Department for Transport

Department of Energy & Climate Change

Department for Environment Food and Rural Affairs

UK Bioenergy Strategy

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Ministerial Foreword

A secure and cost-effective supply of low carbon energy is one of the goals of our Carbon Plan. Used wisely, energy from biomass can make an important contribution to decarbonisation. But used in the wrong ways bioenergy can actually confound our aims, releasing more carbon into the atmosphere and putting at risk fundamental objectives such as food security.

The issues surrounding bioenergy are complex. It is the only renewable source that can be used across all three energy sectors (transport, heat and electricity) and crucially the only one that requires the ongoing use of a fuel that has a cost to supply, compared to sun or wind that are freely available. The limitations to that fuel supply and the competing ways to use the same material and land, from food and construction to natural habitats, add much to the challenge of using bioenergy well.

This strategy is an important framework document. It sets out the Coalition Government's approach to achieving sustainable, low-carbon bioenergy deployment by defining a framework of principles that will govern future policies. These principles set the ground rules for the use of bioenergy so we can be confident that policies which abide by them will deliver genuine benefits. The strategy sets out a systematic way to approach the more challenging issues connected with bioenergy: it describes a framework of principles for future policy development and sets out a broad hierarchy of uses in energy while considering non-energy sectors, but does not set policies and delivery measures and does not dictate how biomass must be used.

In summary, bioenergy can be an important part of the energy mix which will allow the UK to meet its energy and climate change objectives, including the 2020 renewables targets and 2050 carbon reductions targets. We are clear that only bioenergy from sustainable sources should be used to do this. We are confident that this strategy will provide stakeholders with clarity on Government's vision for bioenergy and encourage the sustainable development of the sector. We will continue to engage with businesses in the bioenergy sector and non-energy users of biomass to ensure that the same clarity applies to specific policies in this area.

The strategy is the result of extensive analytical work by a cross Government team, which has been shaped by contributions from a number of external agencies and advisory bodies. The team also drew widely on broader expertise and on the perspectives of many with an interest in the development and impacts of bioenergy, including the Committee on Climate Change's Bioenergy Review (to which this strategy responds). We would like to thank all of those who worked so hard on its development.

Charles Hendry
Minister of State for Energy

Lord Taylor of Holbeach
Parliamentary Under Secretary of State for Environment, Food and Rural Affairs

Norman Baker
Parliamentary Under Secretary of State for Transport.

Contents

Executive Summary

1 It is widely recognised that bioenergy has an important role to play if the UK is to meet its low carbon objectives by 2050[1]. Excluding biomass from the energy mix would significantly increase the cost of decarbonising our energy system – an increase estimated by recent analysis at £44 billion[2]. As set out in the 2011 UK Renewable Energy Roadmap, bioenergy is also an important part of the Government's plans to meet the Renewable Energy Directive objectives in 2020. There are however risks and uncertainties associated with bioenergy: whether it genuinely contributes to carbon reductions; the availability and price of sufficient sustainably-sourced biomass; the relationship between bioenergy and other uses of land, such as food production, and other uses of biomass, such as for construction materials; the environmental impacts on air quality, biodiversity and water resources.

2 This strategy sets out the Coalition Government's approach to securing the benefits of bioenergy. It is the result of extensive analysis by a Cross Government team. In considering how to secure these benefits we have examined the wide range of evidence on the availability of sustainably-produced biomass feedstocks to UK users, the likely carbon impacts of bioenergy compared to possible alternative uses of the biomass resource; and the role of biomass in the energy system compared to other choices for low-carbon energy. The strategy also builds on analysis used for the Committee on Climate Change's Bioenergy Review and includes the Coalition Government's response to that review[3].

3 While we have tried to keep this document as accessible as possible, it is primarily aimed at those with a professional interest in bioenergy and bioenergy policy.

Bioenergy principles: our approach to bioenergy in the UK

4 The UK Government has a responsibility to ensure that its policies only support bioenergy use in the right circumstances. This strategy is based on a statement of four principles which will act as a framework for future government policy on bioenergy.

5 In summary the four principles state that:

- Policies that support bioenergy should deliver genuine carbon reductions that help meet UK carbon emissions objectives to 2050 and beyond.
- Support for bioenergy should make a cost effective contribution to UK carbon emission objectives in the context of overall energy goals.
- Support for bioenergy should aim to maximise the overall benefits and minimise costs (quantifiable and non-quantifiable) across the economy.

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1 DECC, 2050 pathways analysis.

2 Energy Technologies Institute, ESME modelling.

3 CCC Bioenergy review, December 2011.

- At regular time intervals and when policies promote significant additional demand for bioenergy in the UK, beyond that envisaged by current use, policy makers should assess and respond to the impacts of this increased deployment on other areas, such as food security and biodiversity.

6 These principles have been implicit in many of the policies pursued in the recent past, but this is the first time they have been articulated in this way, and the first time the likely implications of each principle for future policy direction has been considered systematically.

7 The aim of these principles is to provide stakeholders with clarity on the circumstances in which Government is likely to be willing to support bioenergy. They will assist policy development and decisions where there are uncertainties and trade-offs. Unlike targets and rules, this principles-based system is flexible enough to remain valid in the face of evolving evidence and technological development and innovation.

8 Clear, enforceable, transparent sustainability criteria have a key role to play across the policy landscape in distinguishing between bioenergy production and use which is consistent with these principles and that which isn't. The pre-eminent concern of the UK Government in bioenergy policy is that bioenergy offers a genuine reduction in greenhouse gas emissions, that this reduction is cost effective and that the biomass is produced sustainably.

9 The strategy notes that current sustainability standards applied to renewables incentives will need to be more stringent in order to meet the principles. This should be done on an ambitious timetable which also allows the supply chain to respond. The introduction of global carbon accounting would increase transparency and so the UK will continue to press for this. The strategy sets out some of the actions that the Government will be taking to create a sustainable path towards meeting the long term aspirations set out by the principles framework including:

- Improving the opportunities from domestic supplies
- Promoting the development of sustainable supply markets
- Promoting the deployment of low-risk technological options

The strategic context for bioenergy

10 The strategy explores the strategic context for bioenergy which will inform the application of the principles. In summary, any future policy should note:

i. The carbon impacts of wood uses: our analysis indicates that the use of wood and energy crops for bioenergy is a good carbon reduction option compared to alternative uses of the resource in certain circumstances but not all.

ii. The potential scale of bioenergy deployment: although highly uncertain, our analysis indicates that sustainably-sourced bioenergy[4] could contribute by 2020 around 8-11% to the UK's total primary energy demand and around 12% by 2050 (within a wide range of 8%-21%). This conclusion is consistent with many other studies. International supplies, particularly from North America, will be a key contributor to this deployment.

iii. The potential impact on non-energy sectors: Non-energy sectors will be impacted by the growth of bioenergy in the UK and other countries. The strategy considers how those impacts should be managed.

iv. The potential impact on food and food production: Bioenergy development can impact on food production and prices, biodiversity and other environmental objectives, and international development and poverty reduction. Our analysis suggests that while UK policy has had limited detrimental impacts so far, there are some tensions and these could grow if bioenergy develops in the wrong way, for example if suitable environmental or social controls are lacking.

11 A defining characteristic of the global bioenergy sector is the high degree of uncertainty surrounding its long term development and the capacity for sustainable increases in biomass supply. Applying the principles requires a careful consideration of this uncertainty against the case need for action in the short term. In order to manage this uncertainty, we will continue to engage with businesses in the bioenergy sector and with non-energy users of biomass, as we have done during the preparation of this strategy. This applies both to new policy measures in this area and to monitoring the direct and indirect impacts of policies once they have been introduced.

12 However, we have not concluded that this uncertainty is so great as to justify inaction. The strategy defines a set of low-risk energy deployment pathways that, based on the current evidence, will be very likely to correspond to the principles and will allow us to develop a bioenergy sector that contributes towards both our to longer term decarbonisation targets as well as 2020 renewable objectives. In summary, these are:

- **Wastes**: use of end-of-life materials for energy can be an optimum use of biomass, where it maximises carbon and cost effectiveness, and where it is consistent with the waste hierarchy;
- **Heat**: use of biomass to provide low carbon heat for buildings and industry (process heating), through either biomass boilers or through use of biomethane. Use of recoverable waste heat from low carbon power generation or industrial processes is also an important component of this pathway;
- **Transport**: provided that sustainability can be assured, and while fossil fuels continue to be used in transport, some biofuels can offer a cost effective contribution to reducing carbon emissions from road transport. There is potential for significant growth in biofuel use, in road and other sectors, in the medium and long term, if advanced technologies using wastes and woody feedstocks are commercialised;

4 Sustainably sourced biomass refers to biomass feedstocks that have not been sourced from high carbon stock land (e.g. peat land or virgin forest) or land that is required for competing uses (e.g. food).

- **Electricity**: use of sustainable biomass as a transitional fuel to reduce carbon emissions from current coal power generation is an important decarbonisation pathway. In addition, combined heat and power generation offers more efficient use of the biomass resources and should be promoted where possible.

The long term development of the bioenergy sector

13 A key finding of the modelling and analysis prepared for this strategy is that over the longer term, the most appropriate energy use will vary according to the availability of carbon capture and storage. Assuming carbon capture and storage for biomass-fuelled systems is available, bioenergy use for electricity and transport could be the most appropriate use.

14 The strategy also identifies the development of biosynthetic gas, hydrogen and advanced biofuels as the key bioenergy hedging options against these inherent long term uncertainties. To realise these opportunities, Government needs to continue to support UK technology research, development and demonstration to provide the fullest range of options that will enable the deployment of the low-risk pathways noted above. This innovation support should aim to sustainably increase feedstock energy yields and develop cost effective process and conversion technologies to optimise energy efficiency and minimise carbon emissions.

15 The principles framework is intended to be durable in a range of circumstances. However the evolving nature of the evidence on supply, demand, innovation and bioenergy alternatives makes it necessary for Government to periodically revisit the analysis supporting this strategy. Stakeholder feedback has indicated that five yearly reviews may be required to take stock of the continued potential for sustainable expansion and inform future policy decisions as these are being shaped.

The Bioenergy Strategy and the Committee on Climate Change's Bioenergy Review

The Committee on Climate Change (CCC) is an expert, independent public body, created to assess how the UK can best achieve its emissions reduction targets for 2020 and 2050 and to assess progress towards the statutory carbon budgets. It was created by the Climate Change Act 2008 and plays a crucial role in the UK's effort to tackle climate change.

Over the past year, the Government has worked closely with the CCC in developing a better understanding of the evidence surrounding bioenergy. The CCC Bioenergy Review includes important analysis that adds clarity and expertise to the complex bioenergy landscape. The Government shares CCC's view that bioenergy has an important role to play in meeting 2050 commitments and putting the UK in a sound position for a longer term low carbon future.

The box below sets out the Government response to the main recommendations made in the review.

Box 1: Government response to CCC's recommendations

CCC Recommendation: Bioenergy penetration. The Government should plan for levels of bioenergy penetration of around 10% of primary energy but no higher to meet the 2050 target.

> **Government Response:** Provided the right mechanisms are in place to guard against unsustainable practices the analysis presented in this strategy indicates that by 2050 bioenergy penetration levels of around 12% could be feasible without jeopardising sustainability[5]. This scenario is highly dependent on the availability of sustainable feedstocks, but it is consistent with other studies in this area[6]. We will however continue to evaluate possible future penetration of bioenergy as we move beyond 2020.

CCC Recommendation: Liquid biofuels sustainability. The Government should argue strongly for extending the European sustainability framework under the Renewable Energy Directive to cover indirect land use change (ILUC) emissions. This should either be through the use of ILUC factors or by capping the use of feedstocks with associated risks of ILUC at sustainable levels.

> **Government Response:** We agree. The sustainability of liquid biofuels must be assured and ILUC should be robustly addressed in European policy. We believe that the use of appropriate ILUC factors is the best approach to achieving this and superior to other options. We are working with European partners and the European Commission to seek a resolution to this issue.

CCC Recommendation: Forest biomass sustainability. The minimum emissions threshold under the sustainability framework should fall from 285 to 200g of CO_2 per kWh. Serious consideration should also be given to introducing a sustainability standard for all wood used in the UK (e.g. pulp and paper, construction) which would provide more confidence that support for biomass in power does not result in indirect deforestation.

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5 Sustainably sourced biomass refers to biomass feedstocks that have not been sourced from high carbon stock land (e.g. peat land or virgin forest) or land that is required for competing uses (e.g. food).

6 UKERC, Energy from biomass: The size of the global resource, 2011

Box 1: Government response to CCC's recommendations

Government Response: We agree with the need for tighter sustainability standards in the future in line with our ambition to decarbonise the UK's energy supplies out to 2030 and 2050. We are clear that any changes to sustainability standards need to be made with sufficient lead times to allow industry to respond in cost effective way. We are exploring this with developers.

The UK Forest Standard sets out Government's approach to sustainable forest management in the UK, regardless of how the wood is ultimately used. The Government's timber procurement policy requires all domestic and imported wood products procured by central Government bodies, agencies and NDPBs[7] to meet legality and sustainability criteria or to be licensed under the Forest Law Enforcement, Governance and Trade measures. Local Government and the wider public sector are also encouraged to comply with them. In addition, the EU timber regulation is designed to ensure that only legally harvested timber can be placed on the EU market. Enforcement of this new regulatory framework and the Government's procurement policy could help ensure forest based bioenergy supply chains develop sustainably. We will also do further analysis to assess whether the increased use of biomass in the UK is likely to add significantly to global deforestation pressures.

CCC Recommendation: Flexibility of targets. Liquid biofuels targets under the Renewable Transport Fuel Obligation and biomass targets in the Renewable Energy Strategy should be regarded as flexible and adjusted in the event that there is insufficient supply of sustainable bioenergy. No new targets for longer-term bioenergy penetration should be set until new regulatory arrangements are introduced to ensure achievement of sustainability objectives.

Government Response: We are committed to meet the legally binding EU targets for renewable energy use in 2020 and to the principle that only sustainably-sourced feedstocks should be used for energy. We will continue to reflect this commitment in UK policy. This includes ongoing monitoring of the safe and sustainable deployment of bioenergy and of the progress towards the target in the light of changing evidence on areas such as indirect land use change.

We recognise that tensions could exist between bioenergy and food prices. Biofuels mandates that can be temporarily flexed or otherwise relaxed at times of agricultural price pressures have been raised in international fora as possible solutions for reducing the severity of these spikes. We will be undertaking further analysis on the potential merits of this and other mitigating options in the coming months.

CCC Recommendation: Accounting. Any new global agreement limiting emissions should fully account for agriculture, forestry and land use change emissions, including those related to the use of bioenergy.

Government Response: We worked to secure agreement to this at the United Nations Framework Convention on Climate Change (UNFCCC) Conference in Durban and will continue to do so. Although the outcome of the Durban conference does not specifically address this issue, the UK is taking action through the Subsidiary Body for Scientific and Technological Advice (SBSTA) with the aim of developing and implementing a work programme in agriculture.

7 Non-Departmental Public Bodies

Box 1: Government response to CCC's recommendations

CCC Recommendation: Carbon capture and storage (CCS) demonstration. CCS should be demonstrated as a matter of urgency, particularly because the negative emissions ensuing when this is used with biomass may be required to meet long-term emissions targets.

> **Government Response:** We agree. The Government is committed to supporting the commercial deployment of CCS. On 3rd April we published a CCS Roadmap and launched a competition for CCS projects. We are participating through the Energy Technologies Institute in the first stages of its engineering study on the issues surrounding biomass and CCS.

CCC Recommendation: Biomass power generation. Support for biomass power generation under the Renewables Obligation (RO) should be focused on co-firing and conversion of existing coal power plants. Any support for new dedicated biomass generation should be limited to small-scale only or, at a minimum, any support for new large-scale dedicated biomass should be limited to a very small number of projects.

> **Government Response:** We agree that the main focus for biomass in power generation should be coal replacement. New dedicated biomass will have a limited role as part of the wider energy mix, focusing on cost effective deployment and carbon abatement opportunities, in line with the principles set out in this strategy.

CCC Recommendation: Biomass heat generation and biogas production. There should be continued support for the use of biomass in heat generation and production of biogas from waste under the Renewable Heat Incentive.

> **Government Response:** Bioenergy can play a role in decarbonising sectors that have limited alternatives, such as industrial heat. The Government's Heat strategy explores further the wider decarbonisation options for heat.

CCC Recommendation: Support for non-bioenergy technologies. Going beyond bioenergy, our analysis confirms the need to continue incentivising energy efficiency improvement, decarbonisation of the power sector, use of heat pumps in buildings, and electric vehicles.

> **Government Response:** We support this, which is why we've taken the measures set out in the Carbon Plan, Green Deal and more. We have also committed £400m to support the market for ultra low emission vehicles which includes consumer incentives, infrastructure provision and focused research and development.

CCC Recommendation: The Government should include in its forthcoming bioenergy strategy an assessment of the global wood industry, with a view to understanding the demand-supply balance associated with increasing use of bioenergy in the UK and other countries.

> **Government Response:** Understanding the implications of bioenergy growth for other user of wood was a key driver for this strategy. We will continue to update our evidence base as necessary given the uncertainties over demand and supply going forward and the evolving nature of the traditional uses of biomass. We will also undertake further analysis of whether the projected additional demand for wood for bioenergy is likely to lead to a significant increase in global deforestation pressures and use that to inform future reviews of bioenergy policies.

Section 1 – Introduction

1.1 Over the past year, Government departments, including Cabinet Office, DECC, Defra, DfT, BIS, the Forestry Commission, DFID, FCO and HMT have been working jointly with Devolved Administrations in evaluating the risks and opportunities surrounding bioenergy to 2020 and to 2050. As part of this assessment we have:

a. Revisited our analysis on the future potential of sustainable supplies of biomass feedstocks;

b. Undertaken analysis of the wider sustainability issues surrounding bioenergy, including the links between UK bioenergy deployment and food prices;

c. Commissioned new analysis with independent experts on the carbon impacts of using wood and energy crops in energy versus other uses;

d. Undertaken extensive analysis of the role of innovation in the bioenergy sector;

e. Commissioned new analysis on the appropriate bioenergy deployment pathways;

f. Analysed the potential links between bioenergy and the wider bio-economy[8].

1.2 Over this period, our analysis and findings have been informed and shaped by close collaboration with a number of agencies and advisory bodies, including the Committee on Climate Change, National Non Food Crops Centre (NNFCC), the Biotechnology and Biological Sciences Research Council (BBSRC) and the Environment Agency. Industry, NGOs and wider stakeholders with an interest in bioenergy have also played a crucial role in developing our analysis through a series of workshops and meetings that took place over the last year.

1.3 The findings of this work are presented in this strategy and the accompanying analytical annex and reports. The strategy does not review specific policies that the Government has introduced to support bioenergy use or pathways by which we expect to meet our renewable energy and carbon reduction targets. The analysis underpinning the strategy analysis has enabled us to develop a set of low-risk actions for the future development of bioenergy in the UK that will shape future policy decisions.

Bioenergy: the policy context

1.4 Bioenergy is one of the most versatile forms of low carbon and renewable energy as it can contribute towards energy generation across the energy spectrum of electricity, heat and transport (see Annex A). In all three sectors, biomass can provide a continuous and constant flow of energy with less variability than some renewable energy sources.

8 More information can be found in the accompanying Analytical Annex

1.5 In the electricity sector, bioenergy offers dispatchable generation with benefits for managing the wider electricity system; in the heat sector it allows the generation of high grade heat that cannot be easily achieved though other low carbon sources; in transport it offers opportunities alongside other Ultra Low Emissions Vehicles (ULEVs) powered by batteries, hydrogen fuel cells for moving away from oil and may be particularly valuable for decarbonising areas such as aviation and heavy good vehicles where there are fewer alternatives to liquid fuels.

1.6 Bioenergy can therefore be an important part of the energy mix, contributing to the long term emissions reductions needed in a carbon constrained world and wider energy objectives such as the 2020 renewables target.

Box 2: UK Government's legally binding targets

2020 Renewables Target: The 2009 Renewable Energy Directive sets a target for the UK to achieve 15% of its energy consumption from renewable sources by 2020. This compares to 3.3% in 2010. The scale of the increase over the next 8 years represents a huge challenge and will require strong contributions from all three sectors of electricity, heat and transport.

2050 Carbon Reduction Target: The Climate Change Act 2008 establishes a long-term framework to tackle climate change. The Act aims to encourage the transition to a low-carbon economy in the UK through unilateral legally binding emissions reduction targets. This means a domestic greenhouse gas emissions reduction of at least 80 percent by 2050 and a reduction of emissions of at least 34% by 2020. Both targets are against a 1990 baseline. The 2008 Act also requires us, to lay regulation to the extent and circumstances in which emissions from international aviation and shipping should be brought within this target, or explain to Parliament why we have not done so, by December 2012.

1.7 Bioenergy can also offer wider opportunities. The diversity of types of biomass that can be used for energy purposes contributes to a diversified energy mix that improves energy security. Through the collection or growth of biomass feedstocks, bioenergy can boost agriculture, forestry and waste management sectors while the transportation and storage of these feedstocks can create new commercial opportunities across the economy[9]. If waste is used as a feedstock for bioenergy, quantities of waste being sent to landfill can be reduced, while greater awareness of the value of biomass may encourage owners of small woodlands to take a greater interest in active sustainable management, which can in turn improve local biodiversity[10].

1.8 However despite the many positives associated with the use of biomass for the production of bioenergy, its use is not without risks. Bioenergy is not automatically low carbon, renewable or sustainable. For example, there are potential indirect impacts of bioenergy on land use that can significantly change the carbon stored in land across the world. This creates the risk that some forms of bioenergy could result in greater greenhouse gas emissions than fossil fuels (see Annex B). Furthermore, poor resource management can lead to significant environmental, social and economic impacts that could outweigh

9 NNFCC, UK jobs in the bioenergy sectors by 2020, 2011

10 Forestry Commission, Woodfuel Implementation Plan, 2011–2014

bioenergy's wider energy benefits. In a world of rising populations, demographic changes and increased demand for food and water[11] the growing demand for bioenergy feedstocks, and the land that these require, could put even greater pressure on resources, unless managed prudently. Use of biomass for energy can also create challenges for other biomass using sectors that compete for the available supplies, both domestically and internationally. The international nature of the bioenergy market also adds further complexity.

1.9 Currently bioenergy accounts for 3% of total primary energy consumption in the UK with the majority (65%) being used in power generation. Its relative cost effectiveness against other alternative renewable technologies[12] makes it an attractive option for contributing towards the delivery of our renewables target which requires us to generate around 227 TWh[13] of energy from renewable sources by 2020. However it is essential that bioenergy which contributes to our short and medium term targets, such as the 2020 renewable energy targets, also puts the UK in a good place for longer term decarbonisation. This strategy defines a framework of principles that set out the key criteria for determining the right course of future bioenergy deployment and by using current evidence develops a set of low risk actions that will set sustainable deployment pathways for biomass in the context of our future energy system.

Box 3: Stakeholder feedback – what we have learned

We ran an informal evidence gathering process in the autumn and winter of 2011, including written evidence, individual meetings between key stakeholders and team members and collective stakeholder meetings.

We heard from: academics working on bioenergy; professional associations representing bioenergy businesses; environmental groups and development charities; power generators; those with a business concern in bioenergy and other professional interests.

We are extremely grateful for their responses, all of which have informed the development of this report. We have not attempted a comprehensive summary, but this box highlights some repeated themes.

All stakeholders wanted Government to set clear policy. Bioenergy businesses raised the need for:

- a clear signal that bioenergy is an important part of the energy mix;
- policy decisions to be sensitive to the longer timescales over which investment decisions are made;
- Government action to do more to facilitate development of new technologies and 'first of a kind' approaches;

11 United Nations Environment Programme, Division of Technology, Industry, and Economics: The Future of Food and Farming: Challenges and choices for global sustainability, Foresight, Government Office of Science, January 2011

12 See accompanying Analytical Annex

13 DECC estimate based on Updated Energy Projections 43

Box 3: Stakeholder feedback – what we have learned

- Ministers to focus public attention on UK opportunities from bioenergy, particularly those accruing from innovation and research, as well as risks.

Bioenergy businesses also expressed concerns about the impact of European level decisions on UK business competitiveness and the effects of different subsidy and sustainability regimes in competing countries.

Non-energy users of biomass expressed strong concerns about the impact of subsidising the use of biomass for bioenergy on their businesses, in particular the price and availability of wood. They also noted the need to take advantage of opportunities that maximise overall the carbon and economic benefits of woody biomass. This is explored in Section 3, in particular Box 8.

Environmental and development groups expressed concerns about:

- sustainability issues, particularly of imports, including fears about carbon savings arising from carbon accounting issues;
- emissions from direct and indirect land use change, including deforestation pressures;
- enforceability of sustainability criteria;
- instances of apparent poor corporate behaviour in the developing world incentivised by European biofuels demand;
- the link between bioenergy and food prices.

There was a recognition that there are many different estimates of potential supply. All estimates are characterised by different assumptions which leads to a considerable range of uncertainty. However, the vast majority agree that there is likely to be a large enough supply of feedstocks to enable bioenergy to make a worthwhile contribution.

Section 2 – A framework of principles governing UK bioenergy policy

2.1 The Government has a responsibility to ensure that its policies only support bioenergy use in the right circumstances (recognising that government policies are only one of the many factors which affect how biomass is used in the energy system).

2.2 This strategy is based on a statement of four principles which will act as a framework for future government policy on bioenergy. The aim of these principles is to provide stakeholders with clarity on the circumstances in which Government is willing to support bioenergy. By taking a principles based approach we can set a strategic direction for bioenergy that can remain constant even as new or better evidence emerges and the global context for bioenergy changes.

2.3 These principles are outlined below, with a brief explanation of why they are necessary and how they could be applied. Further detail and analysis underpinning these principles is provided in Annex B.

2.4 Many of the principles make reference to the concept of sustainability. This encapsulates the carbon impacts of bioenergy as well as the land and water requirements of growing biomass for energy use relative to the fossil fuel alternative. We recognise however the Government's wider sustainability framework which includes economic and social impacts. All aspects of this broader definition are captured by the four principles described below with further discussion set out in Annex B: Sustainability of bioenergy[14].

2.5 These principles aim to foster the development of sustainable bioenergy markets. They therefore should be applied in a way that balances the long term objectives with the short and medium term needs of enabling innovation, supply chains, infrastructure investment and markets to mature. For example this includes support for innovative technologies that face high costs in the short term but which offer opportunities for future cost effective deployment.

14 Further information on UK Government policy on sustainable development can be found here: http://sd.defra.gov.uk/

Principle 1: Policies that support bioenergy should deliver genuine carbon reductions that help meet UK carbon emissions objectives to 2050 and beyond. This assessment should look – to the best degree possible – at carbon impacts for the whole system, including indirect impacts such as ILUC, where appropriate, and any changes to carbon stores.

Why is this principle needed?

2.6 GHG emissions occur at various stages of the process to convert biomass into energy[15]. Emissions may also occur through change in the land on which feedstocks are grown. These emissions can be either direct (e.g. bioenergy feedstocks change the carbon stock of the land on which they are grown) or indirect (e.g. where the use of land for bioenergy leads to displacement of existing activities to new land or the intensification of production on existing agricultural land). The harvesting, transport and processing of the feedstock to a suitable form for energy also creates emissions.

2.7 A large proportion of biomass used for bioenergy also has multiple alternative uses. For example, trees harvested predominately for bioenergy could be used for paper, furniture or construction materials (in practice trees often provide material for both products and bioenergy). Alternatively, trees could be left in the forest to complete their natural lives. These different uses have different carbon implications, depending on whether the carbon contained by trees remains locked in solid material or is released to the atmosphere through energy conversion, composting, rotting or some other means of disposal.

2.8 Quantifying the carbon balance of bioenergy is complex and uncertain. This principle recognises that policies should only support bioenergy where the reductions in emissions through the use of bioenergy exceed any new emissions created as a consequence of the policy. This assessment must include the emissions resulting from re-directing biomass from other uses which store carbon as well as taking account of direct and indirect impacts to the best degree.

How can this principle be applied?

2.9 The Government is already taking a leading role in promoting policies that, where legally possible, are accompanied by criteria on carbon assessments. Financial incentives for bioenergy, such as the Renewables Obligation and the Renewable Transport Fuel Obligation set out requirements for reporting on greenhouse gas emissions from the whole lifecycle of the feedstock development and combustion.

2.10 The Government is also working to address concerns over the incomplete accounting of emissions from bioenergy in international agreements, where any biomass sourced from countries not signed up to the Kyoto Protocol is automatically accounted as carbon-free (see Annex B).

15 International Energy Authority, Task Group 38 (http://www.ieabioenergy-task38.org/description/task38folder.pdf)

Box 4: Land use change

Land use change (LUC) is the general term used to describe a change in the way land is managed or what the land naturally produces, for example a change from natural grasslands to agricultural production or an intensification of production. Deforestation is one example of LUC.

In bioenergy systems, such changes may happen on the land used to produce the biomass (for example, the planting of miscanthus as a future energy crop on unused land). This is sometime referred to as direct land use change (dLUC). Our current sustainability standards include reporting requirements on direct land use changes in areas with high biodiversity value or high carbon stock – including primary forest, protected areas, peatland and wetlands. However, the protection provided by these standards must be kept under review.

Alternatively, if existing agricultural produce or land is used for bioenergy (for example if oilseed rape is used to make biodiesel) there may be no direct land use change. By taking biomass products away from the existing uses there will however generally be an increase in the price of those leading to greater production elsewhere both through more intensive production and by bringing more land into production. These changes are known as indirect land use change (ILUC).

ILUC emissions are inherently uncertain. The vast majority of studies have however concluded that ILUC leads to increased greenhouse gas emissions for biofuels produced from conventional crops. Not all feedstocks have the same ILUC impacts but when ILUC is considered, some biofuels can have greater carbon impacts than fossil fuel alternatives (see Annex B).

The EU sustainability criteria for biofuels do not currently include a consideration of ILUC. As the main aim of Government support for bioenergy is to reduce carbon, it is crucial that policies consider ILUC. We are working with our European partners on this issue and have called for the European Commission to amend the sustainability standards applied across the EU to address the risk from ILUC.

Building on the evidence gathered for this strategy, we are also planning on developing an interactive land use and bioenergy calculator that could help inform future discussions on this area. For example, the tool will provide more information on overall carbon savings or emissions related to bioenergy pathways using biomass sourced from different land types, so could help inform discussions around international carbon accounting.

Principle 2: Support for bioenergy should make a cost effective contribution to UK carbon emission objectives in the context of overall energy goals. Bioenergy should be supported when it offers equivalent or lower carbon emissions for each unit of expenditure compared to alternative investments which also meet the requirements of the policies.

Why is this principle needed?

2.11 As outlined in Principle 1, there are ongoing emissions involved in bioenergy which vary according to many factors. This means that – unlike other renewables – there is no automatic link between the cost of energy produced and emissions reductions. A bioenergy source that had a low cost per unit of energy might still be a very expensive way of reducing carbon if significant emissions are associated with its production. Bioenergy policies must therefore assess the cost effectiveness of bioenergy in reducing carbon emissions as well as producing energy compared to alternative options.

How can this principle be applied?

2.12 Policies involving bioenergy should calculate the implicit cost of reducing one unit of CO_2 relative to the energy source that biomass will displace. This should be compared to the same calculation for the alternative marginal technology that could achieve the aims of the policy.

2.13 We recognise that undertaking this comparison carries methodological difficulties. For example:

- the ‘displaced’ energy source may not always be clear to start with – e.g. for electricity generation, is it the average grid intensity of carbon or the likely ‘alternative’ fossil fuel generation that would be built?
- the ‘displaced’ source may change over time. – e.g. in the next decade or two a biogas heating system in industry might be displacing a natural gas fired system, while in 20 years time it might be an electric system.
- In diverse energy systems it may be challenging not to oversimplify the carbon impacts associated with diverse feedstocks, processes and efficiencies of the equipment used.
- Some of the methodological uncertainties are inherent in the nature of bioenergy. In the face of such difficulties, policies will need to calculate these effects to the best degree possible and ensure that any assumptions are transparent and clear.

2.14 It should be noted that carbon standards are a key driver of the ‘carbon cost effectiveness’ of a bioenergy policy. Tightening these standards can improve the carbon cost effectiveness of bioenergy compared to these alternatives by reducing the amount of permissible carbon in any given form of bioenergy (see Section 4.3 for an illustration).

Principle 3: Support for bioenergy should aim to maximise the overall benefits and minimise costs (quantifiable and non-quantifiable) across the economy. Policy makers should consider the impacts and unintended consequences of policy interventions on the wider energy system and economy, including non-energy industries.

Why is this principle needed?

2.15 Any policy that changes market practices will have implications for the wider economy, both within the energy system and non-energy sectors. In the case of bioenergy, these impacts can arise both from the use of biomass feedstocks that could be used in other sectors across the economy; as well as the conversion of these feedstocks into energy that displaces alternative forms of generation.

2.16 Bioenergy can have both positive and negative impacts in the wider economy. For example, bioenergy can be beneficial to the farming economy as well as to woodland owners and managers. On the other hand, it can adversely affect the viability of sectors which compete for the same feedstocks, such as construction and livestock farming; as well as of industries positioned to take advantage of new technologies to produce renewable products using biomass as a source material.

2.17 If used for energy, biomass can offer cost effective ways of generating renewable energy, minimising the impacts on consumer bills of meeting the Government's renewable targets. When sourced from a wider range of countries, biomass can lead to security of supply benefits and reduced price volatility. These potential benefits need to be assessed and balanced against the wider environmental impacts of bioenergy covered in Principle 4.

How can this principle be applied?

2.18 In line with Government guidelines for assessing policy options appropriate consideration should be given to wider impacts. Options should be explored for how best to mitigate them. This is particularly important where unintended consequences could act against the wider decarbonisation of the economy.

2.19 In order to ensure that wider impacts are understood, Government will continue to engage with businesses in the bioenergy sector and non-energy users of biomass at an early stage as policies are being developed and later as part of the implementation, monitoring and evaluation of those policies.

Principle 4: At regular intervals and when policies promote significant additional demand for bioenergy in the UK, beyond that envisaged by current use, policy makers should assess and respond to the impacts of this increased deployment. This assessment should include analysis of whether UK bioenergy demand is likely to significantly hinder the achievement of other objectives, such as maintaining food security, halting bio-diversity loss, achieving wider environmental outcomes or global development and poverty reduction.

Why is this principle needed?

2.20 The UK is part of a global economy which will demand increasing quantities of bioenergy. Cumulatively this demand can exacerbate food price increases at times when they are high for other reasons. This is particularly the case over short time periods where production does not have time to respond. The Government is clear that the production of biomass for bioenergy must not pose a threat to food security, in the UK or internationally. Our analysis suggests that while UK policy has had limited detrimental impacts so far, there are some tensions and these could grow if bioenergy develops in the wrong way, for example if suitable environmental or social controls are lacking (Annex B).

2.21 Demand for bioenergy can also present risks for biodiversity and ecosystems through loss of semi-natural and natural habitats (such as forest clearance), intensification of agricultural production and the potential introduction of non-native invasive species. There is, therefore, a potential tension with the Government's commitment to halt and reverse biodiversity loss and ecosystem degradation and address water stress, both domestically and internationally. By contrast, a number of reports[16] show that perennial energy crops, such as short rotation coppice and miscanthus, if cultivated in the right place and in the right way, can be better for biodiversity and water quality than arable crops such as wheat and maize. There will also be benefits if energy demand leads to unmanaged forests being brought back into management[17]. The precise impacts depend on the previous nature of the land, the nature and location of the new crops and their management.

2.22 Further discussion on the relationship between bioenergy, food, the wider environment and international development is provided in Annex B.

How can this principle be applied?

2.23 Risks can be reduced and benefits increased by: taking steps to create additional feedstock supply in appropriate ways, thus reducing the pressure for agricultural expansion into natural habitats; applying standards and safeguards effectively to exclude biomass from unsustainable sources; monitoring impacts and undertaking periodic reviews of policies and measures to ensure bioenergy expansion proceeds at a sustainable pace.

16 Karp, A. et al: Social, Economic and Environmental Implications of Increasing Rural Land Use under Energy Crops, 2010; Fry, Slater et al: The biodiversity of short rotation willow coppice in the Welsh landscape, 2009

17 Forestry Commission, Woodfuel Implementation Plan, 2011 – 2014; Forest Research and North Energy Associates, Carbon impacts of using biomass in bioenergy and other sectors: Forests, 2012

How do these principles cumulatively affect the energy system?

2.24 In the next chapters, we set out our findings on the potential implications of applying the sustainability principles to the availability of bioenergy resources. We also show the potential deployment pathways that can deliver the best use of biomass resources in a carbon constrained world. To address the uncertainty surrounding these pathways but still set out a sensible direction of travel, we have drawn on the latest available evidence. This has been used to identify a series of illustrative scenarios which we consider represent a plausible range of sustainable bioenergy futures for the UK, within the wider energy system.

2.25 This analysis provides us with insights on the deployment pathways that can allow us to meet our future carbon reduction targets most cost effectively both in the short/medium term (2020/2030) and in the longer term (2050). These are also resilient to different scenario assumptions and surrounding uncertainties. Full details can be found in the Analytical Annex and accompanying reports.

Box 5: The overall energy impacts of bioenergy

An important issue which is not captured in the principles, but which government will analyse and monitor is the energy cost of particular uses of bioenergy.

Capturing the energy in biomass and delivering it as useful energy in, for example, a power station or vehicle, requires energy (something that is not unique to bioenergy). This energy input reduces the final yield of energy from the biomass fuel and is, effectively, an energy cost. We should pay attention if the energy costs of an energy, bioenergy pathway or technology are a significant proportion of the total energy delivered by the process.

As an example of the scale of potential energy costs, DECC has undertaken a preliminary calculation of energy costs included in transporting bioenergy feedstock to a power station for electricity generation, for a number of transport scenarios. The analysis, which will be available on the DECC website shortly, also included carbon emissions and financial costs of transport. The scenarios considered transport of wood chips, miscanthus bales or municipal solid waste over different distances (ranging from 50 to 5000 km), using road, rail and ships. The results demonstrate that the energy costs of transporting biomass feedstocks for the particular scenarios can range from around 2 to 46% of the energy generated by combustion at the power station for the scenarios considered. The carbon emitted from the transport can range from 1 to 20% of the carbon savings achieved by replacing electricity from the National Grid with that generated at the power station. The energy and mass density of the feedstock, distance transported and the mode of transport all influence the energy, carbon and economic cost, with road transport over large distances (e.g. 400 km) and shipping from distant sources (e.g. 5000 km) having particularly large energy and carbon impacts. We plan to develop this analytical approach further to provide further evidence on the wider impacts of bioenergy policies.

Section 3 – Applying the principles to bioenergy resource supplies

3.1 Any assessment of biomass resource availability for bioenergy, especially imported supply, is subject to significant uncertainties, particularly over the longer term. Actual levels of supply for different feedstocks will depend on wider market developments, at domestic and international level, as well as the prices that different players will be willing to pay to access these markets at each point of time. In developing this strategy we have considered some of these factors including: global demand for biomass, land productivity and technological development, competing uses for land and biomass prices.

3.2 Recognising the uncertainties and complex interactions that will shape the future bioenergy landscape, we have taken a cautious approach in our analysis by developing ranges of sustainable bioenergy supply that may be available to the UK. These ranges, which include both domestically sourced and imported supply, do not attempt to forecast how UK demand breaks down into quantities of each particular feedstock. Instead they set out the scale of sustainable supply that could be available to the UK based on assumptions about future supply markets and prices. Analysis in Section 4 then shows how projected UK demand that can be met sustainably from these levels of available supply.

Scenarios of future sustainable resources

3.3 Developing scenarios on the potential availability of future biomass resources is a challenging task that has been the focus of numerous studies at both global and regional level. In this strategy the analysis is based on work undertaken by AEA Technology[18] on the potential future biomass supply to the UK, modified to reflect feedback received from stakeholders and update of certain feedstock assumptions (e.g. UK waste). A full explanation of the AEA methodology and the supply assumptions used in this strategy can be found in the AEA report and our accompanying Analytical Annex.

3.4 The supply ranges take into account wider literature on the potential availability of biomass feedstocks as well as the extensive analysis presented in the CCC Bioenergy review. As discussed in Section 2, it is important to consider direct and indirect land use change impacts arising from the production of bioenergy resources and to ensure bioenergy crops are grown on land which would not otherwise be used for food.

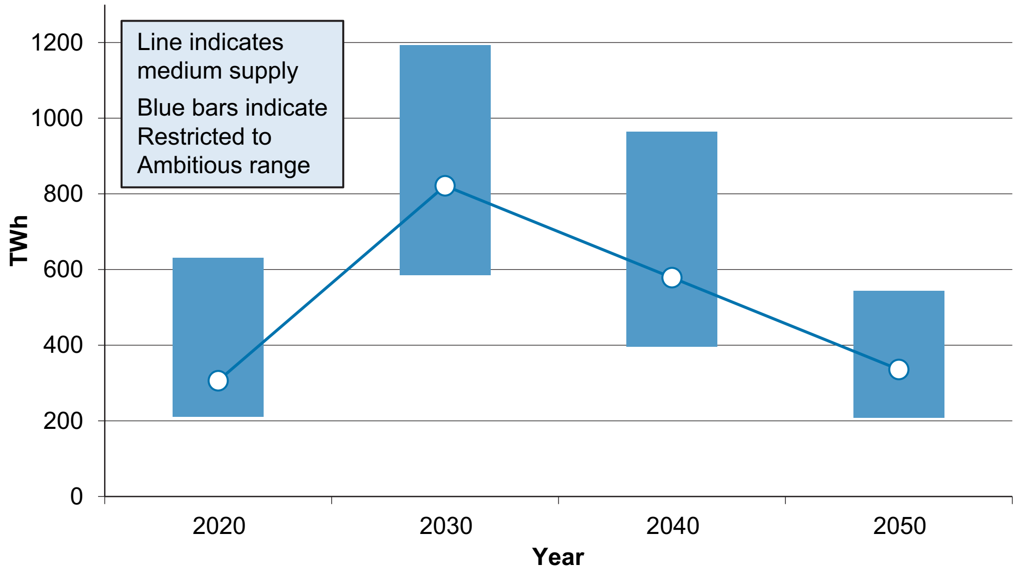
3.5 The feedstock availability estimates used in this strategy recognise these issues by limiting supply to land that may became available through better farming practices and increased land productivity of abandoned or “spare land” (i.e. land that would not be used for food/feed production), rather than re-allocation of land use from current economic or environmental activities. It is important however to recognise that ILUC is very difficult to estimate and our analysis does not explicitly model the impact of ILUC or the measures

18 AEA UK and Global Bioenergy Resource, 2011

required to mitigate its occurrence. Furthermore, it is important to consider the carbon stock of abandoned land and its potential for carbon sequestration from alternative uses. The ecological value of abandoned land should also be considered carefully. The current sustainability criteria (Annex B) will prevent the use of abandoned land of high carbon stock.

3.6 Figure 1 and Box 6 below shows the ranges resulting from our feedstock supply analysis implying total domestic and imported supply to the UK of around 200-650 TWh in 2020[19] and 200-550 TWh in 2050[20].

Figure 1: Biomass supply ranges for bioenergy (including domestic and imported supplies) potentially available to the UK from 2020 to 2050



Source: DECC analysis based on AEA biomass resource model
Note: Full assumptions included in Analytical Annex

Box 6: Key assumptions of supply availability ranges

The key assumptions behind the three supply scenarios are:

- Restricted supply – low biomass prices (£4/GJ on average) with high constraints to deployment of feedstocks and low international development. From the tradable commodities the UK has access to 10% of the global traded volumes that could be available up to 2020, reducing to 1.5% in 2050 as carbon constraints tighten and competition for resources intensifies.

19 Corresponding to 9%-26% of projected 2020 primary energy demand (DECC, Updated Emissions Projections, 2011)

20 AEA provide bioresource estimates out to 2030. DECC supply scenarios are based on ranges derived from AEA to 2030. UK sourced supply is assumed to be held flat from 2030 to 2050, and imported supply is assumed to be on a downward trajectory towards 2050. See accompanying Analytical Annex for further details on these assumptions.

Box 6: Key assumptions of supply availability ranges

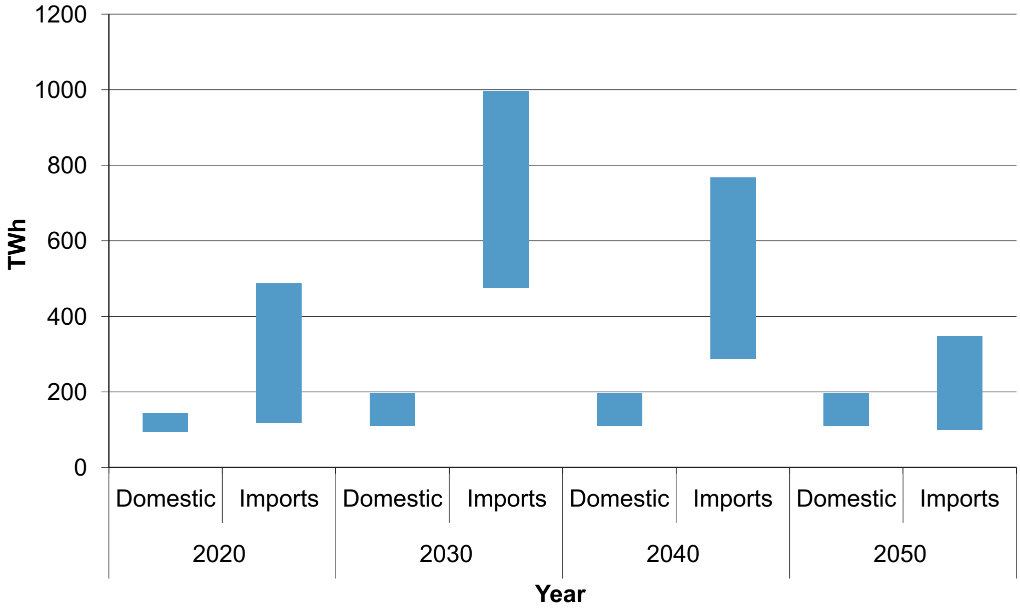
- Medium supply – medium biomass prices (£6/GJ on average) with medium constraints to deployment of feedstocks and medium (business as usual) international development. UK has access to 10% of the global traded volumes that could be available up to 2020, reducing to 2% in 2050. Global planting rates of energy crops are delayed by 5 years compared to the AEA assumptions reflecting near term uncertainties on the global development of energy crops.
- Ambitious supply – high biomass prices (£10/GJ on average), low constraints to deployment of feedstocks and a high international development. UK has access to 10% of the global traded volumes that could be available up to 2020, reducing to 3% in 2050.

Further details on these assumptions, including the range of additional global land assumed to go to bioenergy and a breakdown by feedstock type, are available in the accompanying Analytical Annex.

Domestic supplies

3.7 Although biomass imports are expected to make up the majority of the supply available to the UK, domestic resources are expected to play a role in providing a cost effective and sustainable source of feedstocks to 2020 and beyond. Domestic biomass can contribute to establishing a stable and secure biomass supply base for the UK bioenergy sector.

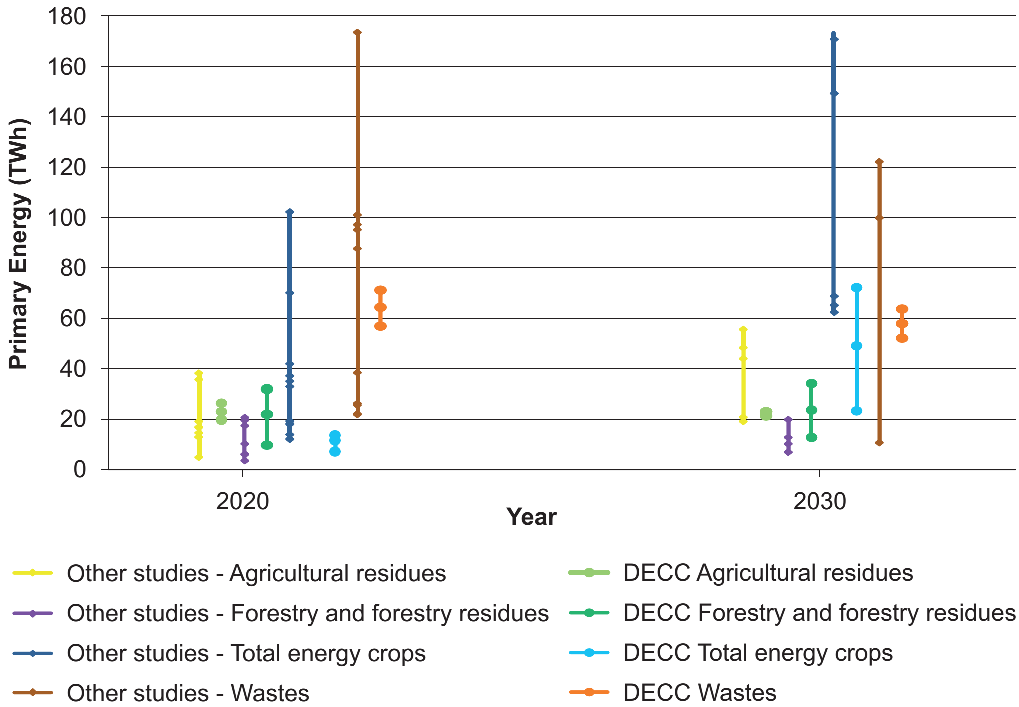
Figure 2: Range of domestic and imported biomass supply (TWh) implied by supply scenarios from 2020 to 2050



Source: DECC analysis based on AEA Biomass resource model

3.8 Our analysis suggests a reasonable level of domestic feedstock that is now available for the production of energy in excess of 75TWh of bioenergy. There is potential for this to rise by at least 20% to around 90TWh by 2020 with further growth potential leading up to 2030 (our low estimate assumes 110TWh). Higher biomass prices and the removal of deployment barriers could release significantly more domestic supply to the market. Our estimates of potential available domestic supply of different feedstocks are within the range suggested by existing studies[21] (Figure 3) and therefore, it is not unreasonable to suggest that this potential could be realised provided the right deployment barriers are addressed.

Figure 3: Estimated potential biomass supply in 2020 and 2030, broken down by source (DECC estimates in the context of recent studies)



Source: Chart adapted from UKERC literature review of existing studies on UK biomass resources (2010)

3.9 The amount of residual waste from municipal and commercial sources is expected to decline gradually to 2030 as policies to encourage better environmental and energy outcomes succeed (i.e. waste prevention, reuse and recycle). Better waste management practices that reduce the amount of waste going to landfill will lead to potentially greater supplies available for energy production. Overcoming deployment challenges, such as tackling the financial barriers blocking suitable waste infrastructure from developing, improving community acceptance, developing methods for calculating the renewable content of waste and developing energy from waste markets, will help realise further potential from energy from waste generation.

21 UKERC, Working Paper: The UK bio-energy resource base to 2050: estimates, assumptions, and uncertainties, 2010

3.10 The greatest growth in domestic biomass supply is expected to come from agricultural residues and perennial energy crops. Our analysis suggests that existing domestic energy crops, such as miscanthus, short rotation coppice (SRC) and other grasses including reed canary grass and switchgrass, could see a significant increase in deployment from its very small current level (Box 7). This growth will require increasing planting rates and the development of a still nascent market.

Box 7: Direct land use change carbon impacts of energy crops and energy crop potential in the UK

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

Analysis shows that energy from biomass crops can have lower direct carbon impacts (0.5 to 6.1 t CO_2e/ ha/yr) than food crop production (3.4 to 11 t CO_2e/ ha/yr).

This result requires considerable qualification as the actual changes in land use when biomass crops are grown in place of food crop production can lead to additional emissions as a result of indirect land use change (ILUC) (see Annex B). Carbon impacts from ILUC are uncertain but potentially large relative to the carbon impacts of growing and using bioenergy crops, e.g. up to 37 t CO_2e/ha/y for international ILUC (PAS 2050, 2011). It is therefore important that energy crops deployment does not compete with food production.

The theoretical maximum available land for SRC and miscanthus in the UK, not impinging on food production, has been modelled to be between 0.93 and 3.63 Mha in England and Wales[22]. Depending on the gross margin that can be obtained from the cultivation of energy crops, research suggests that SRC uptake could be between 0.62-2.43 Mha representing between 3-13% of the 18.26 Mha of agricultural land in the UK (under a gross margin of £241/ha). If this land were used for miscanthus uptake could be 0.72-2.80 Mha (at a gross margin of £526/ha). If used for electricity generation, for example, this 2.8 Mha could correspond to total potential generation of 59.3TWh equivalent.

However energy crop plantings in the UK are currently small, estimated at around 0.01 Mha (equivalent to 0.21 TWh if used in electricity generation). The potential to upscale is currently restricted by UK planting and harvesting capacity, grower acceptance, economics, technology compatibility and social resistance related to concerns around long-term land use change. It is estimated that increasing the amount of current UK plantings by 20% every year could result in 0.04 Mha (0.22% of UK agricultural land) of energy crops in the ground by 2020 (equivalent to 0.85 TWh if used in electricity generation). This falls around the lowest range of potential and hence could feasibly be exceeded, but only if planting rates were to increase significantly.

Sources: NFCC, Domestic Energy Crops: Potential and Constraints Review, 2012; ADAS, Carbon impacts of using biomass in bioenergy and other sectors: energy crops, 2012

22 This would correspond to between 6% and 24% of the total land area of England and Wales or 9% to 35% of land currently under some form of agricultural production

3.11 Supplies from UK forests are also expected to increase. Around 10 Million green tonnes of wood each year is currently harvested in the UK from woodlands and forests. Harvested timber supplies a range of markets including sawmills, panel board producers and energy generation. In recent years significant progress has been made in developing the woodfuel supply chains (in 2007 around 0.5 Million tonnes of wood were delivered to energy markets, increasing to 1.5 Million tonnes in 2010[23]). The Forestry Commission's current softwood production forecast estimates that the UK softwood harvest is due to peak at 12 Million green tonnes in the period 2017-21(equivalent to around 6 Million oven dried tonnes (odt)).

3.12 The option of bringing unmanaged woodlands into production could increase supply and, with appropriate woodland management that avoids significant reductions in the forest carbon stock, help reduce carbon emissions (Box 8). The Government is already funding such schemes, for example under the Rural Development Programme for England. However, more work is required to ensure that woodfuel supply businesses are viable in the long term and that woodland creation and sustainable woodland management is encouraged across the UK. The contribution of UK forestry resources is however expected to remain relatively small and focused on fuelling the renewable heat market given the competing uses for these resources and high volumes required to power electricity generation plants. DECC supply scenarios imply between 1.8 and 6.1 Million odt of UK forestry resources[24] by 2020 – though the upper end of this range is equivalent to the entire current UK harvest and so will require substantial interventions to bring these resources into the market. It is important to ensure that the use of wood for energy does not lead to the displacement of wood for non-energy uses, as this could lead to significant emissions.

Box 8: Carbon impacts of harvested wood

Forests contain vital carbon stocks. They are also integral in regulating the earth's atmosphere. Forest GHG dynamics involve "removals" (or "sinks") as well as emissions (or "sources") of GHG. Human management and natural disturbances, such as forest fires and storms, can have a strong influence on the pattern of emissions and removals from forests.

We used lifecycle analysis to quantify the carbon balances associated with different forest management approaches and uses of forest wood[25]. The scenarios analysed included: using harvested wood for bioenergy (heat or electricity); choosing alternative uses (such as construction products); or leaving the forest unharvested or unmanaged.

Our analysis (illustrated in Figure 4) indicates that in GHG terms, taking a long-term perspective (i.e. 40 to 100 years) and avoiding 'worst case' and unfeasible disposal options for wood products (i.e. wet landfill without energy recovery or dry landfill):

23 UK Wood Production and Trade, 2011

24 Forestry resources include: Arboricultural arisings, forestry residues, sawmill co-products, short rotation forestry and stemwood.

25 Forest Research and North Energy Associates, Carbon impacts of using biomass in bioenergy and other sectors: Forests, 2012

Box 8: Carbon impacts of harvested wood

a. Managing and harvesting existing conifer and broadleaf forests in the UK for wood and bioenergy to displace non-wood products and fossil fuels results in lower total GHG emissions than leaving the wood unharvested to continue to sequester carbon. This includes in some cases restoration of production of ‘neglected’ broadleaf forests in the UK, provided the right management procedures are followed and the right choices are made for the use of wood;

b. Optimal GHG scenarios generally involve use of forest for the production of both material products and bioenergy, with re-use and recycling wherever possible;

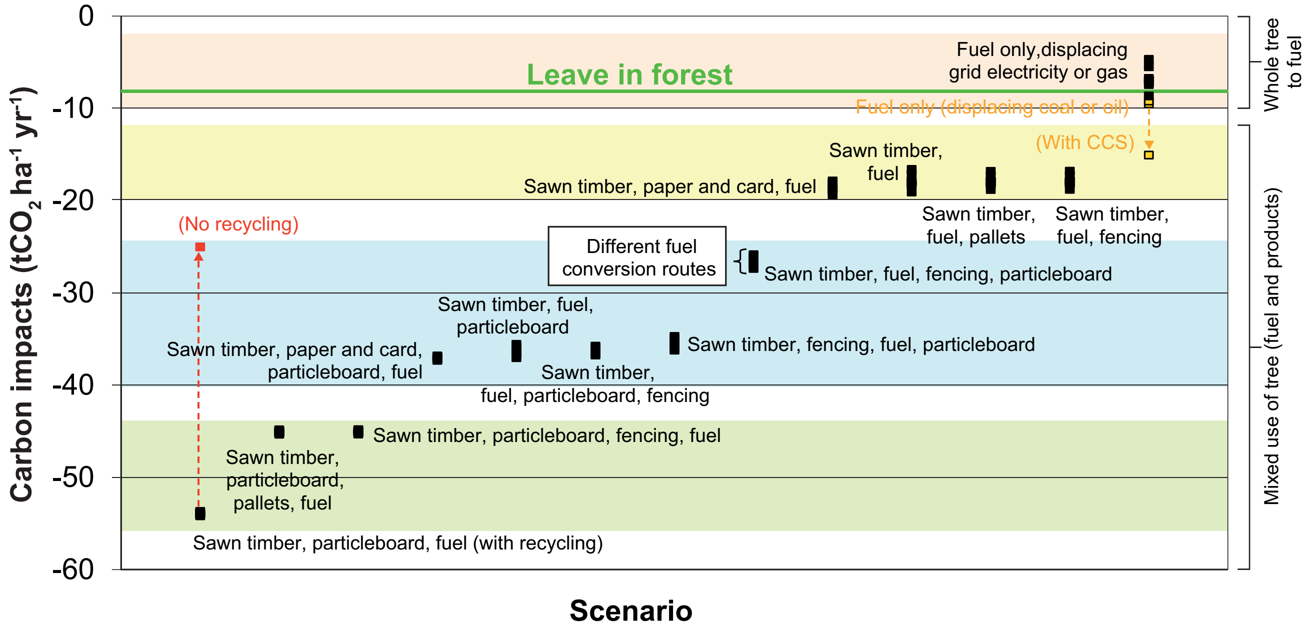
c. Using small roundwood and sawlogs as a source for materials and bark and branchwood as a source for bioenergy (i.e. a ‘conventional product mix’ in terms of priorities for coniferous wood use) is often the optimal use of the forest wood. With respect to small roundwood and sawmill residues, GHG reductions can be achieved through some use for bioenergy as well as for materials depending on how the wood is processed, transported and used. The use of the entire tree for bioenergy is undesirable as it is generally associated with sub-optimal carbon scenarios and can result in increased greenhouse gas emissions;

d. Prioritising use of wood as a material implicitly requires the future adoption of effective recycling and disposal strategies for wood products.

Figure 4 provides a snapshot of some of the scenarios examined. The scenarios include a mixture of conventional current practices, where, for example, harvested wood is used for a mixture of purposes. They also include less conventional examples, where harvested wood is used in greater amounts for bioenergy or for bioenergy only. The green line represents additional sequestration of carbon in a managed forest over a 100 years, if wood is not harvested for bioenergy or products, thereby allowing forest carbon stocks to increase. Negative results indicate a net reduction of emissions, compared to the current non-wood alternatives.

Box 8: Carbon impacts of harvested wood

Figure 4: Carbon sequestered and emissions avoided (saved, compared to a reference scenario) by harvesting UK conifer forests and using the wood in different applications to displace non-wood products and fossil fuels



Source: Forest Research and North Energy Associates, Carbon impacts of using biomass in bioenergy and other sectors: Forests, 2012

Notes: Carbon impacts are calculated over a 100 year time horizon and wood is assumed to be disposed of at end of life by burning in a Waste Incineration Directive-compliant power only plant. For clarity, results involving production of medium density fibreboard have been excluded.
The coloured bands highlight broad classes of results (from bottom to top).

- Green band: carbon savings when harvested wood is converted into a range of products, such as sawn timber, particleboard, pallets and fencing, with some associated production of bioenergy, mainly from wood that can't be used in products. The scenarios in the green band are representative of how the use of wood from conifer forests would be prioritised in the UK, under current conditions.
- Blue band: carbon savings when the mix of wood products still involves production of sawn timber and fencing, but a larger fraction of wood is used for fencing, pallets, paper and bioenergy, rather than for particleboard.
- Yellow band: carbon savings if wood is used to produce just sawn timber and fuel, with some production of pallets, fencing and paper, but with no production of particleboard. The carbon saved is typically half of that calculated when particleboard is also produced as part of the mix of products. The carbon savings associated with particleboard are partly due to recycling a large fraction of wood in the manufacturing process.
- Orange band: carbon savings if all of the harvested wood is used entirely for bioenergy. The carbon impacts are about the same as would be achieved if harvesting in UK forests was to be suspended and forest carbon stocks were allowed to accumulate (green line). The carbon impact depends on what type of fossil energy source the bioenergy displaces; and on whether carbon capture and storage technologies can be applied (dashed yellow arrow).

The dashed red arrow illustrates the calculated change to carbon savings if particleboard were to be produced without using any recycled wood.

3.13 Domestic cereals, oilseeds and sugar crops are expected to continue to make a modest contribution, though bioenergy related demand for these feedstocks may decline as first generation biofuels are superseded by advanced fuels in the medium term. In 2009 around 3% of total UK cereals were used to produce biofuels, generating around 0.6TWh of energy[26]. By 2020 biofuel production in the UK[27] may use similar quantities of cereals as the current UK tradable surplus in wheat[28]. (DECC supply scenarios suggest between 0.2 and 0.3 Mha of UK oil crops by 2020). Other arable crops such as maize and grass silage, currently contribute to 0.08 TWh of energy from farm-scale anaerobic digestion[29]. This is likely to increase, although Government is working with industry to limit the growth in crop-only AD in order to target support at increasing energy from waste, by exploiting manures and slurries which could generate around 2TWh by 2020. However, in order to improve the economic and, in some cases, the technical viability of AD plants the Government recognises purpose grown crops as a feedstock used in co-digestion with food wastes and most typically agricultural wastes, will be important. The three DECC supply scenarios imply around 3.7 to 5.0 Million odt of agricultural residues by 2020.

International supplies

3.14 The development of international biomass production, access to global markets and the price at which these resources can be accessed will be a key factor determining the actual volumes of biomass that will be available to the UK. Estimating the availability of global supplies to the UK in the future, given the uncertainty around these key factors is very difficult, and any assumptions must be considered with this caveat.

3.15 Not all bioenergy feedstocks are likely to be suitable for international trade. Currently there is only a developed international market for biofuels, with another for woody pellets also evolving at a fast pace. Markets for other feedstocks may evolve over time. We expect the UK to continue to be a net importer of these supplies while facing increasing competition from other countries. Our analysis assumes that the UK has access to 10% of the global traded volumes up to 2020, with the share reducing to between 3%-1.5% by 2050.

3.16 The majority of these supplies are expected to be from perennial energy crops. As noted above our scenarios assume that there is sufficient land available for these crops to be grown in areas around the world that are not in competition with other economic activities. By 2020 our supply scenarios for global agricultural residues are equivalent to around 0.6 – 2.2 Mha, and 0.04 – 2.6 Mha for global oil crops. It is assumed woody biomass (predominantly energy crops) will make up the majority of international supplies to the UK, indicating a range of 3.7 – 17.2 Mha equivalent.

26 RTFO quarterly report, 2009-10

27 It should be noted that the UK biofuels production from cereals is expected to produce a by-product that can be used as animal feed, reducing the potential impact on the feed markets.

28 Based on FAPRI baseline – to be published imminently

29 Based on Anaerobic Digestion portal

3.17 Production on unused land or land of low ecosystem service value is key to ensuring that growth in use of bioenergy is achieved without adverse carbon, biodiversity and water impacts. Increased yields and feedstock innovation will significantly alter the amount of energy that can be sourced per hectare of land but our analysis shows that our estimates are in line with other studies that examine land availability and production yields: this is illustrated by Figure 5 below.

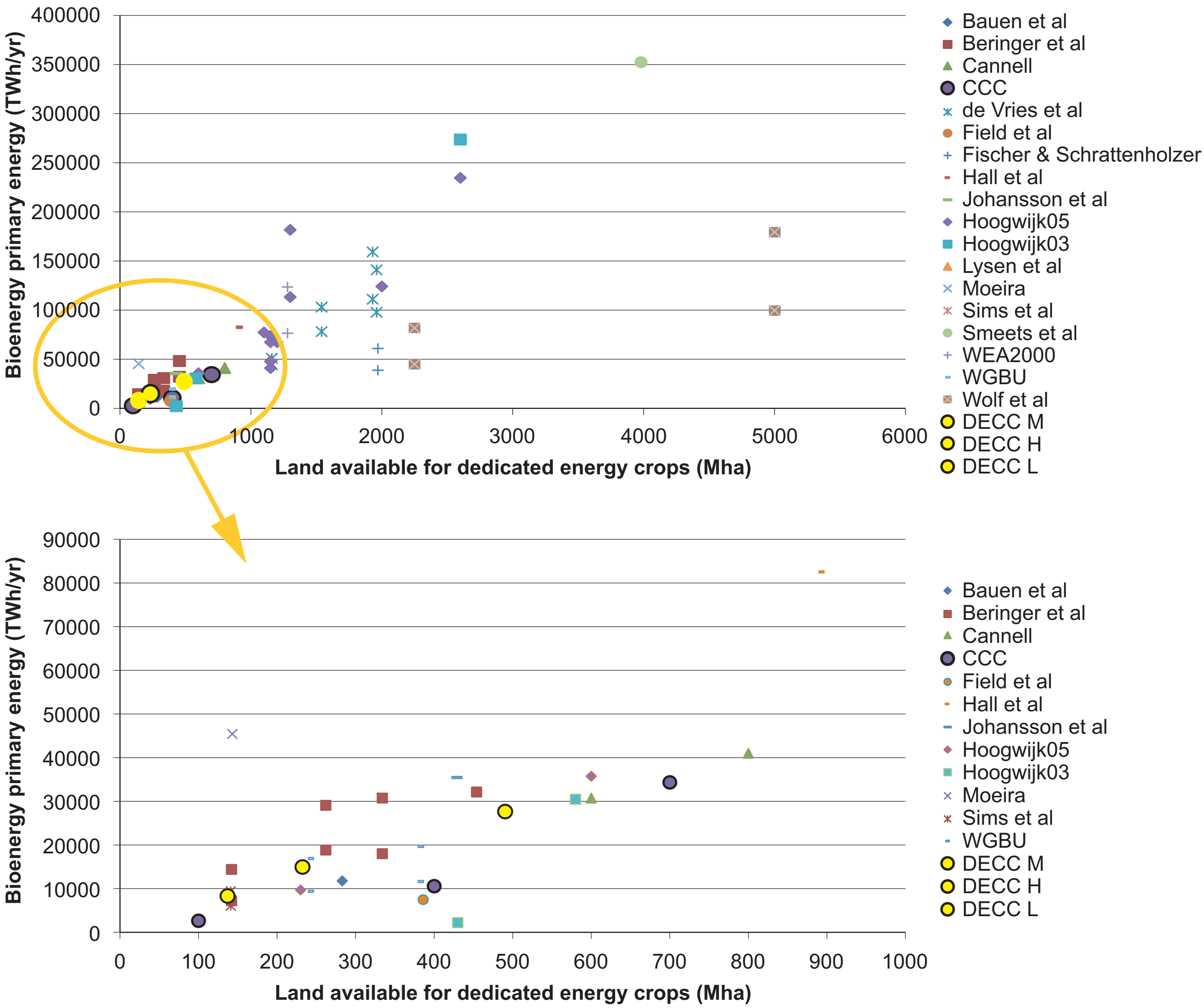
3.18 Nevertheless, we need to recognise the high degree of uncertainty. In our scenarios the range of additional land used for bioenergy production globally by 2030 is 0.1 to 0.5 billion hectares. This compares to current global arable land use of just under 1.5 billion hectares. As the CCC Bioenergy Review pointed out, although FAO analysis suggests that up to 700-800 Mha may be available for growing energy crops, this is highly uncertain[30]. Indeed, given the concerns and uncertainties, the Government's Foresight Report: The Future of Food and Farming concludes that we should plan for very limited additional agricultural land in future over and above currently abandoned agricultural land. To reflect these uncertainties we have considered a highly restrictive supply scenario in the accompanying Analytical Annex.

3.19 This strategy assumes that energy crop production is widely dispersed across the world, with regions such as Latin America and China having a significant role alongside North America and the EU, while forestry supplies are sourced mainly from North America and the EU. Although there is uncertainty over longer term market developments that will determine the origins of the feedstocks that the UK may use[31], the international bioenergy market is expected to have a wide range of suppliers from several countries. This diversity of supply will help to spread risk. Taking this into account, as well as the additional dimension of diversity that bioenergy could introduce to our energy mix, it is reasonable to expect biomass to contribute to the UK's energy security and reduce our dependence on fossil fuels.

30 This land may have a high carbon content and be rich in biodiversity; it may be used for grazing livestock or subsistence farming; there is a high degree of uncertainty around productivity, including limitations to water supply (which may become more pronounced in a world subject to climate change); for land where productivity is not prohibitively low, it is unclear whether growing dedicated energy crops would be economically viable, given limited experience of this to date.

31 IEA bioenergy, Bioenergy – a sustainable and reliable energy source, 2009

Figure 5: Global land availability for energy crops (DECC estimates in the context of estimates from recent studies)



Source: UKERC (2010)
Note: High DECC estimate takes account of water scarcity and land degradation. Low DECC estimate also takes account of planting rates and sustainability.

Role of technology research, development and demonstration:

3.20 Our scenarios of available sustainable feedstock do not assume any technological breakthroughs in the area of cultivation and growth of biomass supplies. However, emerging analysis from the Bioenergy TINA[32] suggests that improvements in energy crop yields, particularly of woody/grassy crops suited to UK conditions, could lead to significant increases in the availability of sustainable resources. This area is currently being supported by the Biotechnology and Biological Sciences Research Council, among others (Box 9).

32 Evidence provided by the Low Carbon Innovation Coordination Group Bioenergy Technology Innovation Needs Assessment (TINA)

Box 9: Case study of research on biomass feedstocks

BBSRC[33] Sustainable Bioenergy Centre (BSBEC) is a virtual centre of 6 academic research groups created in 2009. The centre focuses on the biochemical bioenergy pipeline from growing biomass through to conversion of biomass to bioenergy. Its research activities focus on:

- understanding the underlying biology of energy crops to improve their 'energy' yield; and
- investigating novel approaches of maximising the energy yield of energy crops and their conversion into energy products.

A key objective is that bioenergy should be economically, environmentally and socially sustainable. This 5 year programme is supported by £20million from the BBSRC and the research has attracted a further £4million funding from fifteen leading industrial associates who also bring business expertise and perspectives.

33 BBSRC – Biotechnology and Biological Sciences Research Council

Section 4 – Applying the principles to deployment pathways

4.1 This section sets out analysis on where available bioenergy resource may be most effectively used to meet longer term decarbonisation needs as well as the 2020 renewable energy targets in a way that is likely to be consistent with the principles (low-risk pathways). It is intended to show the potential impacts of a deployment pathway consistent with the approach taken in this strategy. It is not a review or projection of existing policies.

4.2 Although the analysis presented in this section is focused on energy uses of biomass, we have captured the potential decarbonisation opportunities offered by other sectors though the inclusion of wood in construction[34]. It has not been possible to model other non-energy sectors at this time but this is a possible area for development in the future.

Bioenergy and the wider bioeconomy

4.3 In this section we consider which areas of the wider bio-economy[35] will be most sensitive to the use of biomass resources in the energy sector. This analysis is directly relevant to the application of Principle 3, which recognises that bioenergy can impose costs on the wider economy and that we should seek to minimise these, while maximising the benefits that bioenergy offers in other areas.

4.4 Rapid advances in biotechnology are enabling a number of economic sectors to use more biomass. The OECD has predicted that by 2030 the bio-economy could contribute 2.7% of GDP across OECD countries[36]. In the UK alone, the renewable chemical sector using biomass as a feedstock is expected to be worth between £4bn and £12bn by 2025 (which entails a projected growth between 5% and 11% per annum). Analysis by OECD also suggested that the potential of industrial biotechnology and bio-based products to cut carbon dioxide emissions could range from between 1 bn and 2.5 bn tCO_2e/yr[37].

4.5 In a world with higher overall demand for biomass, producers of feedstocks will be the key beneficiaries of the increased demand with additional opportunities across sectors such as forestry, arable farming and waste management. Bioenergy can also offer further opportunities by driving innovation in materials that can be used in non-energy sectors (for example, the production of biofuels through a variety of advanced conversion technology routes could be used to produce a range of co-products in what could be termed as a "bio-refinery").

34 Poyry, Alternative uses of biomass in decarbonising industry, 2011

35 The Bioeconomy refers to the set of economic activities relating to the invention, development, production and use of biological products and processes.

36 OECD, The Bioeconomy to 2030, Designing a policy agenda, Main Findings and Policy Conclusions, 2009

37 idid

4.6 However, bioenergy deployment also increases competition for sectors that use this material as input to their production processes. Some of these sectors will be able to switch to non-biomass sources while others will have no alternative e.g. animal feed, food and drink or wood products. Box 10 shows some of the different sectors which use biomass as a feedstock, along with whether it is possible for the sector to switch to using an alternative, non-biomass source.

Box 10: Biomass uses in non-energy sectors

Sector	Ability of sector to use alternative to biomass	Types of biomass used or produced
Agribusiness and animal feed	Non-switch	Miscanthus, sugar beet, wheat, corn, barley, oilseed rape, algae
Automotive manufacturing	Switch	Crops (wheat, corn, rapeseed) and wood
Cement	Switch	Wood, hemp, waste (including meat and bone meal, sewage sludge, paper)
Chemicals	Switch	Wood, algae, straw, waste, wheat, corn, palm oil and other vegetable oils, rapeseed, jatropha, grasses, tallow, sugar beet, wheat starch
Construction (chip board, MDF,OSB, sawn timber)	Non-switch	Wood, sawmill co-products, recycled wood
Food and Drink	Non-switch	Wheat, sugar, corn, rapeseed, vegetable oils and seeds
Wood processing	Non-switch	Wood
Wood Furniture	Non-switch	Wood panels, sawn wood
Paper and Board	Non-switch	Wood and paper waste
Waste management	Non-switch	Wood waste, cooking oil, tallow, food and green waste, sewage sludge, waste paper, agricultural waste, solid recovered fuel

Switch: Sector where alternative to biomass available
Non-Switch: Sector where no alternative to biomass available

4.7 The extent to which the gains and losses from the expansion of bioenergy occur will depend on the ability of sectors to access alternative types of feedstock, their ability to take advantage of wider innovation benefits, and their position within the global biomass market. The ability of non-energy sectors to switch between biomass and other material can contribute to understanding the impacts of bioenergy in the wider bioeconomy under Principle 3.

Role of sustainable bioenergy in our future energy system

4.8 Predicting the most appropriate uses of biomass at any given point is an inevitably uncertain task, especially when looking further into the future. However, there are certain pathways that have low risk associated with allowing us to meet our short term renewable and carbon targets, without locking us into unsustainable deployment for the longer term; and are attractive as hedging options against the longer term uncertainties.

4.9 In assessing these pathways we have also compared the estimated life cycle emissions of biomass energy and other energy supply chains. We recognise the importance of environmental benefits from alternative biomass uses outside the energy sector but conclude that these low-risk pathways satisfy Principle 1 (overall carbon benefits) and Principle 4 (not interfering with other objectives) .

High level findings

4.10 We conclude that the biomass feedstocks that could be available to the UK for bioenergy could sustainably[38] provide between 8 and 11%[39] of the UK's primary energy demand in 2020 rising to between 10% and 14%[40] in 2030[41]. In the context of the existing literature, this is a cautious estimate that relies on the appropriate mechanisms being in place to guard against unsustainable practices, however analysis shows that sufficient sustainable resources can be available to meet this demand.

4.11 Estimates of these contributions further into the future are highly uncertain: we expect the role of bioenergy to evolve as legally binding targets on renewables are met, carbon constraints tighten and technological advances take place. The long term contribution of bioenergy in our energy system will also depend significantly on the costs that the UK might face accessing biomass supplies in international markets, when faced with increasing competition from other countries. Based on the medium resource availability scenario presented in Section 3 (335 TWh of resource by 2050) and assuming that the UK will access a decreasing amount of the international supplies from 2030 onwards, our analysis suggests that by 2050 bioenergy could contribute approximately 12%[42] of UK primary energy. This contribution could be significantly higher if availability and costs of sustainable feedstocks are more favourable.

38 Sustainably sourced biomass refers to biomass feedstocks that have not been sourced from high carbon stock land (e.g. peat land or virgin forest) or land that is required for competing uses (e.g. food).

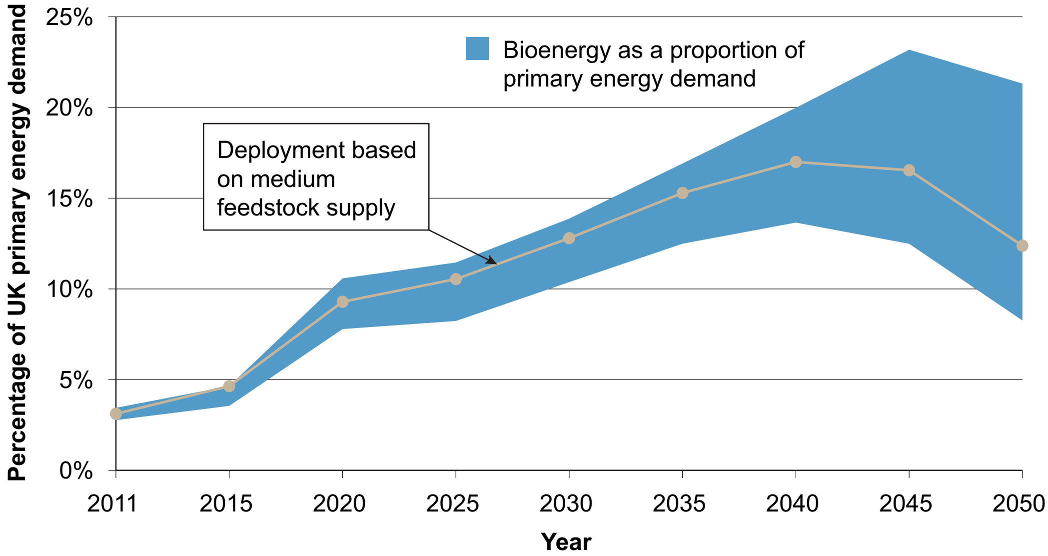
39 Equivalent to around 150 – 210TWh

40 Equivalent to around 215 – 300TWh

41 Redpoint, Appropriate Use of Biomass, 2011

42 Equivalent to around 280TWh

Figure 6: Potential bioenergy contribution to overall primary energy input.



Source: DECC analysis based on Redpoint Appropriate Use of Bioenergy model
Note: The 2050 ranges presented in this graph are driven primarily by assumptions about UK access to global traded volumes set out in Section 3.

4.12 The crucial role that bioenergy has to play in helping us decarbonise different parts of the energy system leading up to 2050 is supported by analysis across a range of studies. The recent CCC Bioenergy Review noted that unless low-carbon bioenergy accounts for around 10% of total UK primary energy demand, meeting the overall 2050 emission targets will be extremely difficult (even if Carbon Capture and Storage (CCS) is available). Similarly, recent analysis from the Energy Technologies Institute[43] (ETI) indicates that the removal of biomass from the energy mix could increase the costs of decarbonising our energy system by £44 bn in 2050 (Box 11). Efficient low-carbon bioenergy deployment is therefore crucial for the decarbonisation of the economy and as such certain segments of the energy system could be characterised as non-switch with respect to their decarbonisation options.

43 Energy Technologies Institute (ETI) is a partnership between global industries and the UK Government bringing together projects and partnerships accelerating the development of affordable, clean and secure technologies to help the UK meet its legally binding 2050 climate change targets.

Box 11: ETI analysis of role of biomass to 2050

ETI's Energy System Modelling Environment (ESME) is a tool that aims to help explore the whole energy system, including interactions between power, heat, transport and infrastructure. It optimises energy system designs, considering the performance, costs and rates of installation for new technologies. Potential supply, demand and infrastructure options are defined against geographic location.

Scenario analysis using ESME comparing the abatement costs of different decarbonisation scenarios to 2050 where key technologies are removed from the mix are shown below. The table compares the cost to the energy system of a scenario which removes biomass as a technology option, with scenarios where CCS is removed as an option, and a scenario in which there is no further improvement in energy costs and efficiencies. For each scenario the ESME model performs an optimisation to find the least-cost energy system design for the UK. There are significant uncertainties in estimating future costs of technologies, which the ESME model treats by defining ranges and distributions for the future values of uncertain parameters. This analysis demonstrates that scenarios without bioenergy are likely to add significantly to the cost of emissions reduction.

ETI ESME Scenarios	Additional 2050 Energy System Costs[43]
No biomass	+£44bn
No CCS	+£42bn
No further technology development	+£106bn

Source: ETI

4.13 Within the limits of sustainable supply, our analysis suggests the low-risk bioenergy pathways to 2030 are:

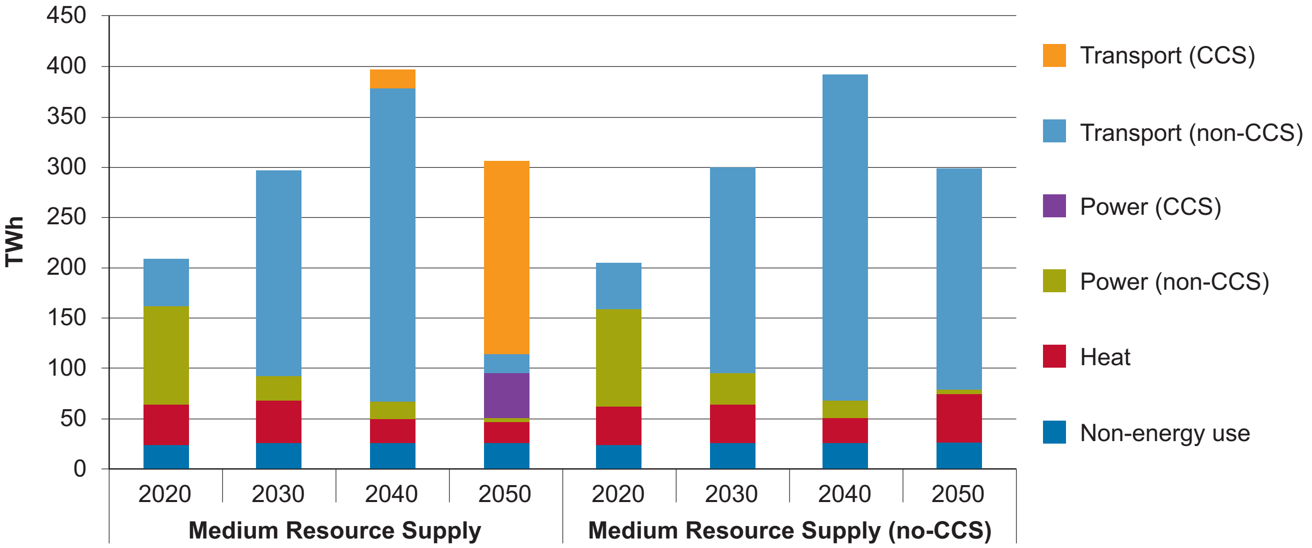
- Generation of heat and electricity through combined heat and power processes and with the efficient utilisation of recoverable wastes[45];
- Use of biomass to provide low carbon heat for high temperature industrial processes, through either solid biomass or biomethane boilers, as well as a transitional role of biomass for heating buildings and the use of recoverable waste heat from low carbon power generation or industrial processes;
- Use of sustainable biomass in decarbonising power generation which currently uses coal as a feedstock;

44 Energy system costs includes all capital, operating and fuel costs for energy technologies in the UK, including energy conversion (e.g. power plants), energy infrastructure (e.g. storage and transmission) and end use technologies (e.g. cars). The capital cost of existing stock is excluded, e.g. for domestic dwellings the capital cost of new-build only is included. Costs are presented in undiscounted terms, in 2010 year prices.

45 Through capture and combustion of landfill gas and sewage gas and energy from waste. Waste heat largely generated by AD and CHP plants.

- So long as the sustainability can be assured and while fossil fuels continue to be used in transport, some conventional biofuels[46] can offer a cost effective contribution to reducing carbon emissions from road transport. There is potential for significant growth in biofuel use, in road and other sectors, in the medium and long term, if advanced technologies using wastes and woody feedstocks are commercialised[47].

Figure 7: Biomass deployment for primary energy under medium feedstock availability scenario with and without CCS (TWh / year)



Source: DECC analysis based on Redpoint

Notes: "Non-energy uses" refers to new potential biomass deployment opportunities from use of wood in construction that could deliver cost effective carbon savings. This is being included as an illustration of potential non-energy uses of biomass. Other sectors have not been included due to data limitations[48]. Transport CCS refers to CCS with hydrogen production (including gasification of biomass to generate negative emissions).

4.14 Moving through 2030 and beyond, the deployment pathways become highly dependent on the costs and availability of biomass feedstocks as well as the commercial viability of different technologies (in particular that of CCS). The combination of bioenergy production with CCS could be a key mitigating option for the future through production of 'negative emissions', significantly increasing the cost effective options towards 2050 (Box 12, Figure 7). In that period, our analysis suggests that the priority should be for continued use of biomass resource in process heating, and in the transport sector, either through bioenergy hydrogen production with CCS or through biofuels for aviation and shipping if CCS is not available. Without CCS there is only a minor role for the long term use of biomass in power generation (to 2050) due to availability of low carbon alternatives in this sector.

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46 'Conventional biofuels' are biofuels produced from crops (such as sugarcane and oilseed rape) or waste oils, and are commercially available now.

47 This analysis does not assess the impacts of emissions trading on the use of bioenergy in traded sectors. This may significantly alter the scenarios for the uptake of biofuels in aviation, where the purchase of emissions reductions certificates is expected to be an important alternative option for UK aviation.

48 Poyry report to the CCC, Alternative Uses of Biomass in Decarbonising Industry, 2011

4.15 The development of flexible bioenergy technologies which can contribute to the decarbonisation of different sectors is a way of mitigating against the inherent uncertainties of projecting deployment scenarios over such long timescales (including the uncertainties around CCS). Emerging analysis from the Low Carbon Innovation Coordination Group Bioenergy Technology Innovation Needs Assessment (TINA) suggests that the development of advanced conversion technologies, in particular reliable gasification and clean-up processing at scale, is crucial in allowing us to achieve this. Variants of this technology are key in the production of advanced biofuels (e.g. BTL[49]), biopower (e.g. integrated combined cycle gasification[50]) and bioheat (e.g. bio-SYN[51]). Technology innovation in these sectors to reduce cost and increase efficiency is critical to support the development of flexible bioenergy which can adapt to the uncertainties described above.

Box 12: Bioenergy Carbon Capture and Storage

CCS has the potential to become an important low carbon technology over the next 40 years. Bioenergy carbon capture and storage (BE-CCS) could produce bioenergy in the form of biopower, biohydrogen, bioheat and biofuels, but most significantly permanently store underground the waste carbon from these processes that was taken from the atmosphere by plant growth, providing net carbon removal from the atmosphere or 'negative emissions'. These negative emissions could then be used to offset fossil fuel emissions from other harder to decarbonise sectors. This makes BE-CCS an exceptionally valuable technological option.

As yet there are no full commercial scale CCS projects in the world, but there are eight operational CCS demonstration plants, nearly all linked to natural gas processing. Most of the individual components in the CCS process are already used in other applications, such as injection facilities for the use of CO_2 in enhanced oil recovery operations.

49 BTL or Biomass to Liquid can produce liquid biofuels such as bio-diesel by Fischer-Tropsch synthesis of syngas produced by gasification of woody/grassy materials.

50 Integrated combined cycle gasification or ICCG is widely used in coal power generation. The two main products from the gasification process are both used to generate power. Syngas is combusted and the heat is used in a steam turbine.

51 Bio-SYN or bio-SYNgas or synthetic natural gas can be produced by gasification of woody/grassy feedstocks into syngas (a gas mixture comprised primarily of carbon monoxide and hydrogen).This can be used to generate power, converted to methane (synthetic natural gas or SNG) or to liquid fuels.

Box 12: Bioenergy Carbon Capture and Storage

Earlier this year the Government launched a new CCS Commercialisation Programme in order to support practical experience in the design, construction and operation of commercial-scale CCS projects, including those using biomass as a fuel source. The aim of the Programme is to enable private sector electricity companies to take investment decisions to build CCS equipped fossil-fuel power stations, in the 2020s, without Government capital subsidy, and at an electricity market price that is competitive with other low carbon generation technologies.[52]

The Government also launched the CCS Roadmap, which sets out the strategic context for the Government's interventions to support the development and deployment of cost competitive CCS and the steps being taken to achieve this outcome.

The private public partnership, the Energy Technologies Institute, launched its Biomass to Power with CCS project in May 2011. Due to be completed in the summer of 2012, the project is aiming to explore at an engineering level, the cost-effectiveness, technology challenges, technology developments and the likely time-scales for implementation required for biomass to power combined with CCS. It is looking at what opportunities it could generate for the UK and will also help inform the sector's UK benefits case. The research is incorporating feedback from existing international demonstration projects that include biomass co-firing, as well as dedicated biomass to power conversion projects. The project is being delivered through CMCL Innovations, in conjunction with Cambridge University, Doosan Babcock, Drax Power, EDF Energy, E4tech, Imperial Consultants, and Leeds University.

The Government also recognise that full exploitation of the potential from BE-CCS will require further work to understand how trading in negative emissions may be incorporated into carbon trading mechanisms in the long term, either globally or at regional level, such as within the EU-ETS.

Biomass in power generation

4.16 Biomass in power generation currently accounts for less than 3% of the total electricity generation in the UK. Going forward our analysis indicates that biomass in power generation has an important transitional role which can contribute to the cost effective delivery of our renewable targets. The range of biomass in power generation to 2020, which are consistent with our principles, could be 20 to 40 TWh of delivered energy in 2020, accounting for 5% to 11%[53] of total power generation. Use of biomass to allow for decarbonisation of the current coal plants through co-firing and conversions, as well as use of landfill gas, sewage gas and Combined Heat and Power (largerly wastes) are the key routes for delivery of this deployment in line with longer term carbon constraints (Figure 8).

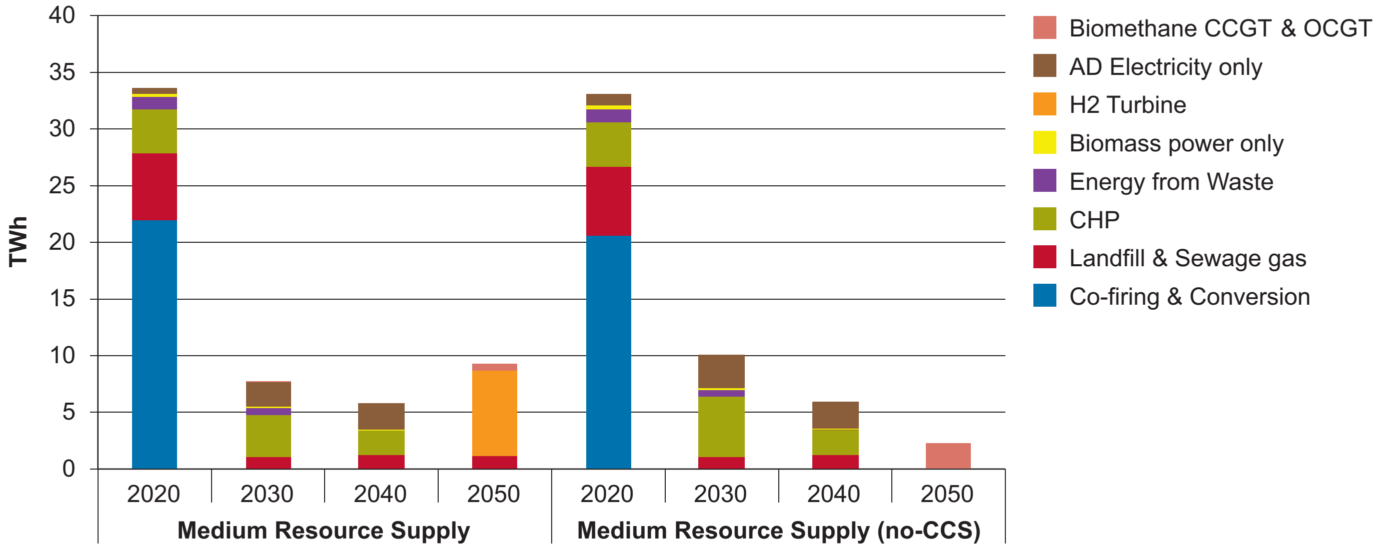
52 Bidders were asked to register their interest by 13 April 2012 and to submit bids by 3 July 2012.

53 Based on DECC analysis using Redpoint modelling

4.17 Beyond 2020 as the needs of other harder-to-decarbonise sectors increase (e.g. aviation, shipping), the cost effective deployment pathways for biomass in power generation are likely to fall significantly. Modelling suggests that this would be limited to uses of wastes[54], CHP and biomethane in Combined Cycle Gas Turbine (CCGT) and Open Cycle Gas Turbine (OCGT) to provide peak electricity. The technical and financial viability of CCS in combination with biomass that allows generation of "negative" carbon emissions is therefore a key prerequisite for any substantial role of biomass in power leading up to 2050.

4.18 Emerging analysis from the Bioenergy TINA suggests that technology innovation will be needed to support the role of biomass in the power sector. Innovation should focus on improvement to current systems, increasing efficiencies and developing boilers which are robust to a wider range of feedstocks. More advanced technologies such as large scale gasification to power, would also need demonstrating at scale in a system that is robust to a variety of feedstocks. In addition, innovation to integrate these technologies with CCS, requires the development of CCS systems as well as their modification or re-engineering to use biomass.

Figure 8: Energy delivered from biomass use in power generation under medium feedstock availability scenario



Source: DECC analysis based on Redpoint

54 Art 3(1) of the revised EU Waste Framework Directive (2008/98/EC) defines the following: "Waste means any substance or object which the holder discards or intends or is required to discard", see http://www.defra.gov.uk/environment/waste/legislation/. Defra is in the process of updating the Guidance on the "Definition of Waste" with a revised version due to be published in late Summer 2012.

Box 13: The wider context in electricity generation

Leading up to 2050 demand for electricity generation is expected to increase. While greater energy efficiency will reduce demand this will be outweighed by rising demand from electrification of heating, transport and parts of industry, and economic and population growth. The 2050 futures set out in the recent Carbon Plan[55] suggest that supply may need to increase by around 30–60%, requiring an average additional low carbon capacity of around 2.5 GW a year for the next 40 years.

Power is expected to be generated largely from a combination of renewable, nuclear and fossil fuel stations fitted with CCS technology in 2050, with unabated gas playing a significant role during this transition to a low carbon economy. As set out in the Electricity Market Reform White Paper the Government's aim is to incentivise investment in a diverse and secure range of low-carbon sources of electricity, and in time, competition between these technologies that will help to keep costs down.

Analysis set out in the Carbon Plan showed that renewable electricity could provide 35–50 GW by 2030 and the CCC's Renewable Energy Review suggested that we could have over 55 GW of renewable electricity capacity by 2030, subject to resolution of current uncertainties such as cost reductions and barriers to deployment.

Biomass in coal co-firing/conversions and new dedicated plants

4.19 In 2010 coal generation provided 108 GWh of power, representing 28% of total power generation[56] in the UK. Use of biomass for co-firing with coal and conversion of existing coal fired plants is both a low cost renewable energy and a technology that is highly likely to meet the requirements of Principle 2. Because biomass will be displacing coal the £/tonne of carbon is significantly lower than the alternative technology (see Box 14).

4.20 Under the current sustainability criteria, conversion of existing coal plants to biomass can lead to a saving of at least 624 kg of CO_2/MWh of power generation[57]. Conversions of coal plants and biomass co-firing is however relatively inefficient in primary energy use compared to alternative biomass uses (e.g. CHP or biomass boilers for heat). The risks of locking in feedstock supplies in these technologies, as decarbonisation needs from other sectors rise to 2050, is mitigated by the expected phasing out of the majority of coal-to-biomass plants in the late 2020s.

4.21 The deployment of new biomass power generation is a less cost effective method of carbon abatement compared to co-firing/conversions, except when fuelled by efficient waste processes. New dedicated biomass plants are more costly to build compared to CCGT plants, while also having a longer expected lifetime than conversions.

55 DECC, Carbon Plan, 2011

56 DECC, Digest of UK Energy Statistics

57 Based on 909kgCO_2/MWh from coal versus 285KgCO_2/MWh from biomass and comparing the lifecycle emissions from power generation from biomass to the direct emissions from UK coal fired power stations.

4.22 However, when compared to the current marginal cost of meeting our renewables target[58] dedicated biomass power generation can presently offer cheaper renewable power. The carbon cost effectiveness and lock-in risks associated with new dedicated non-waste biomass will therefore need to be balanced against the overall costs of meeting our renewable targets.

4.23 In the absence of CCS, the use of feedstocks for dedicated power generation leading up to 2050 should be treated with caution given the other decarbonisation options for this sector and the lack of alternatives for the rest of the energy system. In addition, in a non-CCS world the attractiveness of new dedicated biomass in delivering low carbon emissions is highly dependent on the cost of building the plants and the GHG reductions that biomass can deliver against other low carbon technologies e.g. CCGT plant.

4.24 Once commercialised biomass with CCS could however lead to "negative emissions" that will have a value in offsetting the use of unabated fossil fuels in other energy sectors, providing a flexible route to meeting the challenging reductions in carbon emissions needed as we approach 2050.

Box 14: Carbon cost effectiveness of non-waste biomass in power (new build dedicated plants and conversions/co-firing)

Under the Government's current support mechanisms biomass power generators are required to report against a maximum lifecycle emission of 285 kg of CO_2/MWh. This is 60% less than the average EU emissions from power generation[59] and although representing around 70% lower GHG emissions than a coal fired power generation plant, it only delivers about 30% lower emissions than a modern CCGT.

The figure below shows the relative cost effectiveness of carbon abatement for the conversion of existing coal plants to use biomass, as well as new build, dedicated biomass plants (not using waste as the feedstock), considering different carbon emissions and different levels of required generation support. For new, dedicated biomass plants, the carbon savings are calculated by comparison to CCGT plants, whilst for conversion plants, the comparison is made to coal power plants. The results are compared to the carbon abatement cost associated with the current estimated marginal cost of meeting the 2020 renewables target (around £80/MWh), which is equivalent to the support currently provided to offshore wind.

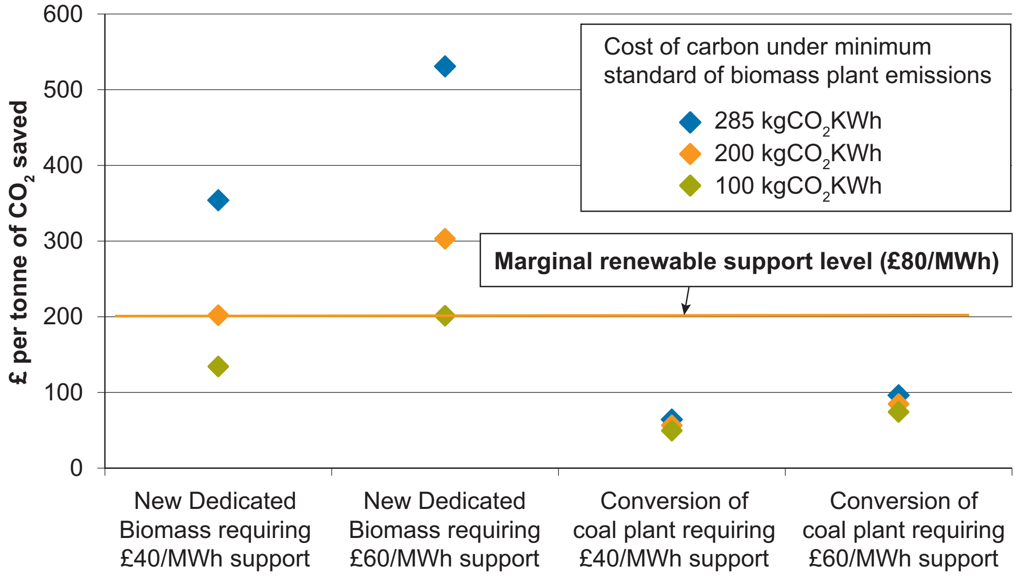
Although in reality most generators will voluntarily be delivering better savings than the current reporting standards, the graph illustrates that conversions of coal plants can offer significantly better value for money in carbon abatement terms when compared to dedicated biomass plants.

58 DECC, Renewable Obligation Banding review consultation Impact Assessment, 2011

59 Report from the Commission to the Council and the European Parliament on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling, 2010 http://ec.europa.eu/energy/renewables/transparency_platform/doc/2010_report/com_2010_0011_3_report.pdf

Box 14: Carbon cost effectiveness of non-waste biomass in power (new build dedicated plants and conversions/co-firing)

Figure 9: Illustrative carbon cost effectiveness of new dedicated biomass against conversions and alternative renewable generation

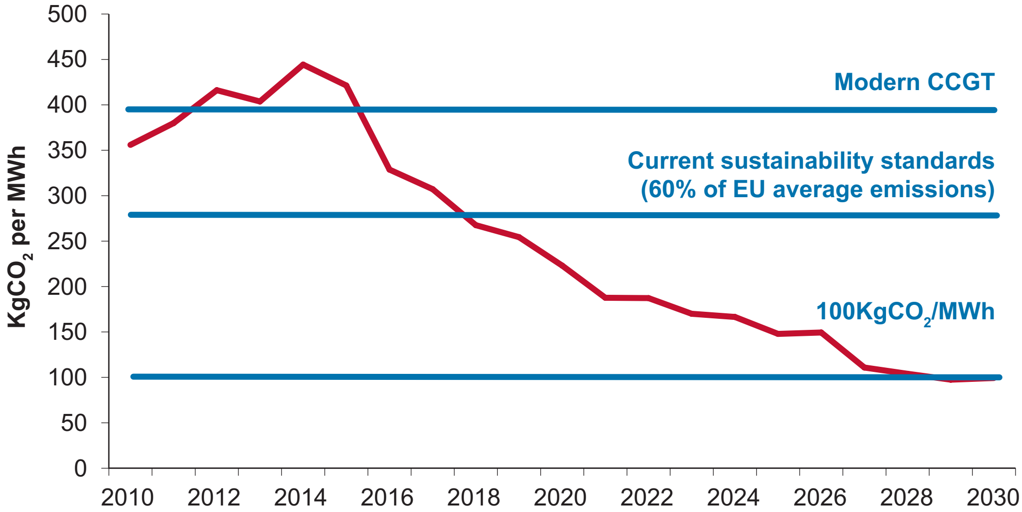


Source: DECC analysis

Notes: Assumed emissions are related to the "feedstock used" only. No 'capital' GHG emissions of building or converting a biomass, CCGT or other renewable plant are included. New dedicated biomass emissions are against CCGT emissions of 398 $kgCO_2$/MWh while conversions are against coal generation at 909 $kgCO_2$/MWh.
Analysis assumes that higher CO_2 standards do not impact the required support for the plants.

4.25 In line with the principles set out in this strategy, as we move towards 2030 and the rest of the power sector moves towards an expected decarbonisation to 100 $kgCO_2$/MWh (Figure 10), tighter carbon standards will be crucial in allowing biomass in power to help deliver a low carbon energy infrastructure. Government policies will need to create the right conditions that allow biomass supply chains and processes to become more energy efficient and less carbon intensive.

Figure 10: Projected Power Sector Emissions Intensity with Electricity Market Reform (CFDs & Capacity Market)



Source: DECC

Biomass in heat

4.26 Bioenergy can service a number of different heat applications with shorter asset lifetimes and lower lock-in risks than some alternatives. Although within the wider options for decarbonising the heat sector, bioenergy is expected to play a relatively marginal role, its contribution will be key in filling the energy needs of vital segments that could be hard to decarbonise in other ways, such as high temperature industrial process. From today, where biomass provides 1% of the total energy needs for heating across the economy, by 2020 biomass could deliver 30 to 35TWh, representing around 6% of the total energy needs of heating[60].

4.27 Looking forward to 2050, the role of biomass in decarbonising industrial heat could become an increasingly important option in certain circumstances, for example if the deployment of CCS is restricted. Our modelling also suggests there could be a potentially greater role for bioenergy use in heat when there are higher levels of biomass resource availability. Figure 11 below shows that by 2050, for the medium supply scenario, the amount of heat generated by biomass could reduce in comparison to 2020. However, in the scenario where ambitious levels of resource are available and CCS technology is excluded, a higher level of bioenergy could be used in the heat sector in the longer term, with most deployment being in high temperature industrial process heating.

60 DECC analysis based on Redpoint modelling.

Box 15: Wider context of the heat sector

The energy required to meet the UK's current heat demand is responsible for nearly half the country's emissions and final energy demand. Demand for heat in 2010 was 712TWh, mainly derived from natural gas electricity and oil.

Future demand is difficult to predict. Improvements in energy efficiency are likely but these may be more than offset by an increase in the number of buildings, economic growth or changes in lifestyles. Decarbonising heat supply is likely to be a vital part of any scenario that successfully delivers the fourth carbon budget and renewable heat is expected to make an important contribution to meeting the EU renewable energy target in 2020. By 2050 the UK needs to have decarbonised heat in buildings almost completely and reduced industry emissions by up to 70% through a combination of efficiency improvements, demand reduction, and fuel and technology switching options. To achieve this, a combination of different technologies and efficiency measures which account of spatial/geographical factors and local contexts will need to have been deployed. This might include the development of large-scale low-carbon heating networks, building-level smaller-scale solutions such as heat pumps, and systems using bioenergy in various forms.

In addition, CHP can maximise fuel efficiency and reduce emissions even with a fossil fuel source, which could later be changed to a low-carbon technology e.g. biomass CHP, recovered heat from a thermal power station or a commercial scale heat pump, depending on the type of heat supplied.

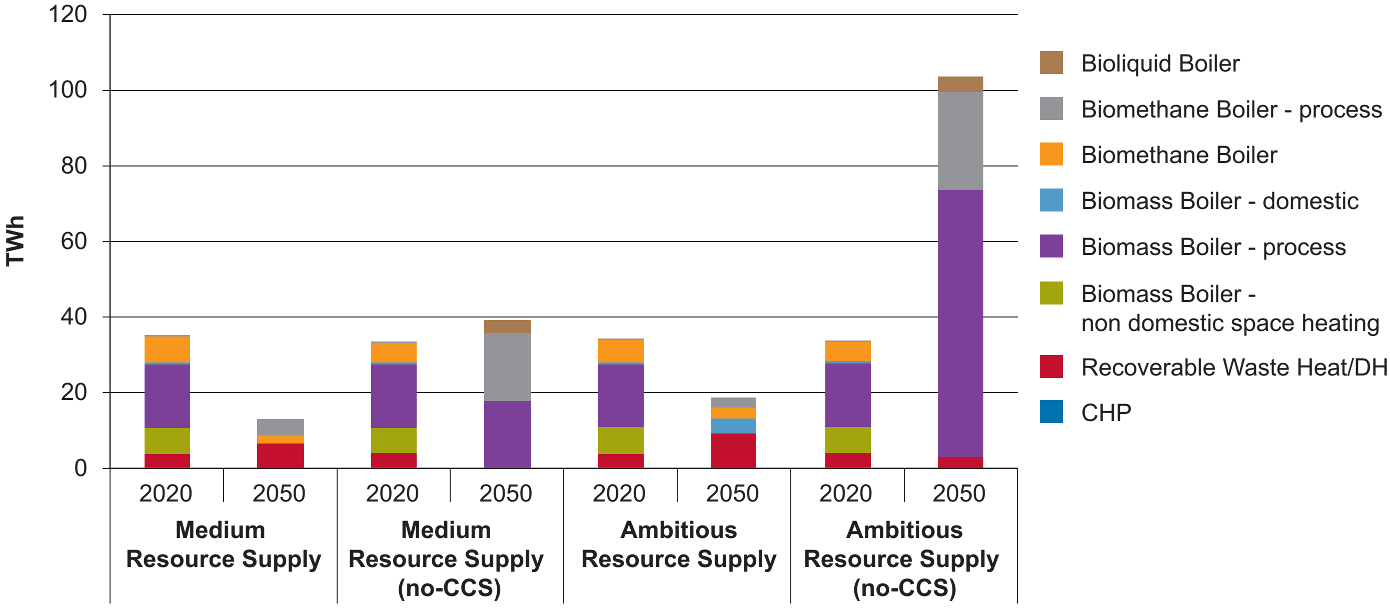
DECC's Heat Strategy includes further details of the options for decarbonising future heating.

4.28 Based on our analysis[61] there are a number of areas where biomass for heating could make a cost effective contribution in a carbon constrained world, and which can be seen as low risk options for the short to medium term. These include:

- A significant ongoing role for using biomass to replace fossil fuel used in high temperature industrial process heating, given the more limited alternative abatement options;
- A transitional contribution in the near to medium term in decarbonising heating both in domestic and non-domestic buildings, in situations where other technologies (such as heat pumps) are not suitable or as cost effective;
- A role for biogas that can be used in space heating in the medium to short term as well as in high temperature process heating in the longer term. In the short-term this is likely to be driven by biomethane injection from AD processes but in the medium term there may be scope for gasification derived bio-syngas;
- An ongoing role in buildings in the form of recovered heat from low carbon power plants and industry using biomass or biogas.

61 Redpoint, Appropriate Uses of Biomass, 2012

Figure 11:Bioenergy heat output by technology under key scenarios



Source: DECC analysis based on Redpoint

Notes: The recovered heat utilisation potential is assumed to be largely generated by AD and CHP plants
Bioemethane boiler refers to industry, commercial/public and domestic applications.

4.29 The preference for bioenergy in industrial processes also has the potential for carbon sequestration through the addition of CCS technology options[62]. For domestic and non-domestic buildings heat pumps and various types of low carbon district heating are expected to provide the most suitable alternative to fossil fuels.

4.30 A range of technology innovation will be needed to develop cost effective and efficient technologies to support this modelling analysis[63]. This includes for example the current Driving Innovation in Anaerobic Digestion programme (Box 16).

Box 16: Waste & Resources Action Programme (WRAP) and the Technology Strategy Board (TSB): Driving Innovation in Anaerobic Digestion (DIAD)

Launched in 2011, this programme aims to identify technologies, processes and/or modifications that will enable the optimisation of the anaerobic digestion (AD) process from feedstock reception through processing and the resulting outputs. The goal of the programme is to make AD work effectively, efficiently or more cost effective resulting in more profitable plants.

62 Our analysis does not include small and medium scale CCS technology options for heat (e.g. for CHP) that may become available in the future due to data uncertainty.

63 Low Carbon Innovation Coordination Group Bioenergy Technology Innovation Needs Assessment (TINA)

Biomass in transport

4.31 Our analysis shows that the long term contribution of biomass to the transport sector is highly dependent on the availability of feedstocks that meet the wider sustainability criteria set out in our principles, the costs of biofuels and the development of other technologies (such as Ultra Low Emission Vehicles). It will also be important to consider the role that can be played in modes where there is no lower carbon alternative. In line with Principle 3 set out in this strategy further use of biofuels will need to take into account the potential impacts on the wider economy and economic growth.

Box 17: The wider context of transport sector

In 2009/10 1,568 million litres of biofuel were supplied under the Renewable Transport Fuel Obligation. This represented 12.8TWh of renewable energy and 3.3% of the total supply of road transport fuels. 71% of this deployment was from biodiesel and 29% from bioethanol[64].

Domestic transport emitted around 137 $MtCO_2e$ in 2009, accounting for around 24% of UK domestic greenhouse gas emissions, by 2050 the transport sector will need to emit significantly less carbon than today. The Government's vision is that by 2050 almost every car and van will produce near zero emissions at the tailpipe, with the UK automotive industry remaining at the forefront of global Ultra Low Emission Vehicle (ULEV) development, demonstration, manufacture and use, driving investment, retaining and creating jobs and delivering growth. The key challenge in transport is decarbonising travel in a way that is both cost effective and acceptable to consumers.

As set out in the recent Carbon Plan, the 2020s is a key transitional decade. Driving further improvements in the efficiency of combustion engines, uptake of ULEVs and the appropriate use of sustainable biofuels will remain a central part of the emissions reductions of the transport sector.

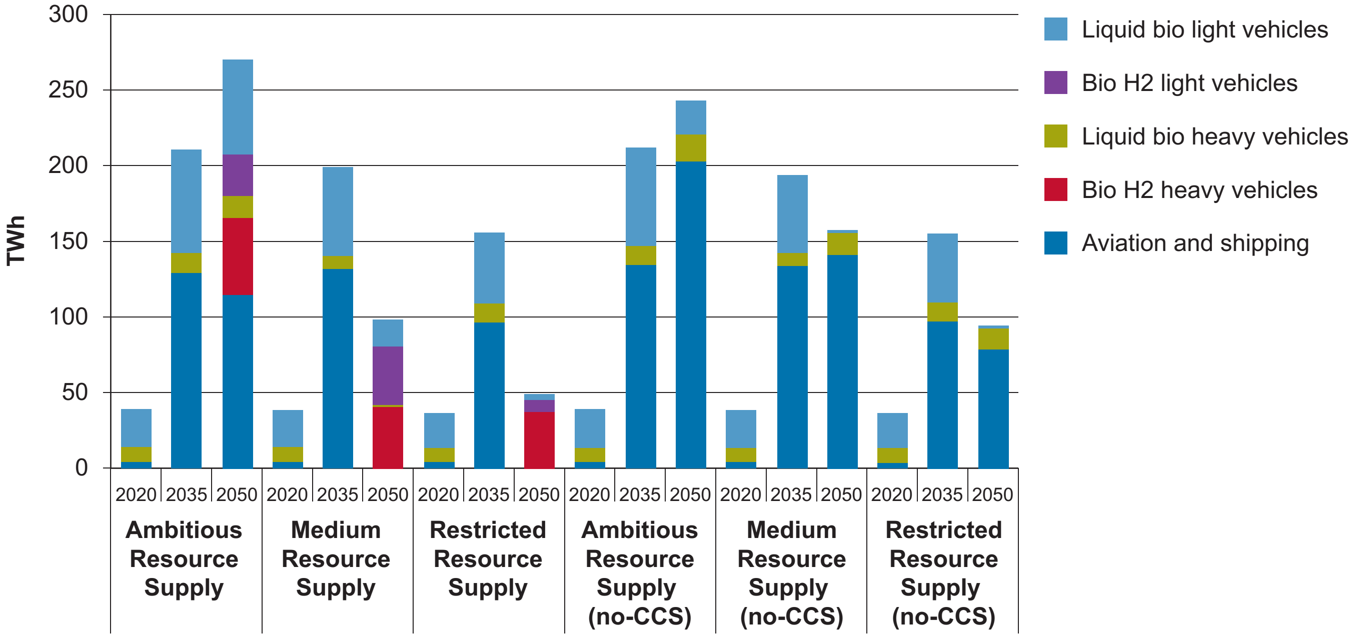
Due to the time needed for fleet turnover almost all new cars and vans sold will need to be near-zero emission at the tailpipe by 2040. These ULEVs could be powered by batteries or hydrogen fuel cells or a mix of these and other technologies, depending on what technology mix proves most cost effective. The freight sector will also need to find lower carbon ways of working, such as modal shift to rail and water, more efficient driving techniques and ultra-low carbon technologies. Domestic aviation and shipping are already included in UK carbon budgets and so will need to contribute to meeting the 2050 target. International aviation and shipping are not currently included. A decision whether to include them is due by the end of 2012.

4.32 In the short term, and potentially for as long as we use fossil fuels, sustainable first generation biofuels (including bioethanol, biomethane and waste-derived biodiesel) offer a cost-effective contribution to reduced emissions from transport in line with our carbon reduction objectives. Addressing ILUC and ensuring the sustainability of low carbon feedstocks is a crucial prerequisite in ensuring that biofuels deliver genuine carbon reductions.

64 Year Two of the RTFO. Available at: http://webarchive.nationalarchives.gov.uk/+/http:/www.renewablefuelsagency.gov.uk/yeartwo

4.33 In the medium-term, the development of advanced biofuels from wastes and wood feedstocks opens the potential for greater uptake of bioenergy. Advanced biofuels could start playing an increasing role in reducing road transport emissions in the 2020s[65]. ULEVs powered by electric batteries and plug-in hybrid technologies will play an increasingly important role and hydrogen fuel cells are expected to join improvements in efficiency of conventional vehicles and advanced biofuels as technologies available to reduce emissions. In heavy good vehicles biofuels and hydrogen fuel cells have the potential to play an important role as pure battery electrification may be more challenging than for light vehicles. Through the 2030s and 2040s our analysis suggests that the deployment of sustainable biofuels in light and heavy road transport vehicles is a consistent cost-effective option under all the supply scenarios assessed.

Figure 12: Potential delivered energy from use of biomass in transport



Source: DECC analysis based on Redpoint
Note: Results are shown as delivered energy for a range of supply scenarios and where CCS technologies are or are not available.

4.34 By 2050, there is considerable uncertainty over how biomass will be most valuably used in the transport sector. The role of each of the low carbon technologies will depend on their relative costs and the availability and cost of CCS technologies, infrastructure, and the type of biomass feedstocks available. It is therefore important to keep options open, neither picking winners nor abandoning the range of low carbon technologies. Aviation biofuels may be a very important use of biomass in the period 2030-2050. However, given the long time horizon there are a number of uncertainties which potentially change the role of biofuels in aviation and other transport areas dramatically.

65 Economic Analysis of Advanced Biofuels in the UK, NNFCC, 2011; Findings from the Low Carbon Innovation Coordination Group Bioenergy Technology Innovation Needs Assessment (TINA)

4.35 The availability of CCS (either for use in conjunction with power generation or alongside the manufacture of liquid fuels), and the availability of biomass are key uncertainties. Under some scenarios, in which biomass supply reduces in the run up to 2050 and CCS technologies become available, the analysis suggests that the supply of aviation biofuels may reduce significantly in the last few years before 2050, with biomass diverted into hydrogen production with CCS for fuel cell electric vehicles. This sudden switching of technologies is a modelling feature driven by the search for the single most cost-effective pathway. Such sudden changes should not be considered a likely scenario for biomass deployment, which we would expect to remain more stable once technologies have secured a market share. The potential for aviation and other sectors in the European Emissions Trading System to purchase international credits, not included in this analysis, may also significantly affect the degree to which emissions are abated in the UK or emissions credits are bought.

4.36 In the long-term, our analysis shows that hydrogen may be used for heavy goods vehicles. However, the use of hydrogen in heavy vehicles is highly uncertain, due to the technical challenge of achieving the power densities in fuel cells necessary to make power-to-weight ratios and costs of these vehicles attractive. Whilst additional considerations, such as air quality regulations, might encourage the use of fuel cell heavy vehicles in niche applications, the feasibility of their wider deployment remains uncertain.

4.37 In addition, cost effective advanced conversion technologies (ACT) offer an important low risk pathway for the future. There is a range of conversion technologies being developed but none has yet been demonstrated at scale. For example, there is potential for a range of transport fuels to be produced from gasification routes using developed technologies which have been proven for other applications (e.g. Fischer-Tropsch synthesis of coal), but which need to be adapted to biomass systems. Other advanced conversion technologies such as Pyrolysis also have potential to produce liquid biofuels in the future (Box 18).

Box 18: Advanced biofuels innovation: Carbon Trust and DECC Pyrolysis Challenge

Using DECC and DfT grant support, the Carbon Trust Pyrolysis Challenge has been bringing together since 2008 industry and academics to develop new methods of producing and upgrading pyrolysis oil from waste biomass such as municipal and wood waste which could be used as a liquid transport fuel.

Section 5 – Setting future policy direction

5.1 There are some courses of action with which it is reasonable to proceed, even allowing for the uncertainties. We describe these as low risk policies in the discussion that follows. These main courses of action include making efficient use of domestic resources, building sustainable supplies, aligning policies that support the key low-risk technology options and supporting innovation across the biomass sector. This section sets the Government's longer term aspirations for these areas and the actions that will be taken to achieve them.

Improving opportunities from domestic supplies

5.2 The energy needs of the UK relative to its domestic supplies of biomass feedstocks mean that imported biomass will be a key contributor towards UK carbon reduction targets to 2030 and beyond. But domestic feedstocks can offer a continuing source of cost effective and sustainable supplies.

5.3 Boosting the productivity and efficiency of biomass production will ease the pressure for agricultural land expansion and reduce many of the associated environmental and social pressures. It will also reduce the price rises associated with extra demand for finite resources. Government policies should, therefore, aim to maximise the opportunities for improving biomass supplies sustainably from all feedstocks, through greater efficiency, reduced wastage, better management of resources, improvements in yields, land productivity and planting rates, as well as improved training and promotion of best practices across agriculture, forestry and waste management sectors.

5.4 There are already a number of Government policies in place that can help deliver this objective. These include:

- Work to increase yields of domestic supplies. The Government is exploring the potential for the sustainable intensification of agriculture via the Green Food project. Such improvements will ideally be achieved by measures which do not require significant additional fertiliser or water use and which include biodiversity safeguards and benefits. (Defra);
- Activities to reduce losses and secure multiple benefits from agricultural production and other major users of biomass, such as the construction and food sectors. Initiatives include moving towards a "zero waste economy", responsibility deals with the food industry to drive down waste, and the use of product standards and guidance (Defra);
- Actions to increase the recovery of wastes and residues. The Waste Policy Review[66] and Anaerobic Digestion Strategy[67] set out the potential for energy recovery from waste in England, consistent with the waste hierarchy, and a set of actions to deliver it. This includes consulting this year on restrictions on waste wood going to landfill, which will aim to improve opportunities for the efficient use of waste wood (Defra);

66 http://www.defra.gov.uk/publications/files/pb13540-waste-policy-review110614.pdf
67 http://www.defra.gov.uk/publications/files/anaerobic-digestion-strat-action-plan.pdf

- Bringing undermanaged forests and woodlands back into management – as well as providing up to 3 Mt per year of additional biomass for energy. The sustainable harvesting of neglected woodland in the UK can bring significant benefits for biodiversity and local employment. The Independent Panel on Forestry (in England) will advise on the future direction of forestry and woodland policy, which includes how woodland cover can be increased as well as options for enhancing public benefits from all woodland and forests. Government will also deliver the recommendations in the Woodfuel Implementation Plan (Defra/ Forestry Commission);

- Encouraging a sustainable increase in energy crop production. Government will explore ways of removing barriers to energy crop production and steering growth in ways which enhance the wider environment (Defra / DECC);

- Coordinated working through Government partners in the Low Carbon Innovation Coordination Group and the EU Strategic Energy Technology Plan. Government will support sustainable bioenergy innovation as part of a suite of low carbon innovation technologies to enable the UK to meet its 2020 and 2050 renewable energy and emissions targets. This will include research and development on yield improvements and technologies which can make better use of wastes and residues (DECC, Defra, DfT, BIS).

5.5 In addition Government departments will work with industry to explore further opportunities for boosting domestic supplies across a range of feedstocks (Defra/Forestry Commission).

5.6 Although the above actions relate to domestic activities, there is also tremendous potential for improving yields and production efficiency in developing countries. This can not only boost bioenergy supplies but also food production and bring valuable revenue to poorer communities. DFID has a series of programmes under way for improving agricultural productivity and transferring knowledge and skills, such as the new generations plantations project.

Promoting the development of sustainable supply markets

5.7 Sustainability standards are the main means through which we ensure the cost effectiveness of bioenergy (Principle 2) and limit its impacts on other sectors (Principle 4). Sustainability standards are set in different ways: many are applied as conditions for receiving incentives, some are set at EU level, while others are being introduced at national level. There are also a number of independent and voluntary schemes, developed by NGOs and business. In addition, there are a range of safeguards which are not specifically linked to bioenergy, such as cross-compliance, agri-environment schemes, the UK Forestry Standard, environmental impact assessment and other environmental regulations.

5.8 Future policies will seek to build on three key areas:

- Continued transparency, monitoring and enforcement: Sustainability standards must retain public confidence. Policies should aim to put as much of the audit trail of compliance into the public domain, to allow for public scrutiny as a lever for improved monitoring and enforcement;

- Harmonisation: There are currently many sustainability regimes. Aligning these across bioenergy and other users will help build robust systems that build industry certainty and investor confidence and reduce market distortions. This should include consistent definitions and methodology for measuring and assessing sustainability, GHG saving and land use change across sectors;
- Tighter standards that drive the development of supply chains: Sustainability standards need to reflect the evolving nature of energy markets in a carbon constrained world. Government policies should be used to influence international negotiations for a uniform and ambitious position that puts bioenergy on a par with other low carbon generation options. We are clear that we must not act in a way which might undermine longer term investment decisions through hasty policies, unless this is an unavoidable response to EU legislation.

5.9 In order to deliver these objectives we will:

- Work jointly with the industry to establish an ambitious but practicable timetable for the supply chain to raise over the longer term the minimum GHG thresholds that accompany Government financial support mechanisms for bioenergy in line with decarbonisation objectives (DECC);
- Maximise transparency of reporting under the UK sustainability standards (DECC);
- Work towards the introduction of mandatory EU minimum GHG saving standards for solid biomass for heat and electricity generation along the lines of proposed UK requirements (see Box 19) and lobby in other international fora for a sustainable approach to bioenergy use (DECC, Defra);
- Work with European partners to see a robust solution to the risk that Indirect Land Use Change (ILUC) emissions reduce, remove or indeed worsen the greenhouse gas savings from some biofuels. We consider that "ILUC factors" introduced into both the Renewable Energy Directive and the Fuel Quality Directive would be the most appropriate solution (DfT);
- Given the importance of reducing agricultural price volatility in the context of achieving global food security and delivering development objectives, we will explore mechanisms for mitigating agricultural price spikes through introducing flexibility into biofuels mandates, or other measures, with a view to alleviating short term price pressures when they appear. This will form part of a wider evidence base that the UK will use to inform its position on the EU reviews in this area in 2014 (DfT, Defra);
- Undertake further analysis on whether the projected increase in UK demand for biomass could increase pressure on deforestation globally, while continuing to work internationally to address and reverse tropical deforestation, through governance reforms, enforcement and improvement of sustainability standards and reforestation / restoration programmes under initiatives such as:
  i. the EU Forest Law Enforcement, Governance and Trade action plan;
  ii. the deforestation strand of the International Climate Fund (REDD+) aimed at tackling tropical deforestation and driving appropriate restoration;

iii. the Forest Governance, Markets and Climate Programme, Forest Europe, the Convention on Biological Diversity, the UN Forum on Forests;

iv. the Global Partnership on Forest Landscape Restoration (Defra, DfID).

- Continue to explore ways of maximising opportunities for sustainable development of bioenergy in developing countries through: extensive zoning, mapping and governance of land usage; piloting of community-scale biofuels initiatives; balancing R&D around potential new technologies and crops; and transparency of reporting from bioenergy generators (DfID);
- Work with industry and other stakeholders to develop and agree a voluntary code of practice for agricultural anaerobic digestion, with the aim of avoiding risks and securing benefits in the context of food security, land use change, the environment and competitiveness (Defra);
- Put in place appropriate safeguards in cases where greater use of bioenergy is likely to prevent the achievement of air quality requirements (Defra, DECC);
- Press for proper account to be taken of the social impacts of bioenergy production in EU policy, in the context of EU reviews in 2014 (DFID, DfT);
- In response to the CCC's recommendations on standards for other products, we will continue with various existing efforts to boost sustainability of farming and forestry. We will also explore consistency between energy and non-energy standards and investigate the scope for improving them, such as promoting the sustainable use of palm oil for all products (Defra).

5.10 In addition, Government will continue to press for the introduction of global carbon accounting to strengthen the transparency of bioenergy's carbon impacts at a global level. We will also promote knowledge transfer to the developing world to maximise the benefits and minimise the adverse impacts that bioenergy could have on their economics and societies.

Promoting the deployment of "low-risk" technological options

5.11 There are some bioenergy deployment options which our evidence shows offer important pathways for the sustainable development of the sector to 2020 and beyond. It is important that future policies and incentives are aligned to incentivise low risk areas that minimise technology and investment lock in to pathways that may become undesirable and minimise lock out of potential vital pathways.

5.12 Based on the analysis presented in Section 4 there is a need for policy alignment that:

- Promotes the replacement of coal by biomass in existing coal plant in the short term;
- Maximises the potential deployment for use of biomass in industrial heat;
- Maintains a flexible approach on the use of biomass in decarbonising transport and continues to strengthen sustainability standards, particularly around ILUC;

- Maximises energy recovery from end-of-life biomass across all sectors, consistent with the waste hierarchy, and re-use for traditional and new wood products before energy recovery in order to promote carbon sequestration;
- Recognises and enables the development of advanced conversion technologies for production of biofuels for use in niche transport sectors where electrification is not suitable and for the production of bioenergy with Carbon Capture and Storage if this becomes feasible (including the development of a market for negative emission credits).

5.13 The following key activities are already underway to address these needs:

- Promoting cost and carbon efficient biomass electricity: through the Renewables Obligation Banding Review consultation, Government has set out proposals to support biomass-to-coal replacement, while also signalling a cautious approach to the creation of new dedicated biomass capacity in the 2013-17 banding period.
- Maximising industrial heat deployment: the introduction and development of the Renewable Heat Incentive is the key policy measure to achieve this aim.
- Maximising energy recovery: consistent with the waste hierarchy the Government's waste policies promote the re-use and recycling of materials where appropriate, with energy recovery only when other uses are exhausted or it forms the best environmental outcome.
- Supporting the commercialisation of biomass with CCS: We are committed to supporting commercial deployment of CCS. The critical next step is to bring down costs and risks by supporting development of technology at scale in a commercial environment. Further actions that we are taking in this area are set out in the CCS Roadmap. The Energy Technologies Institute (ETI) is currently funding a project which seeks to explore, at an engineering level, the cost-effectiveness, technology challenges and technology developments required for biomass to power combined with CCS. The project will help to provide clarity on what further technological developments are required.
- Making capital funding available: From April 2012, the Government will pave the way for the UK Green Investment Bank with a new programme of direct Government investment in green infrastructure. The Green Investment Bank's mission will be to provide financial solutions to accelerate private sector investment in the UK's transition to a green economy. It will work towards a 'double bottom line' of both achieving significant green impact and making financial returns. It has made available £100 million to invest in small waste infrastructure projects (typically in the size range of £15-25 million), on a fully commercial basis.
- Supporting innovation in energy crops, biofuels and biomass for power and heat: Government supports bioenergy innovation research, development and demonstration through a number of different organisations including DECC, ETI, TSB, Carbon Trust and Research Councils UK. These organisations and others come together under the umbrella of the Low Carbon Innovation Coordination Group[68] (LCICG) which this year

68 The Low Carbon Innovation Coordination Group (LCICG) aims to maximise the impact of public sector funding of low carbon energy technology innovation in order to deliver affordable, secure, sustainable energy for the UK, deliver UK economic growth and capabilities, knowledge and skills.

will publish a Low Carbon Innovation Prospectus. This will set out how the members' plan to prioritise and address the innovation needs of a range of key low carbon technologies, including bioenergy, as a means of delivering a joined up and coherent suite of support to industry. In addition, the Research Councils and the Technology Strategy Board have formed a cross Research Council Bioenergy Strategy Coordination Group with the aim of developing a more collaborative, integrated and inter-disciplinary approach to bioenergy research. We will also continue to work through the EU Strategic Energy Technology Plan to support innovative technologies.

Monitoring, evaluation and review

5.14 Given the complexity of issues associated with bioenergy, significant uncertainty will remain about the future impacts of increased demand. Therefore, it will be important to continue to monitor impacts and review policies and measures periodically in the light of information gained from monitoring policy impacts and the outputs of continuing research.

5.15 The Government will explore ways of monitoring and evaluating the impacts of our bioenergy policies. Where policy direction is modified, we will always be mindful of the impact on industry and will give as much notice as possible of any changes.

5.16 We will review how the totality of UK bioenergy policies meets the direction and principles set out in this strategy in at least 5 year intervals.

Annex A: Biomass and bioenergy

A.1 Biomass is defined as material of recent biological origin, derived from plant or animal matter such as wood, agricultural crops or wastes, and the biological component of municipal wastes. These biomass types are used in many different ways: for consumption as food by both humans and animals; as inputs for the production of materials and products; as fuel for producing electricity and heat; and as feedstocks for the production of liquid transport fuels. A significant proportion of this biomass is also currently not used at all or, at the end of its useful life is disposed of in landfill.

A.2 Bioenergy is the production and use of energy or fuels from biomass feedstocks.

Types of biomass feedstock

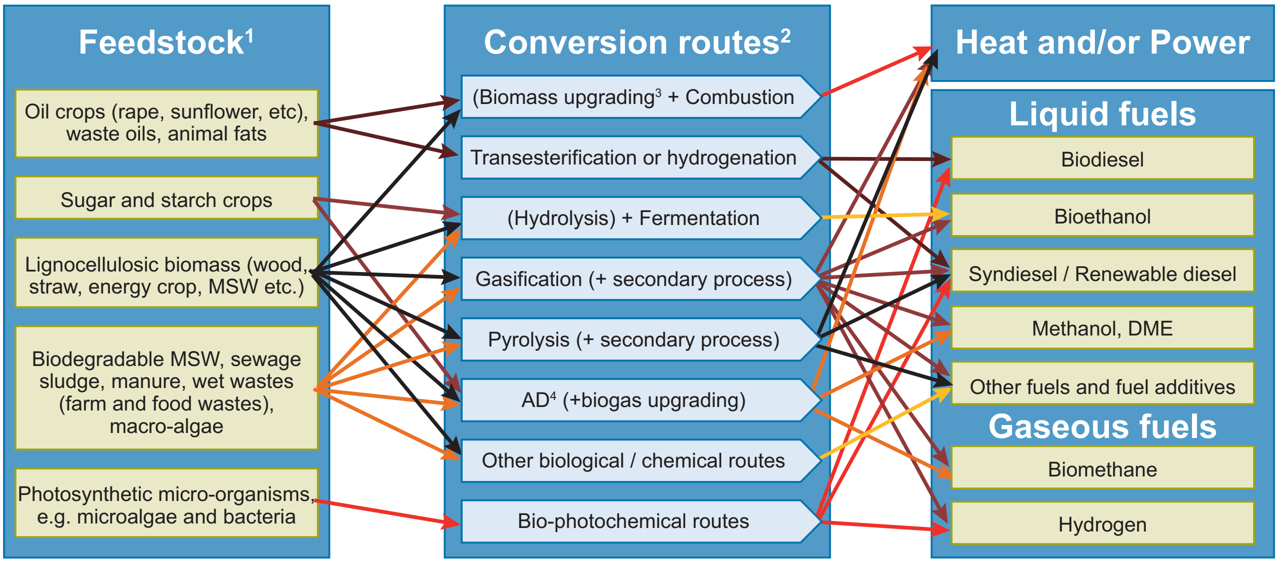
A.3 Biomass is available in many forms and from many different sources, including:

- conventional forestry management, such as thinning, felling and coppicing of sustainably managed forests, parklands and trees from other green spaces.
- agricultural crops, including wheat, maize, sugar, rapeseed or oil palm and crops grown primarily for use in energy generation ('energy crops'), such as short rotation coppice (SRC) or miscanthus grass which can be grown on land unsuitable for food crops.
- biodegradable wastes and residues, including residues from the wood processing (e.g. sawmill residues, parts of trees unsuitable for the wood industry), agricultural residues (straw, husks), sewage sludge, animal manure, waste wood from construction, and food waste.
- Algae. Both microalgae and macroalgae can be grown in either fresh or saline water for use as a feedstock for bioenergy. This is not yet viable at commercial scales, but could in future be an important source of both liquid biofuels and solid biomass.

Conversion of biomass to energy

A.4 Raw biomass feedstocks can be converted to a range of products for use in heat, electricity or transport through a series of conversion steps. Different conversion technologies have been developed that are adapted to the different physical properties of feedstocks as well as the end use. Some routes are more straight forward, e.g. direct combustion for heat, whilst others require several pre-treatment, upgrading and conversion steps, such as those used for the production of liquid fuels. Figure 13 shows the different possible conversion routes which can be employed to produce alternative forms of bioenergy from a wide range of biomass feedstocks.

Figure 13: Biomass conversion routes



[1] Parts of each feedstock, e.g. crop residues, could also be used in other routes

[2] Each route also gives co-products

[3] Biomass upgrading includes any one of the densification processes (pelletisation, pyrolysis, torrefaction, etc.)

[4] AD = Anaerobic Digestion

Source: Synthetic view of the wide variety of bioenergy routes. Bioenergy – A Sustainable and Reliable Energy Source: Main Report. IEA. Bioenergy:ExCo:2009:06 (http://www.ieabioenergy.com/LibItem.aspx?id=6479).

Annex B: Sustainability of bioenergy

B.1 This annex discusses some of the more technical aspects arising from the four principles set out in Section 2 of the strategy.

Sustainability criteria

B.2 In the context of bioenergy “sustainability criteria” relate to environmental, social or economic conditions used to distinguish between desirable and undesirable forms of bioenergy. These criteria may be mandatory conditions that must be met to gain access to the market/support mechanisms or voluntary conditions that are, for example, reported against and used to assess policy impacts[69].

B.3 It is imperative that we are able to distinguish effectively between those feedstocks and methods of production of bioenergy which have desirable environmental outcomes and those which do not. We must also consider how they fit with our other objectives, such as food security and development. This means we need sustainability criteria which are:

a. Clear and consistent;

b. Ambitious;

c. Enforceable.

B.4 Such policies and systems must be manageable for producers and compatible with other regimes while also inspiring broad public confidence. But our ability to assess the different aspects of sustainability is not uniform. Although our policies already include standards that mitigate against harmful greenhouse gas emissions from bioenergy (see Box 19), the process of capturing and assessing wider social and economic development impacts is arguably more complex and subject to interpretation. Given this, we must be particularly mindful of these impacts.

B.5 Bioenergy polices need to follow best practices in mitigating these wider impacts while delivering their primary environmental objectives – the key policy driver leading us to support bioenergy is that, under the right conditions, it offers the prospect of lower carbon energy than the alternatives.

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69 The broad issue of sustainability is discussed *inter alia* at an IEA workshop on bioenergy, in May 2010: http://www.ieabioenergy.com/DocSet.aspx?id=6568&ret=lib. Further information can be found here: http://www.decc.gov.uk/en/content/cms/meeting_energy/bioenergy/sustainability/sustainability.aspx

Box 19: Current sustainability criteria for biomass use energy generation

Solid biomass

From 1 April 2011, under the Renewables Obligation, electricity generators over 50kW are required to report annually on their performance against sustainability criteria for biomass feedstocks they use.

The sustainability criteria are:

- Minimum 60% Greenhouse Gas ("GHG") lifecycle emission saving for electricity generation using solid biomass or biogas relative to fossil fuel; and
- General restrictions on using materials sourced from land with high biodiversity value or high carbon stock – including primary forest, protected areas, peatland and wetlands.

The sustainability criteria apply to the use of imported as well as domestic biomass and biogas for electricity generation but do not apply to waste or biomass wholly derived from waste. The GHG lifecycle assessment, considers the GHG emissions resulting from the production of bioenergy looking from 'ground to grid'. Lifecycle assessment includes consideration of emissions related to cultivation, processing and transport of the biomass feedstock, any direct land use change and the conversion efficiency of the plant.

Following a two year transition period, we intend that from April 2013, generators of 1MWe capacity and above will be required to meet the sustainability criteria in order to receive support under RO.

Further work is already under way to include sustainable forest management criteria, for example by linking with the Forestry Commission's UK Forestry Standard or other international standards. We also intend to consider how any proposals to address indirect land use change (ILUC), currently being considered by the European Commission for biofuels and bioliquids, could apply to biomass and biogas.

Box 19: Current sustainability criteria for biomass use energy generation

Biofuels and bioliquids

Criteria are set out in Article 17 of the EU Renewable Energy Directive (published June 2009). Member states can provide support only to bioliquids that meet these, and cannot impose tougher criteria.

The Renewable Energy Directive Criteria for Bioliquids (& Biofuels) are 3-fold:

- Minimum lifecycle GHG emissions saving of 35% compared to fossil fuel, increasing in 2017 to 50%; and in 2018 increases to 60% for new installations.
- General restrictions on using raw materials from land important for biodiversity or a carbon sink.
- For EU grown crops, requirement to meet Common Agricultural Policy (CAP) cross-compliance requirements.

We intend to introduce sustainability criteria for biomass heat into the Renewable Heat Incentive in 2013.

Principle 1 issues: Life Cycle Assessment

B.6 Life Cycle Assessment (LCA)[70] is a well-established process to quantify the total environmental effects of a product or service, by considering all processes involved, from the production of raw material, to the final use or disposal of products (also known as 'cradle to grave' analysis). The environmental impact can be quantified into several categories, including total primary energy requirement and GHG emissions. In the case of greenhouse gas emissions, carbon dioxide is used as a reference to quantify these impacts.

B.7 When determining the environmental impacts of bioenergy systems using LCA, the following stages of the process are typically considered, although this can vary from study to study:

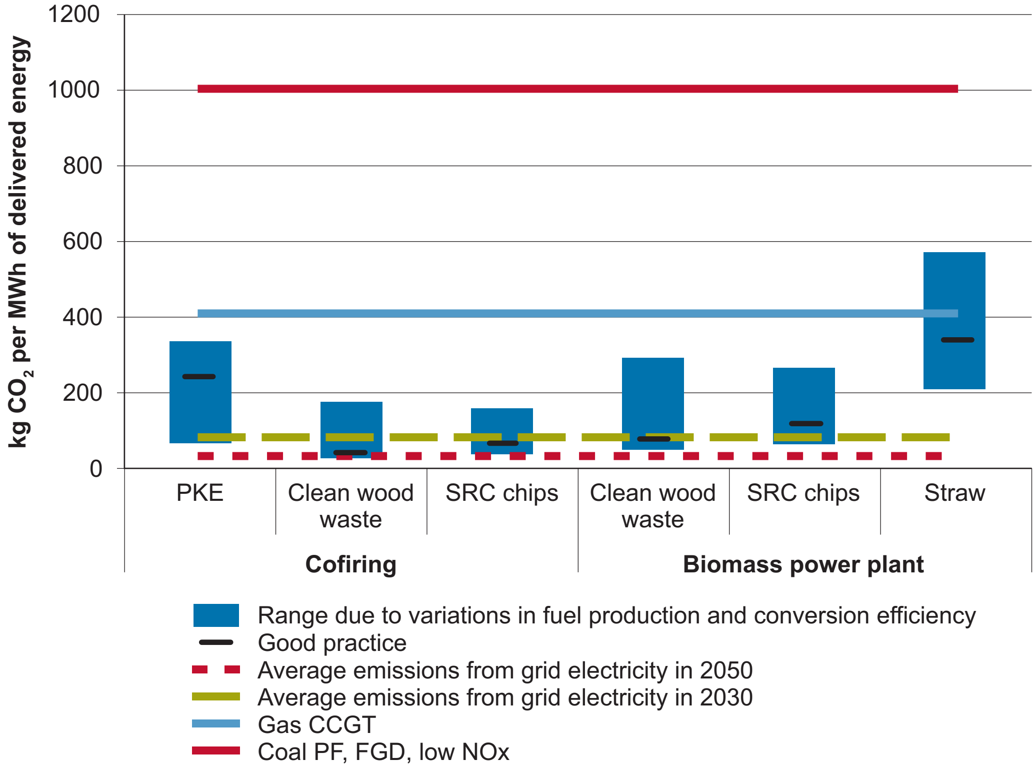
- growth and harvesting of the biomass feedstock (e.g. miscanthus, SRC, sugar cane);
- transport of the biomass to a conversion facility;
- conversion of the biomass to a fuel (e.g. wood chip, liquid biofuels);
- transport of the fuel to its point of use;
- use of the fuel as bioenergy (e.g. combustion in a power or CHP plant);
- disposal of any waste (e.g. glycerol from biodiesel production); and
- the impact of production of co-products, such as ash, that reduce the carbon footprint of products they substitute, for such as fertiliser.

B.8 The analysis aims to quantify the impact of each of these stages. To do this, the inputs and their associated environmental burdens must be determined. For example, when determining GHG emissions associated with growth and harvesting of biomass feedstock, production and use of any required fertilisers should be included, as well as the fuel required to run any machinery needed during cultivation (e.g. to power a tractor). Any changes in the use of land which arise from the growth of bioenergy feedstocks (either direct or indirect) should also be considered to the best degree possible, as these can cause emissions of GHG comparable to or greater than the process itself.

B.9 The GHG emissions and primary energy requirement associated with different bioenergy options varies widely, depending on many factors including the biomass feedstock and its origin, the agricultural practices employed, and the conversion technology used. LCA can be used to compare and contrast different bioenergy options. Furthermore, LCA provides a valuable tool to compare the environmental performance of bioenergy systems with other low-carbon technologies, as well as fossil fuels. For example, Figure 14 shows the LCA results of the GHG emissions from using different biomass sources to generate electricity, and compares the results to emissions from electricity generated from plants powered by natural gas or coal, as well as the projected average national grid emissions of 2030 and 2050. It can be seen that for each bioenergy system, there is a wide range of LCA results, depending on the practices employed.

70 Defined by the Royal Society for Chemistry here: http://www.rsc.org/ScienceAndTechnology/Policy/EHSC/EHSCnotesonLifeCycleAssessment.asp

Figure 14: Greenhouse gas emissions from producing and using different biomass fuels to generate electricity, best to worst practice

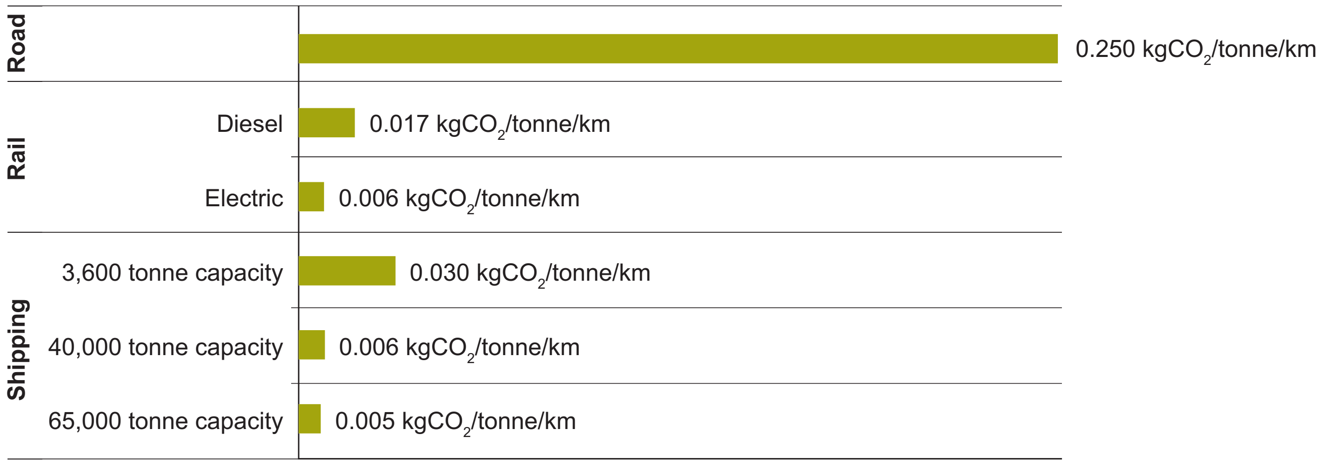


Source: Environment Agency

Notes: Emissions included in the results are from: the growth of the crop or production of by-product, transport, processing and conversion to energy. The ranges shown are the result of expert judgements about a number of the values used in the BEAT2 model. Best and worse practices represent extreme but feasible values for factors such as the distance the fuel is transported. Good practice represents a high level of performance considered to be within the capabilities of plants operating today.
Abbreviations: PKE Palm kernel expeller, SRS Short rotation coppice, CCGT Combined Cycle Gas Turbine, PF/FGD Pulverised fuel with Flue gas Desulphurisation and technology to lower emissions of oxides of nitrogen.

B.10 Different modes of transport can also have a significant impact on the LCA of a given feedstock. For example moving wood chip 200 km by road instead of electric rail could add 29.5 kgCO_2/MWh of electricity generated. By contrast the carbon emissions from shipping it in a 65,000 tonne ship from East Coast of Canada could be around 40% lower, at 17 kg CO_2/MWh.

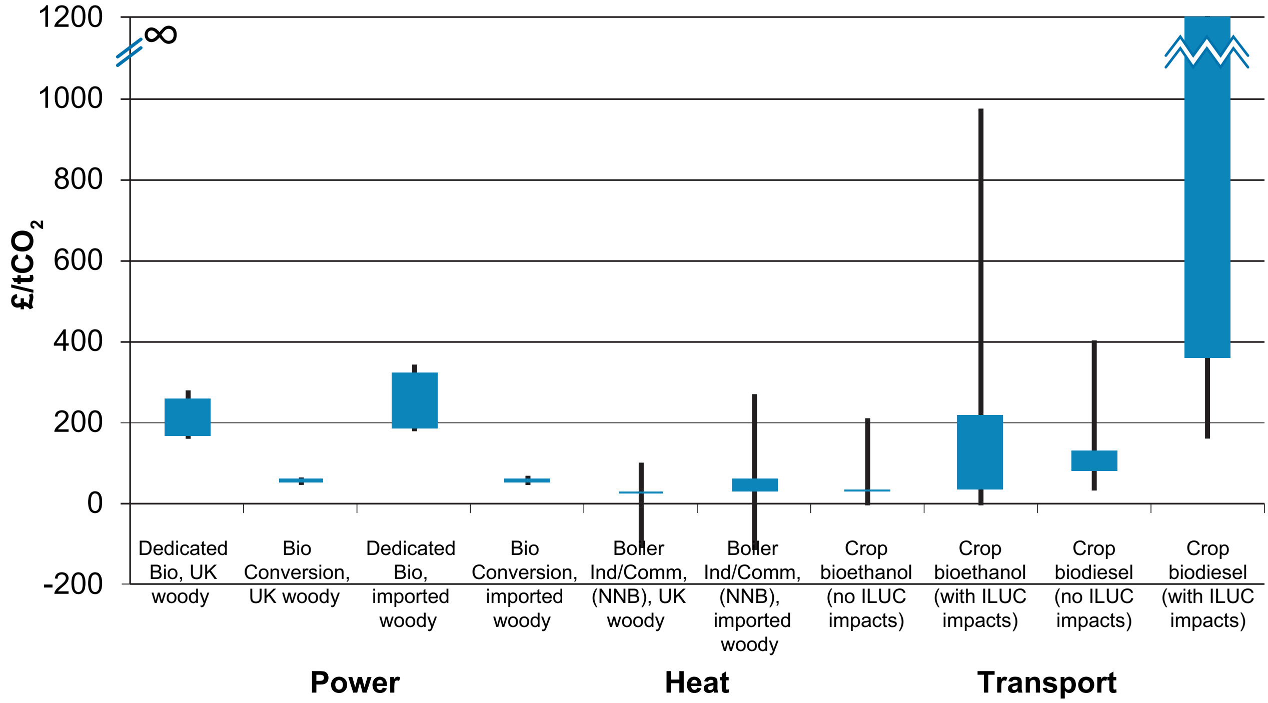
Figure 15: CO_2 emissions of transporting 1 tonne of wood chip per kilometre



Source: DECC analysis

B.11 Life Cycle Assessment has been used for this strategy to provide evidence of the potential GHG implications for different scenarios of the deployment of bioenergy (relating to Section 4 in the main text). There is a range of estimates of the LCA of different feedstocks from existing literature, and the sources used for this analysis are explained in more detail in the Analytical Annex. Combining these estimates with our estimates of generation costs enables us to develop indicators of the cost of abating carbon for different bioenergy pathways and technologies. Figure 16 below shows a selection of these for 2020.

Figure 16: Cost-effectiveness of using bioenergy sources to abate carbon in different applications and sectors, £/tC0$_2$, 2020 estimates, 2010 prices



Source: DECC analysis
Note: Solid bars indicate variation in LCA estimates based on median technology costs. Larger range shown by lines indicates variation in both costs and LCA estimates.
Abbreviations: NNB: Non Net Bound fuel (heating oil)

Principle 1 issues: Carbon emissions from land use change

B.12 Land use change (LUC) is the general term used to describe a change in the way land is managed or what the land naturally produces, for example a change from natural grasslands to agricultural production or an intensification of production. Deforestation is one example of LUC[71].

B.13 Direct and indirect land use change can result from a number of economic activities – it is not solely a bioenergy issue. For example, taking cropland out of production to allow land to regenerate into natural vegetation can have the unintended impact of causing other land to be converted to cropland in compensation or production from remaining cropland may be intensified to compensate for reductions in food supply. In either case, if these activities were to take place in response to introduction of the measure, they are likely to have adverse impacts on net GHG emissions.

B.14 In bioenergy systems, such changes may happen on the land used to produce the biomass. For example, the planting of miscanthus as a future energy crop on unused land, this is sometimes referred to as direct land use change (dLUC). If existing agricultural produce or land is used for bioenergy (for example if oilseed rape is used to make biodiesel) there may be no direct land use change. However, by taking the product away from the existing uses, all other things being equal, this will (relative to the counterfactual) lead to an increase in the price of the product creating an incentive to produce more, either through more intensive production on existing agricultural land or by bringing more land into production. This change is known as indirect land use change (ILUC) because, while it happens as a result of increased bioenergy production, the change is consequential and may be geographically distant.

B.15 In certain circumstances, LUC can lead to positive greenhouse gas GHG benefits but it can also reduce the greenhouse gas benefits of bioenergy or lead to loss of biodiversity or other ecosystem services. Our current sustainability standards place safeguards against direct land use changes in areas with high biodiversity value or high carbon stock – including primary forest, protected areas, peatland and wetlands. However land use change in unprotected areas and ILUC can pose a significant threat to the carbon savings that bioenergy can deliver, particularly from bioenergy produced from agricultural land rather than forestry.

B.16 The scale of land use change (direct and indirect) as a result of bioenergy is uncertain. However, as the main aim of Government support for bioenergy is to reduce carbon emission it is crucial that bioenergy policies consider these accordingly. This leads to some significant methodological and policy challenges that are discussed below.

71 IPCC, Special Report on Land Use, Land-Use Change and Forestry, 2000

The scale of carbon emissions from land use change

B.17 LUC occurs for a number of reasons and bioenergy production is not expected to be the largest driver of these changes[72]. However, as the principle aim of bioenergy policies is to reduce greenhouse gas emissions is it right to consider the impact on land use that these bioenergy use generates. The extent to which bioenergy causes LUC is contingent on how much bioenergy expands, where and how the biomass is produced and related technological practices.

B.18 Indirect land use changes are particularly important for energy feedstocks produced on existing agricultural land. The scale of emissions from ILUC is inherently uncertain. ILUC cannot be directly observed or measured; it can only be estimated using related information, for example, changes in agricultural production, deforestation rates and data on trade patterns. The most sophisticated work to understand ILUC emissions combine these data into computer models of global production and trade of agricultural and other products.

B.19 There have been many attempts to estimate the emissions that result from bioenergy, and particularly biofuel use in Europe and America. In 2010 the European Commission reviewed more than 150 scientific papers and other contributions on ILUC produced between 2007 and 2010[73]. The results are varied and there are many areas of uncertainty that remain. However, there is agreement that bioenergy production does cause ILUC and the vast majority of studies find that the overall impact is increased greenhouse gas emissions.

B.20 One of the studies most suited to understanding the impact of biofuel use in the UK is the work by International Food Policy Institute (IFPRI) for the European Commission[74]. This study looked at the projected European biofuel use up to 2020 and included a detailed investigation of many of the uncertainties in ILUC emissions. Like many studies the report found that emissions are potentially very significant and, unless action is taken to reduce these emissions, when included in the life cycle analysis some biofuels may produce more greenhouse gas emissions than the fossil fuels they replace, as shown below.

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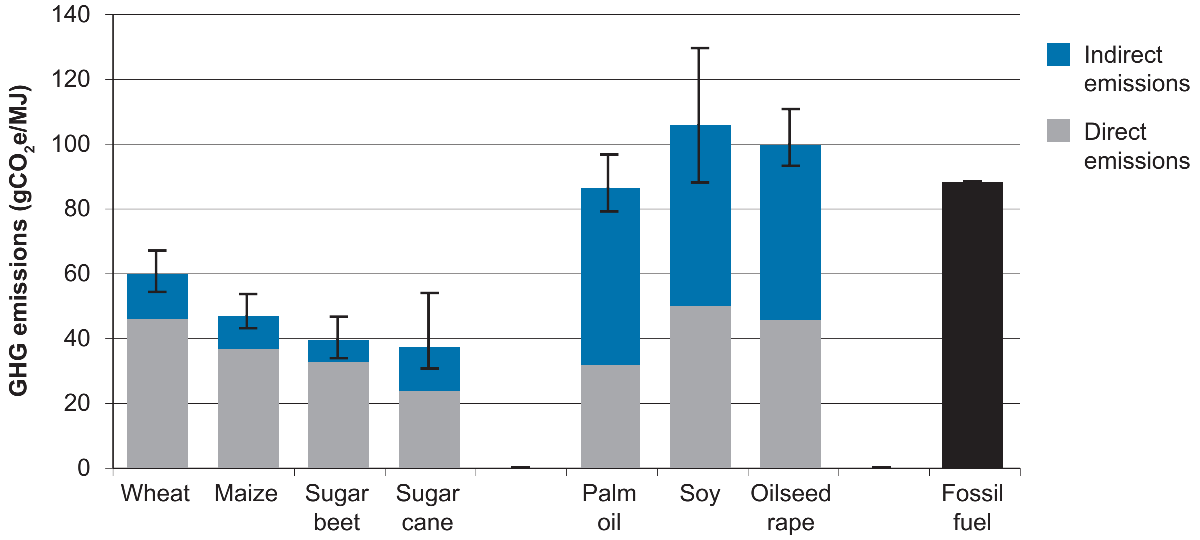
72 Kampman et al., 2008 estimated that land for food and feed will expand between 200-500 Mha by 2020, whereas increased demand for biofuels could result in total demand of between 73-276 Mha (up from 13.8 Mha today). Kampman, B, F. Brouwer and B. Schepers, Agricultural Land Availability and Demand In 2020, Report to the Renewable Fuels Agency, 2008.

73 European Commission: The Impact of Land Use Change on Greenhouse Gas Emissions from Biofuels and Bioliquids: Literature review, 2010

74 Laborde, D., IFPRI. Assessing the Land Use Change consequences of European biofuel policies and its uncertainties, 2011

Figure 17: Estimates of the life cycle emissions from biofuels when ILUC emissions are included



Source: DfT analysis based on IFPR[75]

Principle 1 issues: International Carbon Accounting in bioenergy systems

B.21 It has been argued that there are several flaws in the accounting system for carbon emissions, which may mean that the emissions accounted for underestimate their actual level[76].

B.22 A fundamental problem is that any biomass sourced from countries not signed up to the Kyoto Protocol, such as the US and developing countries, will automatically be accounted as carbon-free.

B.23 The Land Use, Land-Use Change and Forestry (LULUCF)[77] rules are complex. It is clear that differences between the actual facts of carbon reduction and how they are accounted for are unhelpful and that working for more transparent systems is desirable.

B.24 Present negotiations are seeking to include in a future agreement mandatory comprehensive accounting for all agricultural processes and to extend commitments to account for biomass generally to the US and to major developing countries. Achieving this would still fall short of complete carbon accounting, so consideration of ILUC, and/or sustainability criteria, is likely to remain necessary in the medium term. The Government will continue to press for proper accounting of carbon emissions.

75 ibid

76 RSPB, “Bioenergy:A burning issue”, 2011

77 The United Nations Framework Convention pages explain the requirements: http://unfccc.int/methods_and_science/lulucf/items/3060.php

Principle 4 issues: The relationship between food and fuel

B.25 In the context of rising populations, and against the backdrop of climate change, biofuels have been cited as potentially increasing risks to food security over the medium term[78]. The Government believes that food production must remain the primary goal of agriculture and the production of biomass for bioenergy must not undermine food security, in the UK or internationally.

B.26 There are concerns, specifically, that biofuels and biomass policies will lead to higher food prices than would otherwise be the case. Indeed, to the extent that such policies result in an increase in aggregate demand for agricultural feedstocks and/or agricultural land, then they will result in higher agricultural product prices than would otherwise have been. However, the size of the impact, though significant, is more modest than often supposed.

B.27 Analysis by Defra's modelling team using the OECD-FAO Aglink-Cosimo model suggests that the removal of biofuels support at the EU level could have a modest (yet significant) medium-term price reduction impact on the feedstocks used for biofuels production[79]. For example, when EU biofuels mandate support is removed, on average over the projection period, projected EU wheat prices are around 7% lower than in the baseline scenario, vegetable oil prices around 12% lower on average, and oilseed prices approximately 4% lower than baseline levels. This is broadly consistent with earlier modelling by the OECD (2008).

B.28 Commodity price changes are a major contributor to food price changes, but other factors (e.g. energy prices and exchange rates) are also relevant.

B.29 Over and above medium term impacts on agricultural product prices, there is a distinct question about the extent to which biofuel policies have contributed to recent international agricultural price spikes. In that context, a thorough cross-Whitehall analysis of the agricultural price spikes of 2007/8[80] concluded that biofuels had a relatively small contribution in 2008, particularly as far as wheat was concerned. Nevertheless, the report also concluded that the additional global demand for biofuels has and will put upward pressure on the prices for those agricultural commodities used in biofuels production.

B.30 The cross-Whitehall report also raised a question about the extent to which the inelasticity of demand for biofuels makes an important segment of agricultural product demand more inelastic so that international prices are more volatile than they would otherwise be. Indeed, the June 2011 report[81] by ten international organisations to the G20 Agriculture Ministers recommended that failing a removal of support to biofuel production and consumption, 'G20 Governments should develop contingency plans to adjust (at least temporarily) policies that stimulate biofuel production or consumption (in particular mandatory obligations) when global markets are under pressure and food supplies are endangered'.

78 BIS, The Foresight project Global Food and Farming Futures, 2011

79 Defra, Removing Biofuel Support Policies: An Assessment of Projected Impacts on Global Agricultural Markets using the AGLINK-COSIMO model, 2012

80 HMG, The 2007/8 Agricultural Price Spikes: Causes and Policy Implications, 2010 (http://archive.defra.gov.uk/foodfarm/food/security/price.htm, http://archive.defra.gov.uk/foodfarm/food/pdf/ag-price100105.pdf)

81 Price Volatility in Food and Agricultural Markets: Policy Responses, June 2011, contributions by FAO, IFAD, IMF,OECD, UNCTAD, WFP, the World Bank, the WTO, IFPRI and the UN HLTF

B.31 Although the UK demand for biofuels is very small in global terms and, therefore, we do not anticipate that the extra UK demand for sustainable bioenergy to 2020 will create a significant conflict with food production objectives, it is driven by EU mandates for biofuel use and must be considered within the context of the EU demand for biofuels. At a cumulative level this EU demand can exacerbate food price increases at times when they are high for other reasons, particularly in the short term before production has had time to respond.

B.32 Biofuels mandates that can be temporarily flexed or otherwise relaxed at times of agricultural price pressures could produce worthwhile reductions in the severity of these spikes. We will be undertaking further analysis on the merits of this and other mitigating options in the coming months, to help inform the UK's position for the EU bioenergy reviews in 2014.

B.33 A movement to advanced biofuels from wastes and woody material could significantly reduce the direct competition for food feedstocks. It may not however necessarily solve the competition for land and water (depending on the differing characteristics of the second generation feedstocks concerned). It is therefore essential that we continue to monitor the volume and types of bioenergy demand in the UK and their links with food prices and production, in light of the development of food and bioenergy markets.

B.34 We should also aim to learn from the practices of other countries, particularly Brazil, which has completed a comprehensive agro-ecological zoning study[82]. Such work could improve our evidence base about land use, both domestically and internationally, and has the potential to lead to an even more effective way to ensure that bioenergy is produced sustainably.

Principle 4 issues: Wider environment and bio-diversity impacts

B.35 Demand for bioenergy can present risks for biodiversity and ecosystems through loss of semi-natural and natural habitats (such as forest clearance), intensification of agricultural production and the potential introduction of non-native invasive species. There is, therefore, a potential tension with the Government's commitment to halt and reverse biodiversity loss and ecosystem degradation both domestically and internationally, particularly the issue of potentially increasing water stress.

B.36 On the other hand, a number of reports show that perennial energy crops, such as short rotation coppice and miscanthus if cultivated in the right place and in the right way, can be better for biodiversity and water quality than arable crops such as wheat and maize. There will also be benefits if energy demand leads to unmanaged forests being brought back into sensitive management. The precise impacts depend on the previous nature of the land, the nature and location of the new crops and their management, for example by avoiding large swathes of monoculture.

82 Lynd, L.R., Ramlan Abdul Aziz, Carlos Henrique de Brito Cruz, Annie Fabian Abel Chimphango, Luis Augusto Barbosa Cortez, Andre Faaij, Nathanael Greene, Martin Keller, Patricia Osseweijer, Tom L. Richard, John Sheehan, Archana Chugh, Luuk van der Wielen, Jeremy Woods and Willem Heber van Zyl. 2011. A global conversation about energy from biomass: The continental conventions of the global sustainable bioenergy project. Interface Focus 1:71-279.

B.37 Risks can be reduced and benefits increased by: taking steps to create additional feedstock supply in appropriate ways, thus reducing the pressure for agricultural expansion into natural habitats; applying standards and safeguards effectively to exclude biomass from unsustainable sources; monitoring impacts and undertaking periodic reviews of policies and measures to ensure bioenergy expansion proceeds at a sustainable pace.

Principle 4 issues: Air quality

B.38 The combustion of biomass releases not only carbon emissions but also particulates (PM) oxides of nitrogen (NOx) and polyaromatic hydrocarbons (PAHs). These pollutants are harmful to human health and ecosystems. NOx is also involved in the formation of ground level ozone, which as well as being a damaging air pollutant (including the ability of plants to fix carbon), is also a potent greenhouse gas[83].

B.39 The air quality impacts of burning biomass depend on what fuel biomass is replacing, how it is burned, the quality of the fuel and to an extent where it is burned. When biomass replaces large scale oil or coal generation, the impacts are generally positive. However replacement of gas boilers in an urban area has the potential for significant air quality impacts.[84] In rural areas, the use of good quality biomass fuels and appliances replacing existing solid fuel appliances should not noticeably worsen air quality, albeit that no amount of particulate matter in the air is safe. Likewise, this should not cause problems with complying with current UK overall emissions obligations (so-called “national ceilings”), but is likely to be relevant if the current revision of the ceilings results in their tightening.

B.40 Transport biofuels at current substitution levels generally produce no significant difference from fossil fuels on air quality[85]. The one possible exception is emissions of aldehydes from bioethanol, the impacts of which are currently being examined by the Health Protection Agency.

B.41 There are EU legal requirements with respect to air quality which the UK must meet. These include limit values and targets for concentrations of air pollutants and national emissions ceilings for levels of pollutants emitted. The UK has met limit values for pollutants except NO_2, where there are still a large number of exceedences in our towns and cities. For particulate matter the present limits are largely met. But there is no safe level for particulate matter pollution so it is important to continue to reduce emissions. The target value for benzo(a)pyrene (an indicator of PAHs) is being exceeded in some areas where there is significant solid fuel burning. Furthermore, the European Commission’s review of air quality legislation is due to conclude in 2013 and options for strengthening protection will undoubtedly be explored. Looking further ahead, dioxins may become a priority substance under the water framework directive, with a requirement to bring them to zero within 20 years. Local authorities also have duties to improve local air quality and have an interest in the impacts the use of bioenergy might have.

83 For information on emissions levels, please see: http://www.biomassenergycentre.org.uk/portal/page?_pageid=77,109191&_dad=portal&_schema=PORTAL

84 Renewable Heat Incentive Impact Assessment, February 2010.

85 Advice note from the Air Quality Expert Group to the Department for Environment, Food and Rural Affairs; Scottish Government; Welsh Assembly Government; and Department of the Environment in Northern Ireland, on the likely impact of road transport biofuels on air quality in the UK, 2011 at http://www.defra.gov.uk/publications/files/pb13464-road-transport-biofuels-110228.pdf

B.42 Abatement measures are currently in place to control the impacts of bioenergy on air quality. Any energy plant over 20MW is subject to pollution control regulation. For smaller plants, the Government is planning to introduce emission criteria requirements under the Renewable Heat Incentive. Policies should continue to evaluate and quantify the impacts of biomass combustion on air quality.

Principle 4 issues: International Development

B.43 Eradicating poverty and hunger and providing energy is crucial for sustainable development and for the achievement of the Millennium Development Goals. Without access to modern energy services the poor in the developing countries are deprived of many potential income generating opportunities. Whereas some progress has been achieved in providing access to modern energy services in the Asian region, development in Africa is still lagging far behind. This situation entrenches poverty and causes increased unsustainable use of traditional solid biomass (wood, charcoal, agricultural residues and animal waste), in particular for cooking and heating where smoke from inefficient stoves causes health problems and exacerbates climate change. The situation is particularly precarious in sub-Saharan Africa.

B.44 The last decade has seen increased production and use of biofuels as alternative liquid fuel in transport, households, production and power generation applications. This new source of demand for agricultural commodities creates opportunities, but also risks especially for the food and agriculture sectors.

B.45 Bioenergy has the potential to provide communities in sub-Saharan Africa with multiple essential energy services such as electricity for lighting, small appliances or battery charging; for income generating and educational activities; and for pumping water, cooking, and transportation. A good example of harvesting the positive effects of bioenergy is provided by New Generation Plantations project: these are forest plantations that maintain ecosystem integrity, protect the high conservation values and are developed through effective stakeholder participation processes, while contributing to economic growth and employment[86].

B.46 If developed improperly, however, the effects could be increased food prices, displacement of communities and degradation of the environment.

B.47 There is considerable ongoing research to strengthen the evidence base for policy and decision making on different biofuels, in different contexts and using different models for feedstock growth and bioenergy deployment. International organisations, such as the ninth Conference of the Parties (COP) of the Convention on Biological Diversity (CBD) have urged application of sound policy frameworks for the sustainable production and use of biofuels.

B.48 There are several key aspects to delivering positive outcomes from bioenergy for trade and development. Central to them all are two key concepts: comprehensive, enforceable sustainability criteria and secondly, greater transparency.

86 Further details are available here: http://www.newgenerationplantations.com/

B.49 Well-planned bioenergy development can contribute to climate change adaptation as well as mitigation. For example, carrying out strategic environmental assessment (SEA) for bioenergy development provides the opportunity to ensure that the interests of vulnerable and/or marginalized groups (e.g. small holders, vulnerable social groups, indigenous peoples, diversified cultures, migrant workers) are considered in the decision-making process.

B.50 Policy makers should seek to maximise these benefits, offering opportunities for improving the energy security for developing countries and building markets that allow them to take advantage of the value embedded in their natural resources.

B.51 The UK Government would encourage commercial investment in Biofuel development in developing countries to be guided by compliance with the FAO Voluntary Guidelines on Governance of Tenure of Land, Fisheries and Forests in the context of National Food Security[87], and also the Principles on Responsible Agricultural Investment (PRAI) deriving from the 2009 G8 Summit and endorsed by the G8 and G20.

87 Recently published and due to be endorsed by the 38th Special Session of Committee on Food Security in Rome on 11 May

Bioenergy Strategy Glossary

Advanced biofuels

Biofuels produced through application of advanced conversion processes to dedicated energy crops and the lignocellulosic parts of residues, or using novel feedstocks such as algae and bacteria.

Advanced Conversion Technology (ACT)

There are a number of technological options available to make use of a wide variety of biomass types, including wastes. Conversion technologies may release the energy directly, in the form of heat or electricity, or may convert it to another form, such as liquid biofuel or combustible gas.

Advanced Conversion Technologies are the subject of current research, with some demonstration plants in operation, however are not widely deployed. Examples include cellulosic ethanol production, Fischer-Tropsch synthesis, gasification and pyrolysis.

Current conversion processes are mature technologies which are already being widely used to produce biofuels on an industrial scale, including fermentation.

Agricultural residues

The by-products from crops, such as wheat straw and seed husks, as well as other agricultural wastes including slurry and manure.

Agro ecological zoning

Agro-ecological Zoning (AEZ) refers to the division of an area of land into smaller units, which have similar characteristics related to land suitability, potential production and environmental impact.

An Agro-ecological Zone is a land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use.

Aldehydes

An aldehyde is an organic compound (defined as any compound whose molecules include carbon) containing a formyl group. Similar to other combustion emissions, biodiesel exhaust emissions can contain aldehydes.

Anaerobic Digestion (AD)

A process in which micro-organisms break down biodegradable material, particularly animal slurry and food waste, in the absence of oxygen. It produces a methane-rich biogas that can be combusted to generate heat or electricity. Alternatively, the biogas can be cleaned and upgraded to biomethane for injection into the gas distribution network as a replacement for natural gas, or for use as a transport fuel.

Bio-dimethyl ester (BioDME)

DME is being developed as a synthetic second generation biofuel (BioDME), which can be manufactured from lignocellulosic biomass. Currently the EU is considering BioDME in its potential biofuel mix in 2030.

Dimethyl ether (DME), also known as methoxymethane, is the organic compound with the formula CH_3OCH_3. DME is a promising fuel in diesel engines, petrol engines and gas turbines owing to its high cetane number, which is 55, compared to diesel's, which is 40–53. As well as being sulphur-free the simplicity of this short carbon chain compound leads during combustion to very low emissions of particulate matter, NOx, CO.

Biodiversity

The variety of all life on Earth, including all species of animals and plants, and the natural systems that support them.

Bioeconomy

The Bioeconomy refers to the set of economic activities relating to the invention, development, production and use of biological products and processes.

Bioenergy

Energy generated by combusting solid, liquid or gas fuels made from biomass feedstocks which may or may not have undergone some form of conversion process.

Bioethanol

Bioethanol is the principle fuel used as a petrol substitute for road transport vehicles. Generally produced from starchy crops like sugar cane, sugar beet, corn and wheat. As with potable alcohol, it can be made from virtually any organic substance (grass, wood, biodegradable element of municipal solid waste), but the technologies for doing so are not yet commercially viable.

Biofuel

A fuel produced from biomass feedstocks.

Biogas

Biogas is a mixture of gases produced by Anaerobic Digestion. Its major constituents are methane at about 60% and carbon dioxide at around 40% with other gases in trace amounts (mostly hydrogen sulphide and ammonia). The composition of the biogas depends on the type of feedstock and the type of AD. Biogas can be 'upgraded' to more than 97% methane, called biomethane, by removing the other gases.

Bioliquids

Liquid fuels for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass.

Biomass

Biological material that can be used as fuel or for industrial production. Includes solid biomass such as wood, plant & animal products, gases and liquids derived from biomass, and the biodegradable element of commercial and industrial wastes and municipal wastes.

Biomass to Liquid (BTL)

Biomass-to-liquids (BTL) refers to chemical processes that transform biomass into liquid fuels. This is usually distinguished from processes that use enzymes to create cellulosic ethanol or other fuels directly. While biomass-to-liquids technologies include pyrolysis, the most common use of the term refers to the combination of gasification, which converts biomass into syngas. and the Fischer-Tropsch process, which can convert syngas into a range of products, including biodiesel, ethanol and others.

Biomethane

Methane of biological origin (effectively renewable natural gas),generally produced either by cleaning up the biogas that results from anaerobic digestion or via a ‘methanation’ process to produce methane from the synthesis gas resulting from biomass gasification. Biomethane can be injected into the gas distribution network as a replacement for natural gas, or it can be used as a transport fuel.

Bio-economy

The Bioeconomy refers to the set of economic activities relating to the invention, development, production and use of biological products and processes.

Carbon plan

The Carbon Plan published in December 2011, sets out Government plans for achieving the emissions reductions committed to the first four carbon budgets, on a pathway consistent with meeting the 2050 target.

Carbon Capture and Storage (CCS)

Technology which involves capturing carbon dioxide, transporting it and storing it in secure spaces such as geological formations, including old oil and gas fields and aquifers under the seabed.

Co-firing

Combustion of two materials at the same time. For example, biomass can be co-fired in coal power plants.

Combined Cycle Gas Turbine (CCGT)

In a combined cycle gas turbine (CCGT), the hot exhaust gases of a gas turbine, or turbines, are used to provide all, or a portion of, the heat source for a heat exchanger (called a heat recovery steam generator) to supply a steam turbine.

Both the gas and steam turbines drive electrical generators, achieving a greater thermal efficiency than is possible independently. Efficiencies of around 55% are achievable (compared with around 35% at conventional fossil fuel plants).

Combined Heat and Power

A system in which the heat associated with electricity generation is also used for space heating or process heat. In this way the overall efficiency of the process in terms of the proportion of the energy in the biomass fuel that is made use of is increased considerably. Also known as co-generation.

Conventional biofuels

Transport biofuels typically derived from crops and waste using current conversion processes. Examples include bio-ethanol from sugar cane and biodiesel from oilseed rape and used cooking oil.

Co-products

The production of bioenergy can involve the generation of co-products during cultivation, harvesting and processing of the crops into biofuel (e.g. rape meal from the production of biodiesel from oilseed rape). The RED uses the method of energy content to apportion resource inputs and upstream emissions between the co-product(s) and main bioenergy product.

Cross-compliance requirements

The term ‘cross-compliance’ refers to the requirement for farmers to comply with a set of Statutory Management Requirements (SMRs) and keep their land in Good Agricultural and Environmental Condition (GAEC) in order to qualify for EU subsidies including the full single payment and other direct farm payments.

Dedicated biomass:

Power plants that use only biomass feedstock in order to generate power. See also co-firing.

Dedicated energy crops

Crops which are grown with the intention of being used only for the generation of energy. Examples include fast growing trees (such as short rotation coppice willow) and grasses with a high lignocellulosic content (such as miscanthus).

Dioxins

Dioxins are a group of more than 200 chemicals with a similar structure but varying levels of toxicity. Dioxins are found just about everywhere – they are present in the atmosphere, soil, rivers and the food chain. Dioxins are mainly by products of industrial processes including as a result of incomplete burning of organic materials but can also result from natural processes, such as volcanic eruptions and forest fires.

Direct Land Use Change

The conversion of land from one use to another (e.g. from unmanaged forest to cropland, or between two different crop types).

Energy security

There is no perfect definition of energy security, and it can encompass a variety of aspects. At its core lies the concept of physical security (avoiding involuntary interruptions of supply). It can also include elements of price security (e.g. avoiding excessive price volatility), and should be considered in the context of sustainability and affordability.

Feedstocks

Crops or products that can be used to produce bioenergy.

Fermentation

The use of micro-organisms (e.g. yeasts, bacteria) to break down organic substances. Fermentation is used to convert sugars into alcohol to produce bioethanol.

Fischer-Tropsch (FT) process

Production of liquid hydrocarbons, such as synthetic diesel and gasoline, by catalytic conversion of gas.

Food security

Food security refers to the availability of food. In the context of bioenergy it relates to the debate about diverting farmland away from growing food crops to growing bioenergy feedstocks instead, to the detriment of food prices and supply on a global scale.

Forestry and forest residues

Forest sector by-products including residues from thinning and logging (e.g. treetops, limbs, slash and small round wood) and secondary residues including sawdust and bark from wood processing. Forestry and forest residues can also include dead wood from natural disturbances, such as fires and inset outbreaks, biomass grown in forests that are not required for timber production, and biomass from dedicated plantations (e.g. short and long-rotation forestry).

Fossil fuel

Coal, oil and gas are called "fossil fuels" because they have been formed from the organic remains of plants and animals laid down many millions of years ago.

As fuels they offer high energy density, but making use of that energy involves burning the fuel, with the oxidation of the carbon to carbon dioxide and the hydrogen to water (vapour). Unless they are captured and stored, these combustion products are usually released to the atmosphere, returning carbon sequestered (that is, locked away) millions of years ago and thus contributing to increased atmospheric concentrations.

Gasification

Gasification is the heating of organic material at high temperatures with a reduced amount of oxygen and/or steam. This produces a 'synthesis gas' (often called syngas), which typically contains a mixture of hydrogen, carbon monoxide, carbon dioxide and various other hydrocarbons. This gas can be combusted to generate electricity and/or heat. It can also be used to produce other fuels such as biomethane, biodiesel (via the Fischer-Tropsch process) or pure hydrogen.

Green Deal

The Energy Act 2011 includes provisions for the 'Green Deal', which intends to reduce carbon emissions cost effectively by revolutionising the energy efficiency of British properties. The Green Deal financial mechanism eliminates the need to pay upfront for energy efficiency measures and instead provides reassurances that the cost of the measures should be covered by savings on the electricity bill.

Greenhouse Gas (GHG)

Any atmospheric gas (either natural or anthropogenic in origin) which absorbs thermal radiation emitted by the Earth's surface. This traps heat in the atmosphere and keeps the surface at a warmer temperature than would otherwise be possible.

Indirect Land Use Change (ILUC)

Indirect land use change occurs when land for an existing activity (e.g. food or timber production) is converted to grow bioenergy feedstock or a food crop is used for bioenergy (e.g. divert maize to ethanol), which results in the relocation of that displaced activity to another area that is converted.

Joule (J)

A unit of work or energy, equal to the work done by a force of one newton when its point of application moves through a distance of one metre in the direction of the force: equivalent to one watt-second. Related units are: Kilojoule (kJ) = 1000 J, Megajoule (MJ) = 1,000 kJ, Gigajoule (GJ) = 1,000 MJ and Terrajoule (TJ) = 1,000 GJ.

Kilowatt hour (kWh)

A unit of energy, equal to the total energy consumed at a rate of 1,000 watts for one hour. Related units are: Megawatt hour (MWh) = 1,000 kWh, Gigawatt hour (GWh) = 1,000 MWh and Terawatt hour (TWh) = 1,000 GWh. The kilowatt hour is equal to 3.6 million joules.

Kyoto Protocol

Adopted in 1997 as a protocol to the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol makes a legally binding commitment on participating countries to reduce their greenhouse gas emissions by 5% relative to 1990 levels, during the period 1998-2012. Gases covered by Kyoto Protocol are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulphur hexafluoride (SF6), hydroflurocarbons (HFCs) and perfluorocarbons (PFCs).

Lifecycle emissions

The emissions generated for a product system or service over its entire life-time.

Lignocellulosic feedstock

Woody feedstocks with significant cellulose and hemi-cellulose content. Advanced conversion processes are required to break down the cellulose and hemi-cellulose for conversion to liquid biofuels.

Managed forests

In a managed forest, trees are replanted as they are felled. Wood products that come from well managed forests have the most benefits in terms of combating climate change. Well managed woodlands also generally store more carbon than stands that are not harvested.

Mega hectare (Mha)

A hectare is a unit of surface, or land, measure equal to 100 ares ($100m^2$), or 10,000 square meters: equivalent to 2.471 acres. A mega hectare is one million (106) hectares.

Megawatt electrical (MWe)

The megawatt is equal to one million (106) watts. Megawatt electrical is a term that refers to electric power, while megawatt thermal or thermal megawatt refers to thermal power produced.

Methanation

Process to produce methane of high quality from a mixture of chemical compounds, especially the products of gasification (‘synthesis gas’) and fermentation. The methane produced – often known as synthetic natural gas or bioSNG – can then be injected into the natural gas grid, or used in applications such as power generation and production of high-temperature heat for industry.

Organisation for Economic Co-operation and Development (OECD)

The mission of the Organisation for Economic Co-operation and Development (OECD) is to promote policies that will improve the economic and social well-being of people around the world. It was established in 1961 and has thirty-four countries as members.

Particulates/particulate matter (PM)

Airborne PM includes a wide range of particle sizes and different chemical constituents. It consists of both primary components, which are emitted directly into the atmosphere, and secondary components, which are formed within the atmosphere as a result of chemical reactions. Of greatest concern to public health are the particles small enough to be inhaled into the deepest parts of the lung. Air Quality Objectives are in place for the protection of human health for PM10 and PM2.5 – particles of less than 10 and 2.5 micrometres in diameter, respectively.

Pellets

Pellets can be manufactured from woody, energy crop and agricultural residue feedstocks and used as fuel for electric power plants and biomass boilers. Pellets are very dense and have a low moisture content.

Pyrolysis

Pyrolysis is the thermal decomposition of organic material at high temperatures, in the absence of oxygen. It produces gas and oil and leaves a solid residue (sometimes called biocoal) which is richer in carbon content than the original feedstock; the oil can be potentially used directly in ships or upgraded for a variety of transport applications, while the gas can be used in a similar way to the products of gasification.

Renewable Energy Directive (RED)

A European directive that sets targets for all member states, such that the EU as a whole will reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector. UK's target is 15% renewable generation by 2020.

Renewable Energy Roadmap

A comprehensive action plan published in 2011 by the Department for Energy and Climate Change to accelerate the UK's deployment and use of renewable energy, and put the UK on a path to achieve its 2020 target, while driving down the cost of renewable energy over time.

Renewable Energy Strategy (RES)

A plan published by the Government in 2009 to meet the European target of 15% of energy from renewable sources by 2020 (including electricity, heat and transport).

Renewable Heat Incentive (RHI)

Provides financial assistance to producers of renewable heat.

Renewable Obligation Certificate (ROC)

Certificate issued under the Renewables Obligation to an accredited electricity generator for eligible renewable electricity generated within the UK.

Renewables Obligation (RO)

This is the primary support scheme for renewable electricity generation in the UK, and places an obligation on electricity suppliers to source an increasing proportion of their electricity from renewable sources.

Renewables Transport Fuel Obligation (RTFO)

UK legislation requiring fossil fuel suppliers to ensure that a specified percentage of their fuel for road transport in the UK – rising from 3.5% in 2010/11 to 5% by volume in 2013/14 – comes from renewable sources.

Short rotation coppice

Some fast growing tree species, such as willow, can be cut down to a low stump (or stool) when they are dormant in winter and go on to produce many new stems in the following growing season. This practice is well established in the UK and Europe, having been a traditional method of woodland management over several hundred years for a variety of purposes including charcoal, fencing and shipbuilding.

Softwood

Term used to describe the wood of coniferous trees, or conifers themselves, although in fact the wood is not always softer than the 'hardwood' of broad-leaved trees.

Strategic Environmental Assessment (SEA)

A Strategic Environmental Assessment (SEA) is intended to increase the consideration of environmental issues during decision making related to strategic documents such as plans, programmes and strategies. The SEA identifies the significant environmental effects that are likely to result from the implementation of the plan or alternative approaches to the plan.

Syngas

Syngas is the abbreviation for Synthesis gas. It is typically a mixture of hydrogen, carbon monoxide, carbon dioxide and various other hydrocarbons. The syngas is produced from the gasification of organic material. It can be combusted to generate electricity and/or heat. It can also be used to produce other fuels such as biomethane, biodiesel (via the Fischer-Tropsch process) or pure hydrogen.

Technology Innovation Needs Assessment (TINA)

The TINAs aim to identify and value the key innovation needs of specific low carbon technology families to inform the prioritisation of public sector investment in low carbon innovation.

Wastes

Art 3(1) of the revised EU Waste Framework Directive (2008/98/EC) defines the following: "Waste means any substance or object which the holder discards or intends or is required to discard"[88].

Waste hierarchy

Article 4 of the revised EU Waste Framework Directive (2008/98/EC) introduces a hierarchy of options for managing wastes. It gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then other recovery such as energy recovery, and last of all disposal (for example landfill).

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88 Defra will publish extensive Guidance on "Definition of Waste" later in the Summer of 2012. Please visit Defra's website: http://www.defra.gov.uk/environment/waste/legislation/, the relevant pages will be updated in due course"

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