 30 years?) but potentially more remediation issues and there are some concerns about impact on soil structure and drainage. It may, however, suit individual sites better than Miscanthus due to local variations / factors.

SRF **may** offer higher overall yields in the medium to long term and it can be grown on more marginal land but is not commercially proven and it offers the most substantial remediation costs and in effect is a more permanent land use change.

In order to keep the modelling straightforward and reduce the number of outcomes, Miscanthus is used as the predominant crop in the model but references are made to others where appropriate.

On yields, the CCC note that: Productivity improvements though better agronomy and breeding can boost yields from the current average of 12 oven dried tonnes (odt)/hectare to between 15 and 20 odt/hectare by 2050 for both miscanthus and SRC. Current SRF yields of YC12[73] are assumed to remain unchanged.

The CCC do not provide a detailed justification on crop type, merely they note the following[74]:

Table 2 – Summary of CCC Bioenergy crop assumptions (with author's emphasis)

Balanced Net Zero / Headwinds (Baseline)	Bioenergy crop planting reaches 30,000 hectares by 2035, **equally split between miscanthus, SRC and SRF**. The total area with bioenergy crops rises to 0.7 million hectares by 2050. Energy crop yields increase to 15odt/hectare by 2050 driven by better agronomic practices and innovation. Harvested biomass products reach 1.8 million odt by 2035 and 6.4 million odt by 2050
Widespread Engagement (Pessimistic)	Energy crop planting drops to a third (10,000 hectares by 2035) of the level in the Balanced Pathway with **only miscanthus planted**. This results in 1 million odt and 3.4 million odt of harvested output by 2035 and 2050 respectively (p. 240)
Widespread Innovation / Tailwinds (Optimistic)	Energy crop planting doubles by 2035 and reaches 1.4 million hectares by 2050. Developments in innovation allow for miscanthus and SRC yields to increase by 33% to 20 odt per hectare by 2050. This results in the highest level of harvested products (4 million odt) by 2035.

For the purposes of the model, the increase in penetration has been heavily skewed towards Miscanthus only, in comparison to the even split proposed by the CCC (with the assumption that SRF will be grown on the land which is not suitable for miscanthus but at the penetration rates proposed it is insignificant).)

Based on a total eligible area of 7.2 million hectares, the scenarios above show the following 'penetration' rates:

- Baseline 495,000 ha 6.9%
- Pessimistic 210,000 ha 2.9%
- Optimistic 1,073,000 ha 14.9%
- 5k ha/year 145,000 ha 2.0%

Potential Crop Margins

It is usual to look at crop margins for energy crops over a life cycle of say 15 years (though crops may have a productive life of 20 years) because, as has already been noted:

- There is an initial up-front planting cost which needs to be averaged over the life cycle of the crop
- There will be no yield for the first few years and it may take until say year five or six for the crop to reach its full yield potential
- There may be some modest remediation costs at the end which need to be again averaged over the life of the crop

Miscanthus

Miscanthus species originate in Asia and they are perennial, rhizomatous grasses with lignified stems resembling bamboo. Once the plants are established (typically requires 3-4 years) Miscanthus has the potential for very high rates of growth, growing stems that are >3m within a single growing season. While there are many miscanthus genotypes, 'Miscanthus x giganteus' is presently the main one of value for biomass production.

Miscanthus is planted in spring and once planted can remain in situ for at least fifteen years. The miscanthus leaves fall off in the winter, contributing to the development of soil humus and nutrient cycling. Miscanthus produces bamboo-like canes during late spring and summer which are harvested in late winter or early spring. This growth pattern is repeated every year for the lifetime of the crop.

Miscanthus differs from short rotation coppice willow in that it gives an annual harvest and thus an annual income to the farmer. Miscanthus spreads naturally by means of underground storage organs known as rhizomes. However, their spread is slow and there is little risk of uncontrolled invasion of hedges or fields. These rhizomes can be split and the pieces re-planted to produce new plants.

All propagation, maintenance and harvest operations can be done with conventional farm machinery.

The growing and husbandry of Miscanthus is well documented in several handbooks, for example Teagasc/AFBI[75]

Using market prices of £80 per fresh tonne (Terravesta contract price)[76] and the CCC current yield of 12 odt/ha (15 fresh tonnes/ha) as the "pessimistic case', 16.5 fresh tonnes/ha as the 'baseline' case and 19.5 t/ha as the 'optomistic' case then current Miscanthus margins look something like the following:

Fifteen Year Crop Margins — **Based entirely on contractor costs for all operations.**

Base Information: Areas and Prices			
Crop Area			1
ODT & Fresh yield/ha	Optomistic	15.60	19.50
(full production)	Baseline	13.20	16.50
	Pessimistic	12.00	15.00
Weight of bale (kg)			615
Base price per tonne paid			80

Production and Establishment Costs		*£/ha*
Establishment Costs		1931.09
Glyphosate & applic Y2	1	21.37
Topping Y2	1	20.00
Harvesting cost/ha		85.00
Baling cost/bale		7.57
Remediation Costs		168.60

Handling Costs	*£/bale*
Loading in Field	£0.73
Transport to Yard/Storage	£0.38
Unloading and Stacking in Yard	£0.73
Loading Lorries	£0.91
Total	*£2.73*

Haulage Costs	*£/bale*
Articulated Lorry Cost per mile	£4.50
Bales per Lorry	36.00
Distance from Farm Store to Drax	35.00
Transport cost per bale	5.76

Optomistic — **High Performing**

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Yield Development (%)	*0%*	*0%*	*50%*	*65%*	*80%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*80%*
Yield (tonnes/ha)	0.00	0.00	9.75	12.68	15.60	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	15.54
Tonnes produced	0	0	9.75	12.675	15.6	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	15.54
Bales produced	0	0	16	21	25	32	32	32	32	32	32	32	32	32	32	25.26
Income	£0	£0	£780	£1,014	£1,248	£1,560	£1,560	£1,560	£1,560	£1,560	£1,560	£1,560	£1,560	£1,560	£1,560	1242.80
Establishment and Remediation Costs	-1,931	0	0	0	0	0	0	0	0	0	0	0	0	0	-169	-139.98
Husbandry Costs	0	-41	0	0	0	0	0	0	0	0	0	0	0	0	0	-2.76
Harvesting Costs	0	0	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-73.67
Baling Costs	0	0	-120	-156	-192	-240	-240	-240	-240	-240	-240	-240	-240	-240	-240	-191.22
Handling Costs	0	0	-43	-56	-69	-87	-87	-87	-87	-87	-87	-87	-87	-87	-87	-69.02
Haulage Costs	0	0	-91	-119	-146	-183	-183	-183	-183	-183	-183	-183	-183	-183	-183	-145.60
Costs	-1,931	-41	-340	-416	-493	-594	-594	-594	-594	-594	-594	-594	-594	-594	-763	-622.24
Net Cashflow	-1,931	-41	440	598	755	966	966	966	966	966	966	966	966	966	797	620.56
Average Margin	621															

Baseline — **Medium Performance**

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Yield Development (%)	*0%*	*0%*	*50%*	*65%*	*80%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*80%*
Yield (tonnes/ha)	0.00	0.00	8.25	10.73	13.20	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	16.50	13.15
Tonnes produced	0	0	8.25	10.725	13.2	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	13.15
Bales produced	0	0	13	17	21	27	27	27	27	27	27	27	27	27	27	21.37
Income	£0	£0	£660	£858	£1,056	£1,320	£1,320	£1,320	£1,320	£1,320	£1,320	£1,320	£1,320	£1,320	£1,320	1051.60
Establishment and Remediation Costs	-1,931	0	0	0	0	0	0	0	0	0	0	0	0	0	-169	-139.98
Husbandry Costs	0	-41	0	0	0	0	0	0	0	0	0	0	0	0	0	-2.76
Harvesting Costs	0	0	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-73.67
Baling Costs	0	0	-102	-132	-162	-203	-203	-203	-203	-203	-203	-203	-203	-203	-203	-161.80
Handling Costs	0	0	-37	-48	-59	-73	-73	-73	-73	-73	-73	-73	-73	-73	-73	-58.40
Haulage Costs	0	0	-77	-101	-124	-155	-155	-155	-155	-155	-155	-155	-155	-155	-155	-123.20
Costs	-1,931	-41	-301	-365	-430	-516	-516	-516	-516	-516	-516	-516	-516	-516	-685	-559.80
Net Cashflow	-1,931	-41	359	493	626	804	804	804	804	804	804	804	804	804	635	491.80
Average Margin	492															

Pessmimistic — **Low Performance**

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Yield Development (%)	*0%*	*0%*	*50%*	*65%*	*80%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*80%*
Yield (tonnes/ha)	0.00	0.00	7.50	9.75	12.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	11.95
Tonnes produced	0	0	7.5	9.75	12	15	15	15	15	15	15	15	15	15	15	11.95
Bales produced	0	0	12	16	20	24	24	24	24	24	24	24	24	24	24	19.43
Income	£0	£0	£600	£780	£960	£1,200	£1,200	£1,200	£1,200	£1,200	£1,200	£1,200	£1,200	£1,200	£1,200	956.00
Establishment and Remediation Costs	-1,931	0	0	0	0	0	0	0	0	0	0	0	0	0	-169	-139.98
Husbandry Costs	0	-41	0	0	0	0	0	0	0	0	0	0	0	0	0	-2.76
Harvesting Costs	0	0	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-85	-73.67
Baling Costs	0	0	-92	-120	-148	-185	-185	-185	-185	-185	-185	-185	-185	-185	-185	-147.09
Handling Costs	0	0	-33	-43	-53	-67	-67	-67	-67	-67	-67	-67	-67	-67	-67	-53.09
Haulage Costs	0	0	-70	-91	-112	-141	-141	-141	-141	-141	-141	-141	-141	-141	-141	-112.00
Costs	-1,931	-41	-281	-340	-398	-477	-477	-477	-477	-477	-477	-477	-477	-477	-645	-528.59
Net Cashflow	-1,931	-41	319	440	562	723	723	723	723	723	723	723	723	723	555	427.41
Average Margin	427															

Land Use Displacement

A further critical factor is what is the biomass energy cropping displaces.

CCC note that *"to maximise carbon sequestration, planting of energy crops (miscanthus and SRC) in our scenarios is limited to cropland and excluded from permanent grassland. Due to the higher soil carbon stocks planting energy crops on permanent grassland can increase net emissions with on-going soil carbon losses exceeding the carbon sequestered by the energy crop. SRF is grown on both cropland and grassland"*

There is, here, a direct trade-off between economic and environmental factors since the most economical displacement is to displace beef and sheep production (permanent grassland) yet the most carbon optimal solution is to displace more marginal crop production (arable land).

The model allows for two options:

- Displacement of arable land and permanent pasture on a pro-rata basis based on the existing land use in the constituency (apportioned using RPA data (England) and Europa data (Wales)
- Displacement of arable land only

Land use data is sourced from the regional agricultural profiles prepared by DEFRA[77]. Farm business income figures are from the Farm Business Survey for England[78] and Wales[79].

Arable land allocation is based on the regional profiles for combinable crops excluding higher value crops which are unlikely to be displaced e.g. sugar beet and potatoes.

Grassland allocation by dairy, beef and sheep has been estimated for information using livestock units[80] but the displacement calculations look at the net farm business income[81] foregone from arable farms only (and not higher value cropping farms) and beef and sheep farms only (and not dairy) on the basis it is unlikely these more profitable land uses would be displaced.

Value of Miscanthus Margin

A very simplistic calculation has been performed to estimate the total annual average economic value of the miscanthus crop at £80/tonne[82] using 2050 areas, assumptions on yield, and after subtracting the cost of miscanthus establishment, harvesting and transportation. These are broken down by constituency. By 2050, the farm-level value of this margin is as follows:

Baseline	Optimistic	Pessimistic	5k a year
£243m	£665m	£89m	£62m

Labour Requirements and Jobs Created

It is noted that one of the outcomes of this study is an estimation of jobs created. Energy crops are, by their very nature, not labour intensive as once the ground has been prepared there is minimal on-going husbandry requirements simply the task of the annual harvesting and handling of the crop.

Based on miscanthus planted areas, some FTE equivalents for planting, harvesting and haulage have been calculated based on 1 year out of 10 for planting (0.1) and 7 years out of 10 for harvesting (0.7) to give a blended average FTE over ten years.

Specific calculation of post farm gate employment has not been undertaken as it is dependent on many different factors relating to distance and destination but a standard multiplier of two additional beyond the farm gate jobs has been assumed. This is consistent with industry norms, for example from MAFF/DEFRA[83] and from US data[84].

Summary

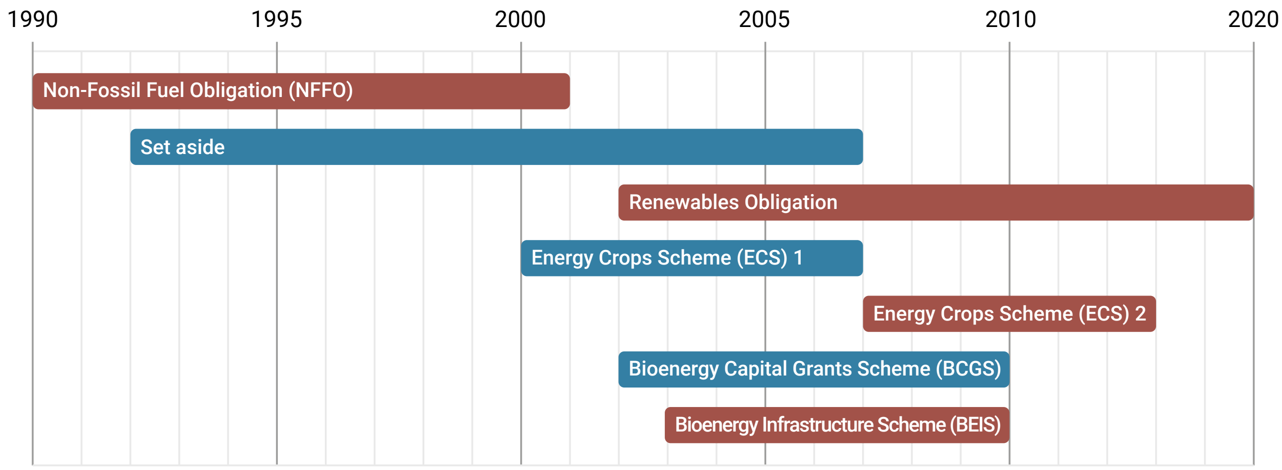
The key outcomes can be summarised as follows:

Economics Baseline				
Total crop area	495,000	ha		
Average crop yield per ha (allowing for productivity gains)	16.5	t/ha		
Tonnes produced (miscanthus)	8,167,500	tonnes		
Value of product (miscanthus)	653,400,000	GBP	£1,320.00	£/ha
FTE jobs	519			
Miscanthus net margin (FBI)	243,439,430	GBP	£491.80	£/ha
Farm level profit improvement - displace arable/grass*	131,105,211	GBP	£264.86	£/ha
Farm level profit improvement - displace arable only*	89,894,093	GBP	£181.60	£/ha
Economics Pessimistic				
Total crop area	210,000	ha		
Average crop yield per ha (no productivity gains)	15	t/ha		
Tonnes produced (miscanthus)	3,150,000	tonnes		
Value of product (miscanthus)	252,000,000	GBP	£1,200.00	£/ha
FTE jobs	220			
Miscanthus net margin (FBI)	89,757,136	GBP	£427.41	£/ha
Farm level profit improvement - displace arable/grass*	42,100,195	GBP	£200.48	£/ha
Farm level profit improvement - displace arable only*	24,616,690	GBP	£117.22	£/ha
Economics Optimistic				
Total crop area	1,073,000	ha		
Average crop yield per ha (allowing for productivity gains)	19.5	t/ha		
Tonnes produced (miscanthus)	20,923,500	tonnes		
Value of product (miscanthus)	1,673,880,000	GBP	£1,560.00	£/ha
FTE jobs	1124			
Miscanthus net margin (FBI)	665,861,539	GBP	£620.56	£/ha
Farm level profit improvement - displace arable/grass*	422,357,262	GBP	£393.62	£/ha
Farm level profit improvement - displace arable only*	333,024,879	GBP	£310.37	£/ha
Economics 5k-year				
Total crop area	145,000	ha		
Average crop yield per ha (no productivity gains)	15	t/ha		
Tonnes produced (miscanthus)	2,175,000	tonnes		
Value of product (miscanthus)	174,000,000	GBP	£1,200.00	£/ha
FTE jobs	152			
Miscanthus net margin (FBI)	61,915,000	GBP	£427.00	£/ha
Farm level profit improvement - displace arable/grass*	29,009,017	GBP	£200.06	£/ha
Farm level profit improvement - displace arable only*	16,937,073	GBP	£116.81	£/ha
* Farm level profit improvement is based on the difference between Miscanthus FBI and the displaced arable or grassland enterprise FBI				
Note: Miscanthus yields and performance based on national averages; variation in topography and climate will mean some regional performance differences				

Annex 2: History of bioenergy policy in the UK

This Annex provides some background to bioenergy policy in the UK since 1990, and is largely based on a wide ranging review of these policies conducted by Adams and Lindegaard.[85]

Figure 7: Timeline of bioenergy policies



A brief summary of some of the key historic policies to support bioenergy in the UK can be found below:

- **Non Fossil Fuel Obligation (NFFO) –** stimulated the market for renewable electricity by mandating electricity companies to purchase a proportion of non-fossil fuel electricity. Ultimately only led to one approved project, Project Arable Biomass Renewable Energy (ARBRE) which failed for a multitude of reasons.
- **Renewables Obligation (RO) –** this was set up to place an obligation on electricity suppliers to source a fixed percentage of their electricity from renewable sources. This helped to stimulate a market for domestic energy crops for a time, but the criteria in the RO were sufficiently wide to allows for cheap foreign imports of these crops.
- **Energy Crop Scheme –** this was a grant to help with the upfront costs of planting energy crops. The ECS did support planting of just over 12,000 ha of energy crops, but only 17.6% of the total budget for the scheme was spent. A number of reasons have been given for the significant underspend. Because there was no support after crop establishment, it took farmers up to 10 years to make a profit on planting. Furthermore, there was a lack of support for the infrastructure needed to support the planting of energy crops. The bureaucracy associated with the scheme has also been cited as a factor.
- **Bioenergy Infrastructure Scheme (BEIS) –** a market incentive to help develop the supply chain required to harvest, process, store and supply biomass to end users. Overall, 79 projects were supported with £7m of funding. This was successful in strengthening the biomass supply chain, and the scheme was highly subscribed. Ultimately, the scheme was scrapped upon the advent of austerity in 2010. This led to the removal of much of the biomass planting that had been supported.
- **Bioenergy Capital Grants Scheme (BCGS) –** a series of capital grants for power stations and Combined Heat and Power projects, designed to act as a “pull” incentive for domestic energy crops production. Overall, the scheme supported four dedicated electricity and seven CHP projects with an installed electrical capacity of 101.3 MW.

- **Set-aside –** this refers to land that farmers must not dedicate to any agricultural purpose, in order to prevent over production, introduced by the European Economic Community (EEC) in 1992. Over 90,000 ha of set aside land was used for non-food crops, the vast majority of this being oilseed rape.
- **Energy Aid payment scheme –** a grant to support the production of energy crops on non-set-aside land. It supported 507,000 ha over the six years it was in place, but over 98% of this went to winter oilseed rape.

In their conclusions, Adams and Lindegaard state:

"Since, 1990 none of the projects, initiatives or schemes described can be viewed as an absolute success for the energy crops sector. The main obstacles that have hindered progress include: the lack of long term supportive energy crops policy, the failure of headline projects and organisations, the lack of competitiveness of long term perennial crop options compared to annual crops, bureaucracy of schemes, the inability of the voice of the energy crops industry to be heard when pitted against larger sectors, and the reluctance of Government to heed recommendations of independent authorities.

25 years of failed energy crops policy suggests that there needs to be a long term strategy and action plan adopted – an energy crops road map towards 2020, 2030 and 2050 targets/aspirations is required. Future support for the sector should consider joining up policy between different Government departments to recognise multifunctional benefits of perennial energy crops. The burden of risk should be shared between suppliers and end-users with local authorities and Local Enterprise Partnerships (LEPs) perhaps providing the support for local heat markets.

Key lessons to learn for future policy-making include developing smaller-scale projects that use established technologies, introduce energy crops in a phased manner so local supply can develop at a steady pace, ensure that supply-side measures are balanced with demand-side incentives, provide grants on the basis of importance of infrastructure, design establishment grant schemes so they manage cashflows more effectively and be linked with end-user markets, provide a competitive advantage for local supply compared to imports, and the administration of schemes could be streamlined."

Endnotes

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