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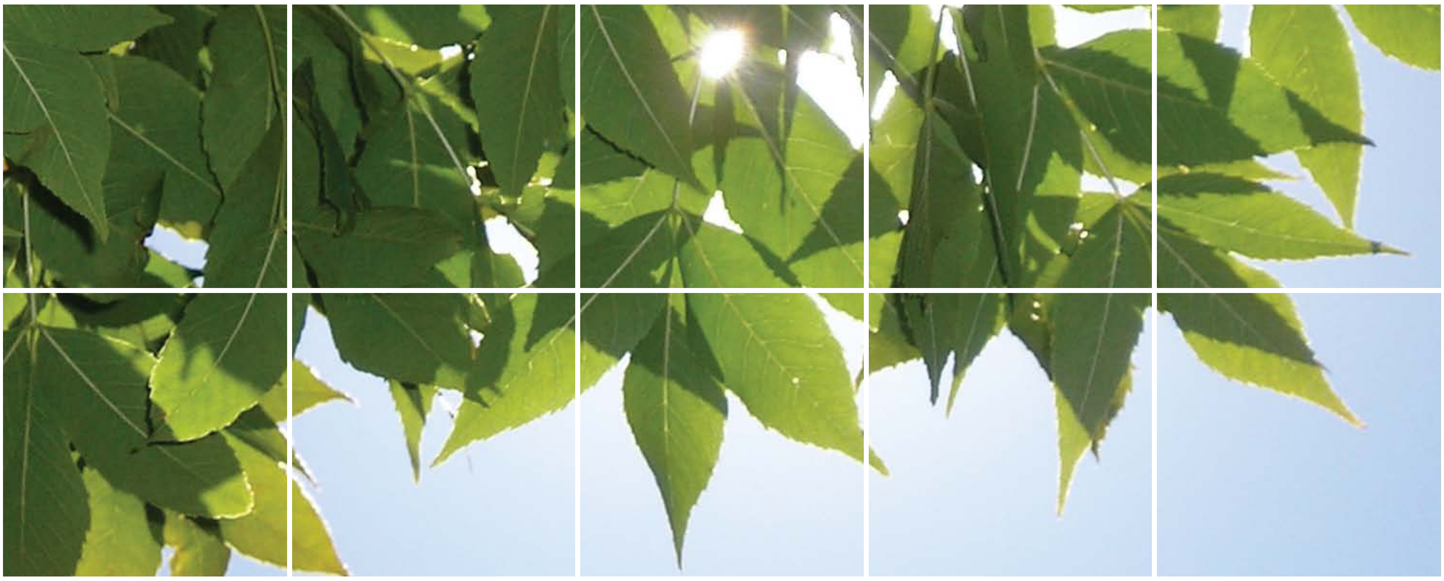

UK and Global Bioenergy Resource – Final report

OXFORD ECONOMICS

BIOMASS Energy Centre

Forest Research

Report to DECC

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Executive summary

This report examines potential biomass supply in the UK between 2010 and 2030, given current constraints and the potential to address some of these constraints. It examines the supply side issues only and does not consider constraints on the conversion and use of biomass. The analysis examined the situation to 2030, based on forward estimates of potential biomass supply and included three international development scenarios: business as usual; high investment; and low development. The resource estimated for 2030 is not available now in many cases; a significant proportion of the supply in 2030 would require considerable investment to become available.

This work was undertaken by AEA and Forest Research. Additionally the analysis forecast future biomass prices and the impact of bioenergy feedstock use on food prices. This analysis was undertaken by Oxford Economics, with support from AEA.

The work was designed to provide models of supply and forecasts of price to DECC that enable the impact of various constraints on supply to be examined. Its aims and objectives were to:

- Assess the potential of UK bioenergy feedstocks likely to be brought to market, taking account of the barriers to deployment of the different feedstocks under different assumptions of how far these barriers could be overcome;
- Assess the availability of global bio-energy feedstocks, taking account of current and future international demand for bioenergy feedstocks, particularly sustainable biofuels, and overlapping demands across all energy sectors – transport, electricity and heat;
- Examine the impact of competing non-energy uses (e.g. for alternative materials);
- Assess likely future established prices for key feedstocks consistent with the supply side potentials found above;

For UK supply we used data from a number of comprehensive studies that describe potential supply for the various feedstocks and factors that constrain this supply. For each source of potential UK biomass supply, estimates were made of the total unconstrained resource from 2010 to 2030. The level of competing non-energy demands were estimated and taken from the unconstrained potential to give the accessible resource to the UK energy market. This was then subjected to constraint analysis, which took account of the likelihood of these constraints being addressed by higher prices for the feedstock or in time. Constraints considered included market, policy, technical and infrastructure constraints. This provided an indication of the constrained resource at a series of prices in the UK. In order to assess the impact of competing demands for land resource and the potential for first generation (1G) biofuels versus energy crops (such as short rotation coppice and miscanthus) for combustion, two scenarios for energy crops were produced: one that maximised 1G biofuels and the other that maximised UK energy crops.

The methodology for assessing the internationally available supply is outlined in the main report. International supply was assumed to be made up of forestry biomass, agricultural residues, energy crops and biofuels supply. Forest Research's Carbine model was used to estimate forestry biomass between 2010 and 2030. This projects forward supply based on historical trends. Agricultural residues were estimated from the literature. To estimate potential energy crops and biofuels we used two land availability scenarios from Hoogwijk (2005) and Van Vuuren (2009). The unconstrained resource was estimated under these scenarios to which we then applied constraint analysis under different scenarios to produce 3 global supply scenarios – Business as usual (BAU), Business as Usual + High Investment and Low Development. The impact of country specific and global demands (from IEA World Energy Outlook projections) was then applied to estimate the amount of resource that might be available for international trading and available to the UK.

There are considerable uncertainties in the assessment of future bio-energy resource and prices. Therefore we developed a scenario based approach under which key insights into drivers and constraints to future supply can be derived. The estimation of the impact of constraints examined in this report is a matter of expert judgement and there is uncertainty associated with these figures. All estimates should be seen as guide based on particular assumptions rather than precise forecasts.

Price model

The price modelling, undertaken by Oxford economics, used inputs of energy supply and demand and the cost of feedstock inputs to produce the bioenergy price forecasts. The model first models international prices for bio-energy and assumes that these are or, in the case of biomass, will become the main drivers of bio-energy prices. Forecasts have been produced for a base case and three alternative scenarios. The scenarios that are modelled here are consistent with the work on supply side potentials. This work is explained more fully in Chapter 4.

Results

The results for biomass supply available to UK are provided in Figures 1 and 2.

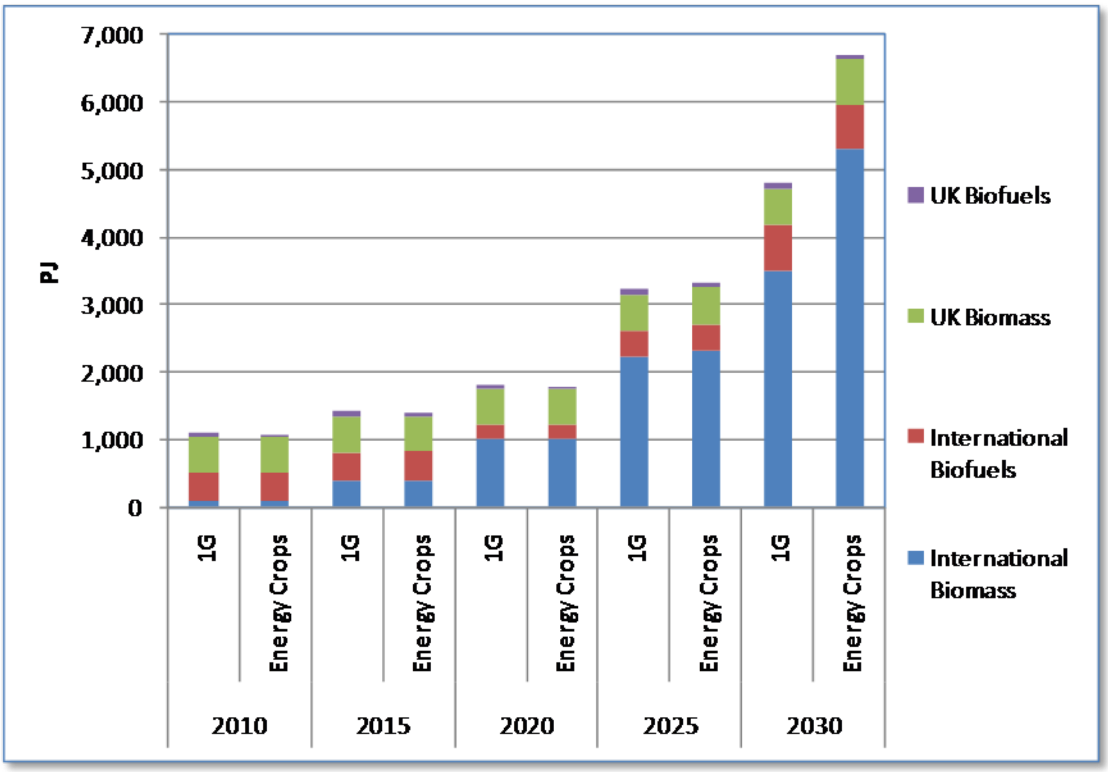
The Key findings from this analysis are:

- A wide range of feedstocks make up the potential UK resource. These include wood, crop and waste resources representing a range of chemical and physical characteristics that will need to be taken into account in their exploitation.
- The supply potential of UK feedstocks varies considerably by price, constraints that could be overcome and time. For example in 2020, we estimate that the total potential supply to be around 450PJ at the £4/GJ price point if easy constraints alone are overcome and around 750PJ at the £10/GJ price point with all constraints overcome for the 1G maximum scenario. By 2030 this rises to around 500 PJ and 780PJ for the same scenario.
- Our analysis suggests that price has a major influence on the availability of many feedstocks, and that is important in overcoming many constraints. This is because:
    - A proportion of many UK feedstocks is available now and at a relatively cheap price, but to develop their full potential considerable investment in collection, processing, logistics, transport, storage etc. is required.
    - For some feedstocks the perception of risk and uncertainty associated with the market means that potential suppliers are hesitant to invest in the infrastructure required. Higher prices would enable a better return to overcome these issues, although, fundamentally, secure market demand is required.
    - For some feedstocks there are competing uses, which are price dependent. These feedstocks will not necessarily go to the bioenergy market unless the price is right.
    - Overcoming constraints are important in developing the supply side of the market, particularly when prices are low. For example, at £4/GJ supply nearly doubles (390PJ to 750PJ) in 2020 under the no constraints overcome and all constraints overcome for the 1G biofuels scenario. At higher prices, some of the resource has already been pulled through from the price effect and the impact is less pronounced – a 40% increase from no constraints overcome to all constraints overcome at the £10/GJ price point in 2020, and even lower – ~30% - in 2030.
- Key constraints on UK feedstocks examined were:
    - **Policy constraints**, including energy and environmental policies. Secure, long-term energy policy can be important, particularly where the investment is necessary to develop the resource. Waste policy may have an influence the use of biomass resources that are also wastes and agricultural and forestry policies may also influence a significant part of the UK biomass resource.
    - **Market constraints**, which can play an important role. This is a relatively new 'immature' market. Potential suppliers often do not understand the market or its potential or they are nervous of being tied to one customer on a long term contract. There are solutions to these issues, but they need to be developed.
    - **Technical issues** were not found to be such large constraints, but may take investment to be overcome. The availability of fuel standards is a good example of such a technical issue. Standards provide clarity on the type of investment (e.g. in equipment) needed to ensure the feedstock produced meets the needs of the market. Other technical issues include combustion characteristics for specific fuels that may result in corrosion or other issues and that need investment in technical solutions if they are to be overcome; and the upgrading and injection of biogas into the national gas grid at competitive prices.
    - **Infrastructure issues** to enable the collection, storage and transport of feedstock. For example there is a need for collection points for dispersed feedstocks, for efficient transport and for effective processing all of which add to the price of bioenergy feedstocks.

- Our analysis shows that imported solid bio-feedstocks (i.e. woody type biomass and agricultural residues) could provide a significant resource to the UK market in the future. In 2020, this could be in the region of around 1,000-1,500 under the BAU and BAU - high investment supply assumptions. This could rise to around 5,300 to 8,900 PJ- by 2030 in these scenarios. However, in the low development scenario the supply increases at a much slower rate, due to low development of the required infrastructure and lack of investment in crop research.
- The results suggest a considerable increase in availability of biomass internationally between 2010 and 2030. Much of this increase is due to the potential planting of energy crops, without which the biomass feedstock resource is much lower. For example, under the low development scenario, feedstock availability is around one quarter of that in the high investment scenario, with most of this reduction due to less planting of energy crops. The future supply of energy crops is therefore a key determinant in the global resource estimates, and contributes to the uncertainty around the global resource estimates.
- Our analysis suggests key areas for imported solid biomass are: EU, Eurasia and other non-EU countries; and North and South America. Together these it is estimated these could provide some 70% of potential UK imports by 2030. Also, while China is not expected to be a big player in the current biomass market, it could be a large net exporter by 2030 if it plants energy crops.
- The analysis also suggests that the availability of sustainable global biofuels is considerably lower than that of solid feedstocks. By 2020 there could be around 200PJ of biodiesel and bioethanol, rising to 650-690PJ by 2030 under the BAU and high investment scenarios. There is a risk that without investment, global supply could be severely constrained – to around 10% of this. The biggest exporters of biofuels are likely to be Latin America and the USA.

Figure 1 shows the biomass resource estimated to be available to the UK, if easy and medium constraints are overcome, and assuming a business as usual global scenario. The availability of UK based feedstock is shown in Figures 2 and 3.

Figure 1 Biomass resource available to UK at £10/GJ with easy and medium constraints met for land use maximised for first generation biofuels crops (1G) and land use maximised for energy crops



Note: These graphs include data from the UK at £10/GJ with easy and medium constraints addressed; and the international resource for the BAU scenario, using the reference demand scenario.

Figure 2 Summary of results for UK biomass supply assuming maximum production of first generation biofuels crops on spare land. Supply is shown for £4/GJ no constraints met, £6/GJ easy and medium constraints met and for £10/GJ all constraints met.

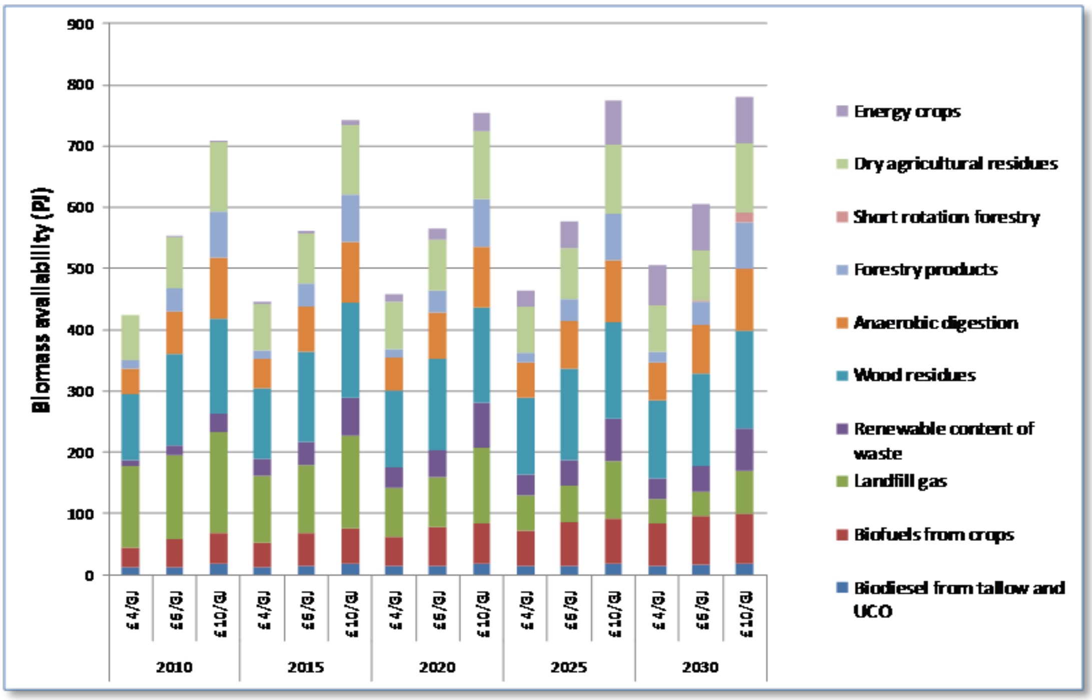
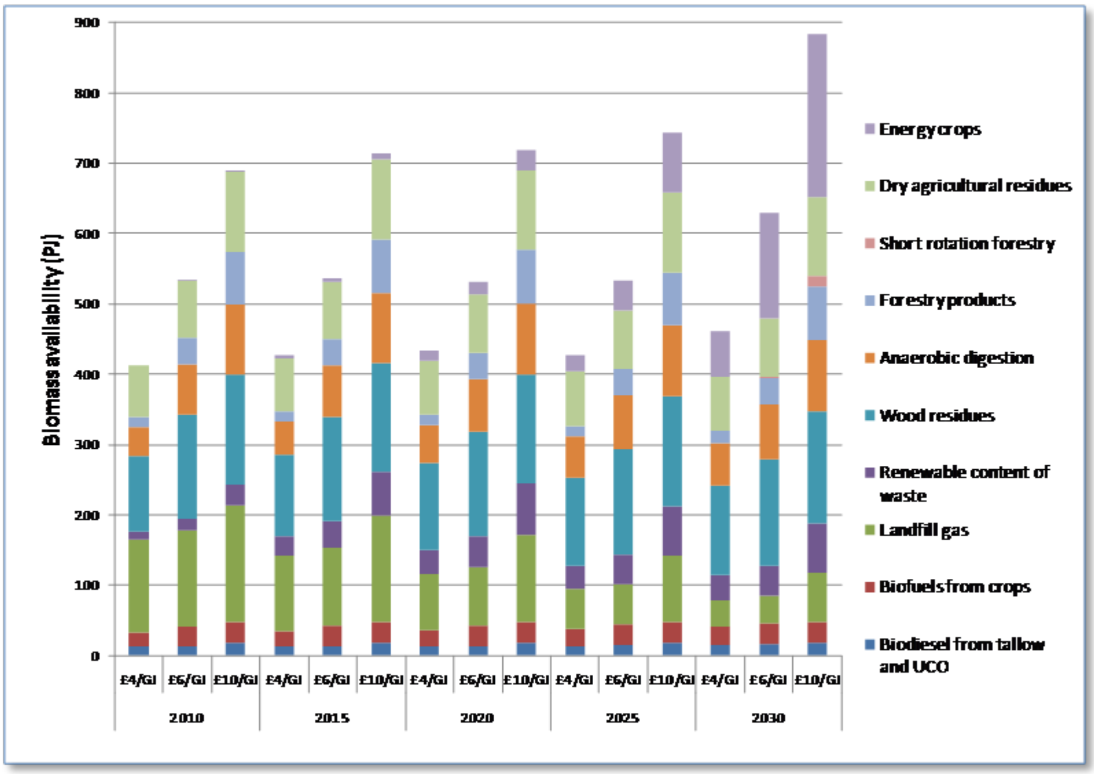


Figure 3 Summary of results for UK biomass supply with no constraints met and assuming maximum production of energy crops on available land. Supply is shown for £4/GJ no constraints met, £6/GJ easy and medium constraints met and for £10/GJ all constraints met.



Key conclusions are:

1. By 2020, the UK could have access to about 1,800 PJ of bioenergy supply; this is equivalent to 20% of current primary energy demand in the UK[1], and would meet the level of demand estimated in the UK Renewable Energy Strategy (DECC 2009). This estimate of supply is based on a price of £10/GJ for biomass feedstocks, assuming that all easy and medium constraints identified for UK feedstocks have been overcome, and a ‘business as usual scenario’ for international supply (with a ‘reference’ global demand for bioenergy). By 2030, mainly due to the development of energy crops globally, supply could rise substantially to between 4,800 and 6,700 PJ, or between a half and three-quarters of current primary energy demand in the UK. The range is due to assumptions about whether the production of energy crops or of 1G biofuels is maximised.

2. UK feedstocks could provide about one-third of potential bioenergy supply in 2020, but by 2030 this has fallen to 10% due to the large increase in the international supply. The increase in bioenergy supply over time is mainly due to more ex-agricultural land becoming available, which allows the planting of energy crops and 1G biofuels feedstocks. However developments in infrastructure and the biomass market, which allow more of the potential resources to reach the market, also contribute to the increase. There is a reduction in biofuels supply by 2020, because only some biofuels production is likely to meet the greenhouse gas saving criteria set in the Renewable Energy Directive (RED) for 2017.

3. These levels of supply are dependent on the development of energy crops both in the UK and abroad and the import of a significant quantity of biomass to the UK, most notably energy crops, but also wood from the forestry sector, agricultural residues, and biofuels (either as finished fuels or as feedstocks). For the biofuels, it is also dependent on the development of sufficient supplies that meet the sustainability requirements included in the RED. To achieve this supply will require considerable investment in land, crop development and equipment. A stable investment environment will be necessary to achieve this.

4. Our analysis shows that a number of constraints could significantly restrict the supply of biomass both within the UK and internationally. Higher prices for biomass will overcome some constraints and that time will address others, but there are intransigent issues that remain very hard to address, particularly terrain and location issues. This means that any analysis based on potential supply alone, without taking constraints into consideration, may be misleading in the amount of bioenergy that can be achieved.

5. Different end use sectors (heat, electricity and biofuels, small, medium and large-scale) have different feedstock specifications and purchasing strategies. They also differ in their need for, and ability to invest in the infrastructure for storage, processing and handling biomass. This means that, although there may be some competition for the raw feedstock, different sectors have different abilities to control the price they pay. This results in sectors experiencing different market conditions. For example, small scale users tend to use logs, pelleted, or briquetted fuels, purchased on the spot market in relatively small quantities, which can expose this sector to high prices (often over £8/GJ). Larger-scale users have more access to long –term contracts, bulk purchase and the ability to use less processed feedstocks, all of which enable them to pursue a strategy to achieve a lower price per tonne (to £6-£8/GJ for some large scale users). At large-scale users may also be able to use plant with more flexible feedstock specifications. This difference is important to the level of uptake of biomass in the UK.

6. There are interactions between the UK and the international market which become more significant when either suppliers or users can access this market. There are already established international markets in biofuels and pellet fuels and these markets tend to influence the price in the UK market for these fuels. While at present, bulk purchases by large end users are typically done under bilateral contracts with the supplier, we consider that in time international trade is also likely to dominate this bulk purchase market and that prices seen in the UK will be set by the international market. Thus international demand will influence the availability and price of biomass used in the UK.

Further details on these key conclusions are:

7. Analysis of constraints within the UK shows that several key constraints have a significant impact on supply and it will be important to address these if we are to optimise supply. The most significant constraints on supply are:

[1] Primary energy demand in the UK in 2009 was 9,211 PJ (Digest of UK Energy Statistics, 2010)

a. Infrastructure for (and the cost of) drying, transport and processing of feedstocks. Increased prices would allow for this investment.

b. Policy uncertainty, which is a key constraint for all bioenergy sectors. This applies not just to support for renewable energy but also to other environmental and agricultural policies. For example, it is not certain what impact the use of land for energy crops may have on Environmental Stewardship for farmers; and uncertainties related to the definition of a feedstock as a waste continues to be important for the cost of developing some waste derived fuels.

c. Perception of risk, which affects bioenergy plant development, notably project finance (both obtaining finance and the interest charged) can be significant constraint.

d. Perception of risk is also important for farmers and the forestry sector. This relates to market dominance by a few key players and the need for considerable upfront investment in some cases. The experience of farmers in other markets influences these perceptions. Developers of plants need to take these concerns seriously and take steps to address them.

8. In addition to the above constraints, we identified a number of threats to the UK supply:

   a. Rises in demand for biomass resources for competing uses;
   b. Growing concerns about sustainability;
   c. Rises in bioenergy targets overseas

   There is a need to be aware of these developments and their impact on UK bioenergy supplies

9. There are potential conflicts between the use of biomass for heat and power and their use for biofuels:

   a. The feedstocks used for the heat and power sectors and the biofuels sector are currently different, but there are potential conflicts in land use for energy crops or first generation biofuels. In our analysis we have compared maximum use of available land for energy crops with maximum use for 1G crops. The analysis shows that in *primary* energy terms the energy potential is greater if the land is planted with energy crops. However, energy crops represent a considerable investment and risk to the farmer; and the planting of crops that could be used for biofuels appear to represent lower risk to the agricultural sector (depending on demand side issues).

   b. The situation is further complicated by the development of second generation/advanced biofuels after 2020. This would result in lignocellulose resources (such as wood or agricultural residues) becoming suitable feedstock for transport biofuels, as well as heat and power and could result in competition between sectors for feedstock.

   Our analysis does not address these conflicts. Further work is needed to understand which is the best use for specific resources.

10. Energy crops (such as short rotation coppice and miscanthus) represent a significant part of the bioenergy resource, both in the UK supply and internationally – over 85% of the international wood based resource is estimated to come from in 2030 and 11-28% of the total UK resource is estimated to be energy crops in 2030. However, there is little sign of wide scale planting in the UK or abroad at present. There is a need to monitor the development of this resource, given its importance in overall supply.

11. In assessing the availability of land for bioenergy crops (woody energy crops and first generation biofuels feedstocks -oil, sugar and starch crops) in the UK and overseas we assumed that land currently used for food (and feed) production will not be available for bioenergy crops. Only land released from agricultural production as yields increase (which means that less land would be needed to meet food and feed demands) is assumed to be available for bioenergy planting. This means our estimates of energy crops and 1G crops for 2030 is dependent on yields for food and feed crops improving and increasing land availability for bioenergy crops.

12. A new resource being explored in the UK is short rotation forestry (SRF). The potential of SRF is not well understood at present, particularly the investment required; environmental impacts; growing conditions; and yields, although trials are ongoing. Further information is needed on

these aspects of short rotation forestry. SRF is a potentially important source of biomass, but it is also a long term crop, with rotations of up to 20 years, that will not be developed unless there is long term stable investment environment in place to support its use.

13. There is a need to be aware of international developments and their impact on the UK market:

    a. The UK will be one of a number of countries importing biomass and there will be competition in the international market. We have taken this into account by assuming that only 10% of biomass potentially available in this international market would be available to the UK.[2] We have assumed that in country demand and alternative uses for biomass will be met first before biomass is supplied for energy. The results show that, providing energy crops can be developed, there will be adequate resource available to the UK to meet its demands by 2030 and particularly so under the high investment scenarios examined. In practice it is likely that demand for energy and non-energy uses of biomass will complete with each other.

    b. The market for chips and pellets is still immature and sensitive to short term supply side shortages or periods of high demand. Current estimates of future demand show that there is considerable potential for increased demand for biomass in the EU over the next five to seven years. The impact of this is difficult to predict. This could lead to sudden increases in demand and prices, at least in the short term that affect the whole market in Europe and may affect the quality of the fuels supplied.

14. Not all biomass supply is directly substitutable in all conversion plants. For example, some technologies, such as anaerobic digestion, biofuels plants and biomass combustion plant are designed to take specific types of biomass, and have tight specifications with regard to composition, particle size and dry matter content of the feedstock. Thus the type of biomass resource needs to be matched with particular conversion pathways suitable for that product.

15. The development of anaerobic digestion (AD) is important to the use of wet biomass resources that are expensive to dry and transport. It may also be an important technology for the organic fraction of solid waste. In addition, there is currently increased interest in the potential to inject upgraded biomethane into the gas grid. However, there are a number of constraints on the development of AD in the UK, including cost and the wide dispersion of many of the potential feedstocks. Studies have indicated that for medium AD scale plants there remain important constraints relating to integration with the energy network. These include the development of cost effective upgrading plant for methane injection to the grid or the cost of power connection for biogas power generators. Although these are not supply side constraints, for AD development of the supply is closely integrated with the development of local plants to take the feedstock.

16. There are considerable uncertainties in the assessment of future bio-energy resource and prices. Therefore we developed a scenario based approach under which key insights into drivers and constraints to future supply can be derived. The estimation of the impact of constraints examined in this report is a matter of expert judgement and there is uncertainty associate with these figures. All **estimates should be used as a guide** based on particular assumptions rather than precise forecasts. The bio-energy price model uses economic theory to model and forecast UK bio-energy prices. A key constraint on the accuracy of both the modelling itself and the results that it produces is that data in this area is very limited. The model attempts to make the best possible use of existing information and as such the forecasts can be seen as a good guide to future price developments. However, it is possible that the conclusions may have to be revised as better information becomes available.

17. The model suggests that in future biomass prices are likely to move more in line with the prices of other energy sources than they have in the past. However, some differences will continue to be observed as biomass prices will be influenced by factors that are unlikely to impact on other energy prices, such as changes in the price of agricultural feedstock. Moreover, bioenergy is likely to continue to offer a price discount compared to other energy sources.

[2] The 10% figure is based on examination of the modelling results that indicate that in the time period being considered, the EU is both one of the regions with the highest demand for biomass, and also that it will need to import significant amounts of biomass to meet this demand. We therefore believe that the EU is likely to be one of the key players in the international biomass market in this time period and that the UK will be competing with other EU countries to secure biomass supply. Overall the UK accounts for about 10% of EU energy demand and this value has therefore been chosen to allow an estimation of how much biomass supply the UK might secure. This situation could change if other regions increase their biomass demand.

18. Price forecasts have been provided for a range of scenarios. In the base case wood pellet and wood chip prices rise by just under 10% in real terms between 2010 and 2020, and then remain roughly unchanged in real terms. This is because the price of the underlying feedstock, other energy prices and the overall demand for energy are forecast to grow only slowly. In particular prices of underlying feedstocks grow more slowly than price inflation as a whole. The price differential between biomass and other forms of energy remains roughly constant overtime in real terms.

19. Prices in the alternative scenarios are impacted by a number of factors that in some cases have a partially offsetting impact on the price forecasts. The scenarios then should be seen as a range of alternative forecasts rather than a simulation of the impact of changing a single assumption.

20. There is considerable variation in biomass price:

    a. Prices vary considerably depending on the time of the year the purchase is made, the growth in demand for the fuel and the amount of biomass purchased (i.e. whether it is bagged or bought in bulk). Bulk supplies often come on a discount compared to bagged fuel. Thus **there is no one biomass price, but a range of prices** within the market place, complicating calculations of the cost of bioenergy. Lower prices (in our case modelled as £4/PJ) tend to be for bulk delivery of chips. The cost of pelleting and bagging increases the price for biomass and means that bagged pellets tend to be available only at much higher prices (often £10/PJ delivered or more).

    b. Different sectors of the biomass market use different biomass resources. For example, the small and commercial heat sector tends to use prepared wood fuels (chips, pellets and logs for the domestic market). Large-scale power generation can be more flexible: plants in operation use solid waste fuels, agricultural residues and wood fuels. The co-firing sector is the most flexible at present. Many plant operators co-fire a variety of fuels, depending on what is available. This means that some plant operators are restricted to specific fuels; and others can substitute fuels depending on price and availability. Consequently the domestic sector, using logs and pellets bought on the spot market, faces high prices and greater uncertainty than large-scale power generation, where plant operators can develop supply strategies and buy in bulk. Commercial heat plant operators, such as local authority and hospital CHP operators generally sign long-term supply contracts and probably see prices between the high domestic and lower large-scale power supply contracts. This **difference in ability to access feedstock at different prices means that different sectors will be faced with different costs**.

Conversion units in this report

Table Conversion units for biodiesel and bioethanol

All conversion units are default values from RFA carbon and sustainability guidance (Version 2)

Characteristic	unit	Biodiesel	Ethanol
Density	kg/litre	0.89	0.794
Lower heating value	MJ/kg	37.2	26.8
Lower heating value	MJ/litre	33.1	21.3
	MJ/US gallon	125.3	80.6
	GJ/US gallon	0.1	0.1
	l/t	1123.6	1259.4

	Bioethanol		
Feedstock	**t ethanol/t feedstock**	**000 litres ethanol/t feedstock**	**GJ ethanol/t feedstock**
Wheat	0.292	0.3678	7.8
Sugar beet	0.0752	0.0947	2.0
Sugar cane	0.0635	0.0800	1.7
Molasses (per t cane)	0.183414	0.231	4.9
Corn (US)	0.31	0.3904	8.3
Corn (other)	0.326	0.4106	8.7
	Biodiesel		
	t biodiesel/t feedstock	**000 litres biodiesel/t feedstock**	**GJ biodiesel/t feedstock**
OSR (if as rapeseed)	0.4085	0.4590	15.2
OSR (if as oil)	0.95	1.0674	35.3
Soy (if soy)	0.1615	0.1815	6.0
Soy (if soy oil)	0.95	1.0674	35.3
Palm (from palm oil)	0.95	1.0674	35.3
UCO	0.875	0.9831	32.6
Tallow	0.875	0.9831	32.6
Sunflower (from seed)	0.4085	0.4590	15.2
Sunflower (from oil)	0.95	1.0674	35.3
Coconut oil	0.95	1.0674	35.3
Jatropha seed	0.228	0.2562	8.5
Jatropha oil	0.95	1.0674	35.3
conversion to HVO per t oil (all)	0.813	0.9135	30.2
cproduction of HVO	0.902	1.0135	33.6
pure plant oil	1	1.1236	37.2

Other conversion units used

Data from Biomass Energy centre (www.biomassenergycentre.org.uk/)

Conversion factors	MJ	GJ	kWh	Tonne oil equivalent
MJ	1	0.001	0.278	24×10^{-6}
GJ	1000	1	278	0.024
kWh	3.6	0.0036	1	86×10^{-6}
Toe	1.055×10^{-3}	1.055×10^{-6}	295×10^{-6}	1

Conversions for wood fuels (from Biomass Energy Centre)

MC – moisture content

Fuel	Energy density by mass GJ/t	Energy density by mass kWh/kg	Bulk density kg/m^3	Energy density by volume MJ/m^3	Energy density by volume kWh/m^3
Wood chips (30% MC)	12.5	3.5	250	3,100	870
Log wood (stacked – air dry: 20% MC)	14.7	4.1	350-500	5,200 – 7,400	1,400-2,000
Wood (solid oven dried)	19	5.3	400-600	7,600 – 11,400	2,100-3,200
Wood pellets	17	4.8	650	11,000	3,100

Agricultural residues

Fuel	Calorific value (GJ/oven dried tonne)	Net calorific value	Source
Straw	19	16 (assuming 15% MC)	Biomass Energy Centre
Chicken litter	19	13.5	DTI (1999)

Conversion for MSW and anaerobic digestion feedstocks are complex and are described in the Annex report.

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Appendices

1 Introduction

This report describes analysis of the biomass feedstock resource available to the UK to 2030. It examines both UK and international sourced biomass feedstocks. Preliminary estimates of the resource available are subjected to constraint analysis to provide an indication of the realistic supply to the UK and to highlight those factors that could be significant in constraining the resource.

The work was undertaken by AEA, Oxford Economics and Forest Research.

Why is biomass feedstock supply important?

The UK faces a target of meeting 15% of its energy needs through renewable technologies by 2020. The Renewable Energy Strategy and underlying analysis (DECC 2009) indicates that bioenergy is crucial to meeting this target in that it could supply a significant proportion of the UK's heat, power and biofuels – and that it could also provide low cost solutions compared to alternatives.

However, the availability of biomass feedstocks and the factors influencing supply are not well understood. Currently biomass feedstocks used for UK heat, power and transport fuels are a mixture of UK sourced and imported supply; and it is likely that this mix of UK and imported supply will continue and be expanded as biomass energy is further developed in the UK. Understanding the limits to this expansion and how other demands for biomass will influence the availability of biomass resource is complex. It is dependent not only on the ability of the UK to supply its own market, but also on demand in the UK and abroad, competing demand for biomass commodities and resources, development of suitable infrastructure for supply, the ability of the supply side to overcome current barriers to development of the resource, development of technologies that enable more effective use of the resource available – and many other resource specific factors and policy related parameters.

Understanding all of these factors is crucial to understanding the stability and security of bioenergy feedstock supply for UK based bioenergy.

1.1 Aims and Objectives

The key aim of this project was to develop a cross-sectoral model of potential UK and global supply of bioenergy feedstock resources to 2030.

The objectives were to:

- Assess the potential of UK bioenergy feedstocks likely to be brought to market, taking account of economic and cultural barriers to deployment of the different feedstocks under different assumptions of how far these barriers could be overcome;
- Assess the availability of global bio-energy feedstocks, taking account of current and future international demand for bioenergy, particularly sustainable biofuels, and overlapping demands across all energy sectors – transport, electricity and heat;
- Examine the impact of competing or supporting non-energy uses (e.g. for industry and for alternative materials) and of competing demands for land, particularly for food needs. This includes the potential impacts in terms of food price increases resulting from competition for land use due to bioenergy crops;
- Assess likely future established prices for key feedstocks consistent with the supply side potentials found above;
- Assess the extent to which bio-energy feedstocks are likely to be grown on land that is currently used for agricultural production and the likely impacts in terms of displacement of food/feed production onto other land areas.

1.2 Feedstock examined

In this analysis we have examined a number of potential UK and global feedstock that could contribute to UK supply. These are listed below.

1.2.1 Potential UK feedstock

The potential UK feedstocks for bioenergy plants analysed in this work are:

- Energy crops (such as short rotation coppice and miscanthus, planted specifically for production of fuel)
- Agricultural residues
- Forestry residues
- Stemwood
- Sawmill co-products
- Arboricultural arisings
- Sewage sludge
- Livestock manures
- Waste wood
- Renewable fraction of Wastes
- Landfill gas
- Crops used for first generation (1G) biofuels (in this report we have assumed these are wheat and sugar beet for bioethanol and oil seed rape for biofuels).

1.2.2 Global feedstocks

The potential global bioenergy feedstocks examined in this work were:

- Agricultural residues
- Forestry
- Energy Crops (assumed to be woody crops such as short rotation coppice)
- Crops used for first generation (1G) biofuels (i.e. all crops currently used to produce biofuels for UK use).

The form in which these feedstocks might be supplied was also considered (i.e. whether they are supplied as raw material or as chips, pellets or as biofuels produced in the country or origin rather than biofuels feedstocks imported to the UK and processed here).

2 Methodology

The work was divided into a series of interacting tasks, as follows:

Table 2.1 Tasks undertaken

Task	Methodology
1	Identification of key bioenergy feedstocks that could be used in the UK and their available resource for 2010, 2015, 2020, 2025 and 2030. Identification of the key energy and non-energy uses for these resources.
2	Identification of key constraints and barriers to bioenergy feedstock supply, particularly where current barriers could prevent significant supply from reaching market. This was done in two parts: a) The first part of the analysis considered **constraints on feedstocks originating in the UK.** This analysis divided the constraints into those arising from market influences, policy, technical constraints and infrastructure constraints that would prevent the feedstock coming to market. Estimates of the impact of these constraints in terms of the percent of the resource they influence and how easy they were to overcome (with time and investment) was used to provide an indication of the actual resource that could be accessed in 2010, 2015, 2020, 2025 and 2030. This approach is described further under "constraints analysis – UK" , section 2.1 below. b) **Constraints on markets for biomass worldwide**. This analysis focussed on the biomass feedstocks that are likely to be imported to the UK. For these feedstocks we identified the key areas where production is likely to be important to the UK and examined constraints in these markets, such as lack of appropriate infrastructure, in country demand and demand in alternative markets. The potential supply of international feedstocks was then considered under a range of scenarios designed to examine future potential development trends for the international biomass market to 2030. Further information on how this work was done is provided in section 2.2.
3	Estimation of prices of bioenergy feedstock price in UK. This task builds on available work, such as the price analysis already undertaken by E4 Tech (2010) and includes estimates available from the supply sector for biomass heat and from large scale biomass power generators.
4	A review of the impact of potential sustainability issues to be faced by bioenergy producers/users on the availability of biofuels for the UK.
5	Development of two spreadsheet models, which provide analysis of biomass availability and price. These models have been provided to DECC separately.

2.1 UK Constraint analysis

2.1.1 UK Feedstock

The starting point for the analysis of the supply of UK sourced feedstocks was to estimate the 'unconstrained' potential. From this we took account of competing demands – for example food, or feedstocks used by industry – which provided a UK bioenergy sector 'accessible' potential. How much of this could actually come to market depends on the ability of the supply side to overcome barriers – which gives a 'constrained' supply potential.

The ***unconstrained resource*** was estimated from data in the literature. The starting point for all estimates in this work was the E4Tech (2008) analysis, unless additional data had made been available in the intervening period.[3] In some cases we interpreted or extrapolated data using different assumptions in order to ensure that they were in line with other estimates we were using.[4] Further details are provided in the Annex report. We have summarised why some of our estimates are different to those of E4Tech in Appendix 1.

Having obtained figures for the unconstrained resource, a view was taken on competing uses and whether or not this competition is price dependent. Competition for biomass feedstocks includes the use of agricultural land for food, feed and other non-food uses; the use of wood for timber, paper, pulp and panel board; the use of waste in recycling or compost; and the use of biomass for biomaterials. Estimates were based on data from the literature, from Government statistics or from sector associations, together with expert judgement based on our experience of the sectors and examination of the prices paid by competing sectors. Only the price dependent resource was considered to be potentially available to the bioenergy sector (i.e. the unconstrained resource minus the price-independent competing uses provides an indication of the "***accessible potential***" for bioenergy).

A view was then taken on how much of the accessible potential is likely to reach market under different assumptions about how far barriers are overcome, resulting in an estimate of the "***constrained potential***" for bioenergy use.

For potential increases in bioenergy crop availability with time we estimated land availability using Defra statistics on current land use and ADAS analysis (ADAS 2008), which indicated the level of land use and under utilised arable land. This provided us with an estimate of land that could be planted with first generation biofuels crops or energy crops, such as short rotation coppice or energy grasses. We assumed that current land required for food production would be unavailable to bioenergy crops, regardless of price. However, as food crop yields are predicted to increase this potentially released more land for bioenergy in the future. We therefore assumed that the land released would be available to bioenergy crops, representing a maximum bioenergy crop resource.[5] However, the level of increase in bioenergy crop will be restricted by the planting material and equipment available, so we have restricted estimates by applying a realistic planting rate.

This analysis does not assume that current grassland would be converted to energy crops.

This approach simplifies the situation somewhat in that sometimes constraints affect competing use as well. However, this effect was not considered significant for this work.

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[3] Key sources included the Biomass Energy Centre, NNFCC reports (e.g. ADAS 2008 and 2008a, which consider land use and agricultural production and NNFCC 2008, which considers sugar beet); WRAP reports on waste wood and other waste availability; Defra reports on waste; and national statistics on waste, agricultural production, agricultural yields and forestry products.

[4] For example, landfill gas, food waste for AD and energy recovery from the renewable fraction of waste were estimated so that there was no double counting of the same resource; and our analysis of landfill gas production was based on different assumptions to E4Tech's

[5] In reality this may be impacted by increasing demand for food world wide as the population increases. This would be reflected in increased prices for food crops in the UK, which could mean that bioenergy crops are not financially attractive to UK farmers.

Figure 2.1 Diagrammatic representation of unconstrained and various constrained resource potentials

Outline concept

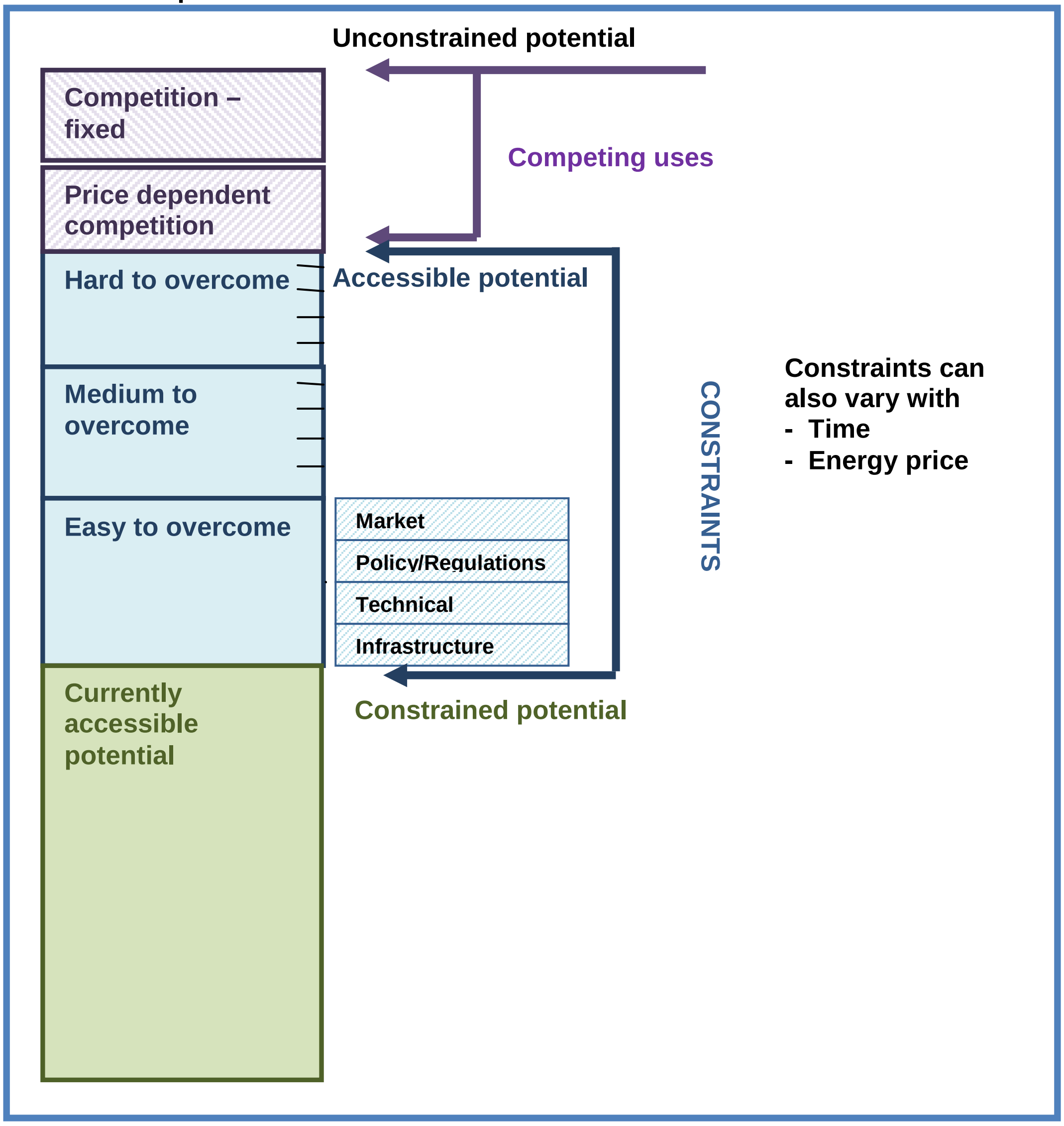

Figure 2.1 continued: Worked Example

Worked example for constraints analysis: Forestry Residues

Unconstrained feedstock availability: 1MT/y or 18PJ

Competing feedstocks: 0Mt/y
% of these that are price dependent: 100%

Therefore amount available for bioenergy: 18PJ

Constraints analysis:

- At £4/GJ – 99% resource is constrained in 2010; 87% is constrained in 2030. Addressing constraints decreases these figures by 7-61% in 2030 depending on whether easy, moderately hard or hard constraints are overcome.
- At £6/GJ – 78% resource is constrained in 2010; 66% is constrained in 2030. Addressing constraints decreases these figures by 4-53% in 2030 depending on whether easy, moderately hard or hard constraints are overcome.
- At £10/GJ - 55% resource is constrained in 2010; 49% is constrained in 2030. Addressing constraints decreases these figures by 3-42% in 2030 depending on whether easy, moderately hard or hard constraints are overcome.

In PJ this is:

Constrained resource potentials (PJ)	2010	2015	2020	2025	2030
"Accessible" resource potential (PJ)	18	18	18	18	18
Constrained potential at £4/GJ:	**0**	**1**	**1**	**2**	**2**
Constraints that are easy to overcome	3	2	2	2	1
Constraints that are medium to overcome	4	4	4	4	3
Constraints that are hard to overcome	11	11	11	11	11
Constrained potential at £6/GJ:	**4**	**5**	**5**	**6**	**6**
Constraints that are easy to overcome	2	2	1	1	1
Constraints that are medium to overcome	2	2	2	2	2
Constraints that are hard to overcome	10	10	10	10	10
Constrained potential at £10/GJ:	**8**	**8**	**8**	**9**	**9**
Constraints that are easy to overcome	1	1	1	1	1
Constraints that are medium to overcome	1	1	1	1	1
Constraints that are hard to overcome	8	8	8	8	8

Constraints estimates

We considered four main groups of constraints:

- Market constraints
- Policy and regulatory constraints
- Technical and
- Infrastructural constraints

Table 2.2 summarises the kinds of constraints that are typical of many bioenergy feedstocks. The impact each constraint had on each feedstock was estimated using a combination of information from the literature and expert opinion, drawing on technical reports[6] and our own experts' experience of bioenergy. This means that the results are to an extent subjective. All estimates should be used as a guide, rather than regarded as absolute certainty.

The analysis considered the importance of each constraint (in terms of the relative amount of resource it influences), how difficult the constraints are to address (easy, moderately hard or very hard), and which are the ones that might enable fastest returns if addressed.

[6] Detailed references are provided in the Annex report

Constraints that acted on only a portion of the supply, or that could be addressed providing relatively low investment was made, were considered easy to address. Likewise, policy issues that could be addressed by stable UK policy or by clarification of specific points were also regarded as easy to address, as it is within the power of Government to influence these issues.

Technical and infrastructure issues requiring investment or a degree of research were assessed as easy or medium constraints, depending on the level of investment required and the extent of the problem.

Constraints that require considerable change in current practices (e.g. in waste management), new technical development were considered to be hard to overcome. Other constraints are by definition very difficult to address (e.g. terrain can sometimes provide a very significant barrier to development of forestry residues). These may not be possible to address in the time scale under consideration.

We then considered how the impact of each constraint may change over time. For example, some logistical issues, such as planting material and equipment for energy crops, provide a constraint that may be overcome within the timescale being considered, but restrict the resource available in the near term.

Price points assessed.

Finally we considered how the impact of each constraint may change depending on the price achievable for the feedstock. As well as being a function of technical availability and non-financial barriers, supply is also a function of price – with higher prices, some of the constraints discussed above will be overcome by the market. This work did not involve full supply-cost curves, so a detailed analysis of the impact of price is not included. However, we considered 3 price levels: £4/GJ, £6/GJ and £10/GJ,[7] representing prices for the supply of the feedstock in bulk, and for woody fuels assuming supply as chips. The lower bound was chosen to be broadly consistent with current prices of bulk chips, while the mid and upper price points were chosen to show how supply might increase if prices for feedstocks increased in the future. A high price of £10/GJ was chosen as the upper bound, so that the full impact of price in determining availability could be seen (for example previous estimates by E4Tech (2010) considered £9.4/GJ to be a 'very high' estimate of bulk prices for chips in 2020). £6/GJ was considered to be a more realistic estimate of the level that prices might rise to in the short to medium term. More detail is provided in Section 4.5.

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[7] These prices are discussed in the relevant sections of the Annex report. For biofuels the price ranges are different and are described as low, medium and high prices, which are also discussed in the Annex report. For waste fuels the same price ranges are used, but the prices are regarded as upper limits with all availability below these prices considered.

Table 2.2 Typical constraints for bioenergy feedstocks

Market	Policy/Regulation	Technical	Infrastructure
Competing feedstock uses, dependent on price. Perceived or real lack of demand. Perception of risks and uncertainty in the market place, particularly compared to alternative uses for feedstocks (e.g. complex, incomplete, immature or long supply chain; need to co-ordinate many organisations). Difficulty in obtaining project finance (due to perceived risks; or due to low level of investment for some schemes compared to typical venture capital requirements). Returns insufficient – poor margins; no or low profit; IRR poor; long payback term. Requirement for substantial upfront investment (e.g. high capital cost investment relative to operational cost). Cash flow issues (e.g. long lag time between initial investment and return) Location of feedstock compared to demand (involving long transport routes) Perception of competition from other fuel suppliers, including international Lack of level playing field internationally (such that investment is not encouraged in UK) Trade barriers (e.g. tariffs on foreign biomass such as the Russian tariffs on export of timber), Inertia (e.g. in farmer attitudes)	Absence of stable long term policies to enable confidence in investment. Regulatory or policy uncertainty; unclear policies (e.g. policy changes; lack of clarity on what is eligible or on reporting requirements). Compliance with supply side legislation and regulations e.g. meeting current and future sustainability standards. Proliferation of sustainability certification schemes Cost of certification for sustainability (particularly for suppliers who may not have resources to achieve this). Level of complexity and long term nature of investment not recognised in market incentives (e.g. for energy crops that cannot be harvested for some years). Lack of grants for capital investment in supply Concern that public perception or tight regulation will limit fuel demand Institutional barriers, such as lack of standards Planning and licensing requirements. Feedstock too complex to meet regulatory requirements Concerns about impact on prices of other commodities	Lack of technology providers for planting, harvesting and processing Technology perceived as complex (e.g. anaerobic digestion). Lack of fuel quality standards (so difficult for suppliers to know what to provide) Lack of suitable energy conversion equipment to handle difficult feedstocks (e.g. waste or residual feedstocks) Cost effective advanced conversion technologies for difficult feedstocks	Lack of harvesting, collection and storage facilities Lack of processing facilities for waste, particularly for more contaminated waste streams Need to increase planting material and harvesting equipment for energy crops. Integration into energy supply markets Lack of transport infrastructure Lack of UK port and transport infrastructure for imported feedstocks.

2.2 Global Bioenergy supply

In addition to UK feedstock, global feedstocks that could be used in the UK were also examined. The analysis examined how significant this resource might be; and how it might interact with the UK resource (i.e. in terms of determining the market price).

International supply was examined on a regional basis and for each region consideration was given as to potential infrastructure constraints, market and trade barriers and domestic demand, to estimate the quantity of feedstocks which might be available for export.

2.2.1 International Biomass Resource

Four internationally traded resources, considered to be the only biomass fuels which would be traded in bulk internationally, were examined:

- Forestry products
- Agricultural residues
- Feedstocks for 1G biofuels/finished 1G biofuels (this includes all crops for the production of 1G biofuels as used in the UK at present).
- ‘Woody’ energy crops (such as short rotation coppice).

Each of these has a unique market or set of conditions which impact how it is produced and traded (for details see Annex 1).

A detailed description of how the four international feedstock resources were estimated is given in the Annex report, but broadly the methodology was:

- Forestry related feedstocks: availability of forestry residues, small roundwood, and sawmill residues was modelled using CARBINE (by Forestry Research). This estimates production of these resources based on trends in afforestation and lumber production, with an allowance made for competing use of these resources in other industries such as pulp and paper and chipboard.
- Energy crops and 1G biofuels feedstocks: these were estimated on a ‘bottom up’ basis using scenarios of land availability and assumptions about yields, yield increases and planting rates. 1G biofuels feedstocks are expressed as the equivalent amount of biofuel they would produce.
- Agricultural residues: as many agricultural residues are not suitable for export, estimates were made, based on a literature review only of the amounts of agricultural residue that might be available for export.

In all cases, resource availability was estimated on a regional basis. As there is some land which is suitable for both energy crops and 1G biofuels, two variants of each scenario were constructed. One in which production of 1G biofuels is maximised and energy crops are only grown on land which is not suitable for 1G biofuels (due to degradation or water scarcity), and one in which, after biofuels demand has been met, preference is given to planting energy crops. In the latter case, planting of energy crops is still often constrained (particularly in early years) by the planting rate constraint and in these cases, remaining land can be utilised for biofuels production. This means that in some scenarios, particularly in early years there is little difference between the two scenarios as energy crop production is always limited by the planting constraint, and the area of land required for their cultivation can be satisfied from the pool of land which is not suitable for biofuels production.

2.2.2 Constraints on International Supply

For each of the feedstocks and regions we considered aspects that might constrain the development or extraction of the resource, and the ability to bring it to market. Two broad categories were considered:

- **Infrastructure constraints**: these relate to physical constraints on developing and exploiting the resource, such as:
  - Distribution and accessibility of land for crop production
  - Distribution and accessibility of forestry resource, and the nature of terrain
  - Transport infrastructure to move crops to storage/ distribution centres
  - Availability of facilities for international transport, such as deepwater ports.
- **Market/ Trade constraints**: these relate to the ability to operate a reliable supply chain to bring the resource to the market for trading, both to supply the domestic and international market, and to develop arrangements for trading. Aspects considered included:
  - Political stability and ability to attract financial investment
  - Development and implementation of standards to define quality of feedstocks
  - Current market maturity for export of bulk goods including feedstocks.
  - Ability to demonstrate compliance with international technical standards and sustainability requirements.

For each region, an assessment was made as to whether the barrier to development in these two categories were very high, high, medium or low, for 2010, 2020 and 2030, under each of the three scenarios described below. This assessment was then used to estimate the percentage of the resource which would be likely to reach the market. Further information on the markets for the feedstock considered in this work is provided in Appendix 2.

The way in which the impact of sustainability standards on the supply estimates was done is described in Box 2.1.

Box 2.1 Impact of sustainability standards on supply

Biofuels used in UK (and the rest of the EU) are required to meet the sustainability requirements set out in the Renewable Energy Directive (RED) (EC 2009). As well as specifying that biofuels feedstocks should not be grown on converted land that previously had a high carbon stock, RED also specifies minimum GHG savings (compared to fossil fuels) that biofuels must achieve – 35% saving by 2013 and 50% saving by 2017 for existing production capacity and 60% by production capacity installed in 2018 and beyond. As we make the assumption that biofuels are grown on land that is ‘spare’ agricultural land, all biofuels would meet the first specification. To assess whether the required GHG savings would be achieved, typical values of savings for biofuel production from the crop/region combinations in the model were evaluated, and an assessment was then made of the percentage of biofuels produced in each region which would meet the RED criteria (see Annex report). For example, where the typical value for greenhouse gas savings for a particular supply are about 40%, it is judged that 20% of the supply might be far enough above this value to meet the 50% criteria. Typical greenhouse gas savings for most of the biodiesel supply modelled are below the 50% threshold set for 2020, and therefore the sustainability standards in the RED, severely limit the amount of biodiesel the EU can import in 2020 and beyond.

From April 2013 **solid biomass and biogas** electricity from plant >1MWe will need to have a carbon intensity of 285.12 $kgCO_2$/MWh or lower to be eligible for ROCs (i.e. a saving >60% relative to the EU fossil fuel comparator) (DECC 2010a). This was announced after the analysis was undertaken for this report and has not been examined in detail in the report. It is difficult to quantify the impact that this would have on the quantities of biomass available to the UK. Wood chips from sustainably sourced forests, or from forest residues or sawmill waste, or energy crops, would all typically meet this criteria, even if transported from countries such as the US or Canada. However, pelleting of the wood (which is currently necessary to ensure that imported wood meets regulations) can substantially reduce the GHG savings such fuels can achieve if e.g. diesel fuel is used for drying the wood prior to milling and pelleting. The use of wood to fuel the drying process however leads to much lower emissions and it is likely that many pellets produced in this way would still meet the sustainability standard.

2.2.3 Scenario Development

In order to examine the impact of global economic, agricultural and technical development, three scenarios of global supply were developed:

- Business as usual (BAU),
- BAU+ high investment
- Low development.

Each of these assumed land use according to scenarios developed by Hoogwijk/Van Vuuren (see Box 2.2), but were extended to include the additional constraints outlined in 2.3.2. Our scenarios are detailed in Box 2.3 and the main characteristics are summarised in Tables 2.3 and 2.4.

Box 2.2. Factors considered significant in global biomass availability

It is important that scenario analysis focuses on those aspects that will have a significant impact on the availability of biomass on the global market to the UK. We believe the most important of these will be:

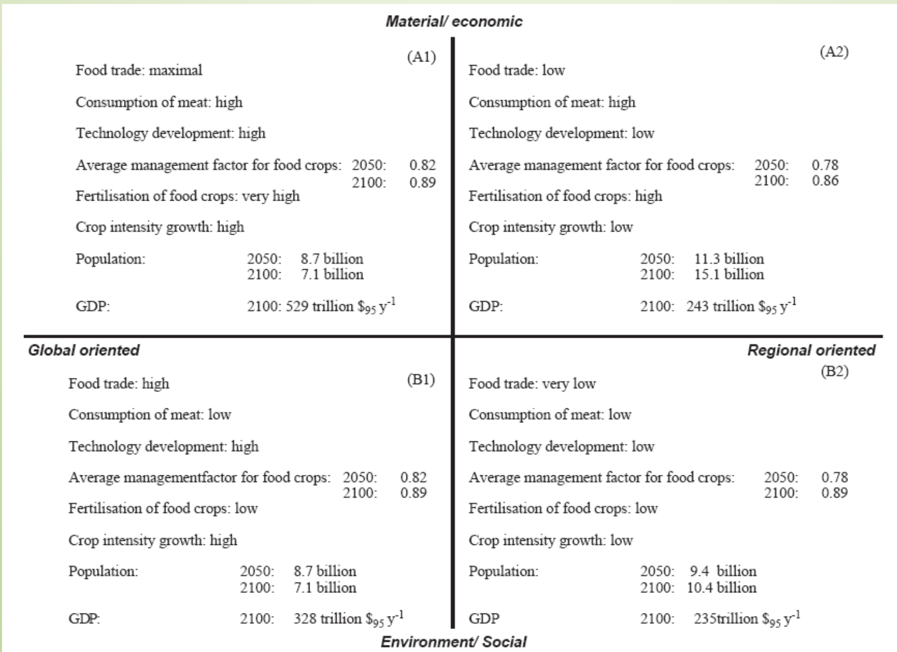
- Availability of land for bioenergy crops: This depends on both the global food/ feed requirements, estimated from population and diet and the amount of land needed to meet this requirement, based on the amount of intensification of existing agriculture and improvements in yield. We used scenarios from Hoogwijk *et al* (2003, 2005) which include explicit assumptions for GDP, yield improvements and intensification of agriculture. This analysis was extended by Van Vuuren *et al* (2009) to take constraints such as water availability into account.

- Yield improvements for energy crops. The amount of energy crops and current first generation biofuels crops depends on increased yields of these crops and we have allowed for this in the modelling. More details of how this was done are given in section 3.3 and the Annex report.

- Development of fuel quality standards: this could be a key requirement in allowing wide scale trading of biomass fuels for heat and power sector. Currently there are no agreed international fuel quality standards, which mean that specifications have to be agreed between each plant operator and supplier. Although some specifications are commonly used (such as Austrian, German and Scandinavian standards for wood fuels) this can mean that there is a proliferation of fuel specifications and that suppliers have to try to match them all. In addition in times of high demand/supply restrictions quality can fall. Development of agreed fuel quality standards would improve the standard of the fuels supplied and prevent this proliferation of different standards.

- Introduction of sustainability standards and the ability of suppliers to meet them and to demonstrate that they have met them.

Figure 2.2 From Hoogwijk (2005): Assumptions related to food demand and supply for the scenarios considered. The A1 and A2 scenarios are used as a basis for our scenario development.



Box 2.3: Development of scenarios for global biomass feedstock

Business as usual

This scenario is based on the Hoogwijk A1 Global Economic scenario (Figure 2.2, Box 2.2). Under this scenario, there is high technology development, the world economy grows at an average of 2% per annum, and poorer regions of the world show good development and growth, becoming more stable politically. It is assumed that this encourages development of infrastructure, and food trade is maximal.

In this scenario current trends for bio-energy production prevail. We have assumed that development of agricultural resources and infrastructure will occur regionally on much the same basis as at present (i.e. those countries already successfully developing their infrastructure, technology and political stability continue to do so, but regions where this is not happening continue to lag behind). This means that much of the bio-energy potential of less developed regions will not be available under this scenario.

In the case of woody energy crops, regional average yields for energy crops were derived from the results in Hoogwijk (2005), and range from 5 odt/yr (e.g. in Southern Africa) to 10 odt/yr (in North America) and 11 odt/yr in the Former Soviet Union. Yields are assumed to increase (as specified in Hoogwijk) at 1.6% per year in the BAU scenario, so are 37% above 2010 levels by 2030.

In the same way as for the modelling of UK energy crop resource, the maximum rate at which planting of energy crops could occur was estimated based on an assumption about the maximum rate at which the area planted each year could be expanded. This was 20% per year for developed economies, 10% per year for transition economies and 5% per year for emerging economies. Overall these planting rates constrain the area available to energy crops substantially: to 15% of the maximum area available in 2020 and 34% of the maximum available are in 2030.

In the case of 1G biofuels feedstocks, current yields were based on data from the RFA, or FAPRI data sets, which were found to be largely consistent with values in the Kline *et al* (2008), OFID (2009) and ADAS (2008a) studies. Yield increases are differentiated by crop and region, but typically are about 0.9% per year in the BAU scenario. This rate of yield increase over time is kept constant for all crops except jatropha, which is currently at an early stage of development so a higher rate of increase was thought possible from 2025 onwards. Full details of assumptions about planting rates, yields and yield increases are given in Annex 1.

BAU + high investment

This scenario is also based on the Hoogwijk A1 Global Economic scenario.

We have assumed this scenario provides opportunities for development of bioenergy, both domestically and through investment from richer countries. There is good technology transfer, enabling yield improvements in all countries. Facilitating trade is important, so product quality standards are developed to allow commodity trading of various grades of fuel. These standards also ensure consistent product quality, which together with reliable delivery, encourages investment by demand side sector. Developing countries are assumed to have the capacity to implement sustainability requirements and demonstrate that they have been met. The UK is also assumed to develop good infrastructure to deal with large quantities of imports (e.g. facilities at ports).

Planting rates for energy crops increase more rapidly in this scenario; yield increases for both energy crops and biofuels crops are the same as in the BAU scenario.

Box 2.3 continued.

In summary this scenario presents an optimistic view of the potential for bio-energy from the land available (but is not a theoretical maximum). Supply is increased substantially from the BAU scenario, due to increased planting and the removal of some barriers by investment, but a large proportion of land which could potentially be used still remains unplanted in some regions. By 2030, this is mainly due to general infrastructure and market constraints (see 2.3.2), rather than the planting rate constraint.

This scenario will still only produce a 'realistically' high level of supply. That is, while planting rates and yields increase more quickly that for BAU, the planting rates still constrain supply. Similarly, while barriers to development are lower than in the BAU case, there are still some.

Low development

For this scenario, we used the Hoogwijk A2 Regional-Economic scenario (Hoogwijk 2005).

Under this scenario we have assumed technology development is slower, and there is less intensification of agriculture and less improvement in yields. Growth in global GDP is lower than for the other scenarios (at 1.6 % per annum), and there is reduced international food trade. These traits combine to give lower potential land availability for bio-energy production.

In addition, we have assumed that there is less infrastructure development in developing countries under this scenario, as it will not be developed for food crops; and that developed countries do not invest in developing biomass supply in developing countries. Yields of energy crops only improve at 1.2% p.a. (compared to 1.6% in BAU) and yields of biofuels corps at half the rate assumed in the BAU scenario. Planting rates for energy crops are also lower.

The combination of lower initial land availability and more constraints on supply mean that this scenario gives the lowest potential for bio-energy production.

Table 2.3 provides a summary of the main assumptions for each scenario, and Table 2.4 provides a summary of assumptions about land availability, yield increases and planting rates under each scenario.

Table 2.3 Summary of main conditions in each scenario for global	Technology development	Agricultural intensification	Agricultural yields for food crops	Global economy	Trade	Infrastructure	Technology transfer	Quality standards	Population growth	Political stability in key producer countries
Business as usual (BAU)	**High**	**High**	**High**	**GDP grows**	**Enabled**	**Current trends**	**Current trends**	**Developed but not all countries can meet them**	**8.7 billion**	**Current trends**
BAU+ High investment	**High**	**High**	**High**	**GDP grows**	**Enabled**	**High investment**	**High**	**Developed and developing countries can meet them**	**8.7 billion**	**Good**
Low development	**Low**	**Low**	**Low**	**Low GDP growth**	**Restricted**	**Low development**	**Low**	**Not developed**	**11.3 billion**	**Poor**

Table 2.4 Summary of yield and planting rate assumptions in each scenario for global supply

Scenario	Land availability	Energy crops Increase in planting rate pa.	Energy crops – yield increase p.a.	Biofuels crops – yield increase p.a.
Business as usual (BAU)	High (Hoogwijk A1 Global Economic scenario)	Developed economies 20% Transition economies 10% Emerging economies 5%	1.6%	Varies by crop and region, from 0.4 to 1.2% but typically about 0.9% (see Annex 1 for details)
BAU+ High investment	High (Hoogwijk A1 Global Economic scenario)	Developed economies 20% Transition economies 10% Emerging economies 5%	1.6%	Varies by crop and region, from 0.4 to 1.2% but typically about 0.9% (see Annex 1) for details)
Low development	Low (Hoogwijk A2 Regional-Economic scenario)	Developed economies 20% Transition economies 8% Emerging economies 2%	1.2%	Yield increases are half those in the BAU scenario

2.2.4 Global Demand Scenario

Reference Demand Scenario

In order to understand what proportion of the feedstock resource in other countries might be traded we also need to take demand in the country of production and other countries into account. To do this we used the 'reference' demand, as predicted in the IEA World Energy Outlook 2009 (IEA 2010), as a basis for our reference global bioenergy demand scenario. The demand for biofuels was cross checked against any mandates which have been set for biofuels use, and the demand updated to reflect any mandates which set legislative targets. For example, the EU biofuels demand was increased to ensure that the requirements of the Renewable Energy Directive would be met in 2020. We also reviewed whether countries had specific targets for the use of biomass in general, but while we identified some general targets for renewable energy use in some countries, and strategic intentions to increase the use of biomass, no specific quantitative targets were identified. The demand for biomass in the heat and power sector in the WEO forecast was therefore not adjusted.

High Biomass Demand Scenario

To test the sensitivity of results to the demand side assumptions, we also considered a high biomass demand scenario, in which there is a higher demand for biomass globally. This is based on the '450 scenario' included in the IEA World Energy Outlook -"an alternative world, with an energy sector that is substantially cleaner, more efficient and more secure, and in which annual energy-related CO_2 emissions peak just before 2020 before falling to put the world on track for stabilisation of the atmospheric concentration of greenhouse gases at 450 parts per million (ppm) of CO_2 –equivalent". Under this scenario, there is a substantial increase in the use of biofuels, principally second generation biofuels, and increased use of biomass for electricity generation.

Other Demand Side Assumptions

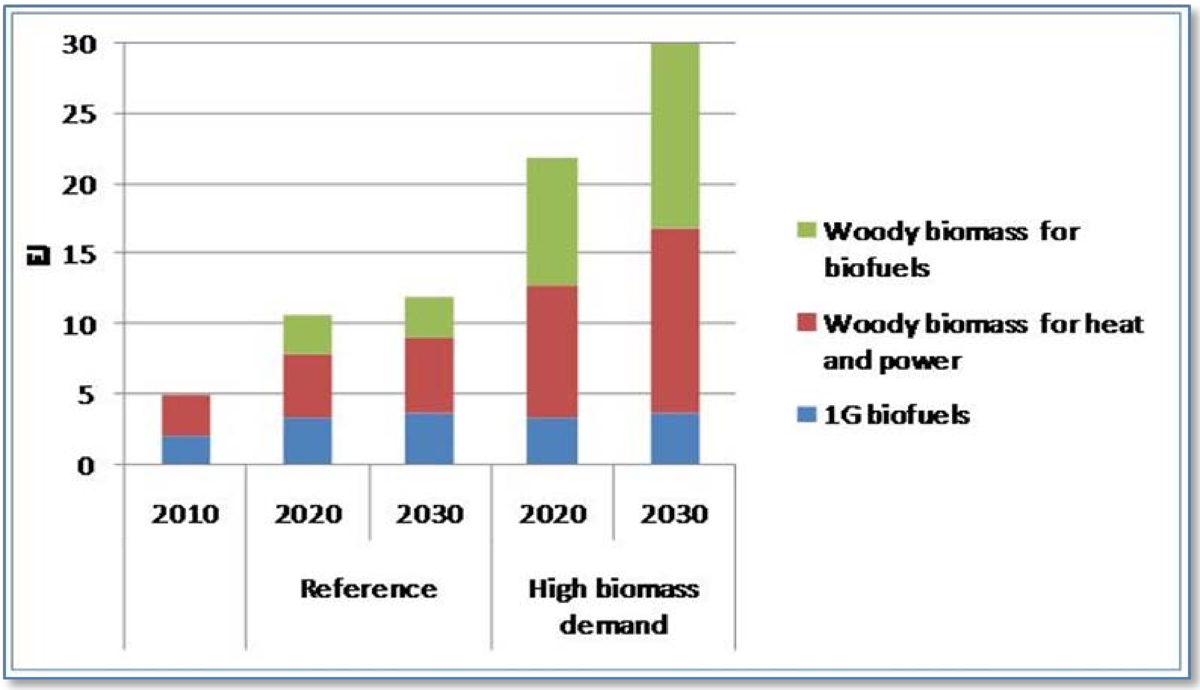
Further assumptions were made around:

- the split of demand between different sectors. This was based on the split in the IEA (2009) reference scenarios, adjusted for a number of countries/regions (e.g. Asia and Africa) to remove the influence of traditional biomass use (i.e. traditional household use of biomass, often collected informally, for heating and cooking[8]);
- the proportion of demand in power, industry and 'other' sectors met with woody biomass. The increase in biomass use for electricity generation in the high biomass demand scenario is assumed to be met mainly (90%) by woody biomass;
- the split between 1G vs 2G biofuels and the proportion of 2G biofuels produced from woody biomass. This was based broadly on E4Tech (2008) with additional information from IEA (2010, 2010a). In the high biomass demand scenario, it is assumed that almost all of the increase in biofuels use is supplied by 2G biofuels and that much of this increase is supplied by woody biomass, on the basis that as low cost feedstocks, wastes and agricultural residues are utilised initially, and that they are a limited resource.

The overall demand for woody biomass estimated in the two scenarios is shown in Figure 2.3.

[8] Traditional uses of biomass are significant in some countries. We have assumed that in 2010, traditional biomass supplied 100% of biomass use the sector 'other' (principally households) in Africa, Latin America and Asia, and 90% of biomass used in the sector 'other' in Eurasia. The commercially traded biomass resources we have modelled are assumed to enter these sectors over time, but there is still a substantial amount of traditional biomass use in 2030.

Figure 2.3 Global demand for woody biomass and 1G feedstocks



2.2.5 Matching International Demand and Supply

Combining the estimates of the international resource with the constraints information gives a constrained resource, which represents the amount of biomass that could be supplied to either the domestic or international market. The next step in the modelling is to subtract the domestic demand in each region for 1G biofuels and woody biomass from this resource. At the regional level, this may result in a surplus or deficit, indicating whether regions are likely to be net exporters or importers of biofuels and woody biomass. At the global level, this indicates the amount of biofuels and biomass which could be available to the international market, once forecast domestic demands have been met; i.e. how much more biomass could be available if countries wished to expand their use of biomass and biofuels.

It is unlikely that any one country would obtain all of this 'surplus', and it is therefore assumed that only a certain percentage of this surplus would be available to the UK. This percentage can be changed by the user in the model, but for the reference runs used to inform this study it has been set at 10%. This is based on examination of the modelling results that indicate that in the time period being considered, the EU is both one of the regions with the highest demand for biomass, and also that it will need to import significant amounts of biomass to meet this demand. We therefore believe that the EU is likely to be one of the key players in the international biomass market and that the UK will be competing with other EU countries to secure biomass supply. Overall the UK accounts for about 10% of EU energy demand and this value has therefore been chosen to allow an estimation of how much biomass supply the UK might secure.

2.2.6 Scenario Runs

A range of results were generated by combining the three core global supply scenarios, BAU, BAU – high investment and low development, with the two demand scenarios to create six sets of results. Within each set of results, two variants are possible, one where production of woody energy crops is maximised, and one where production of 1G feedstocks and 1G biofuels is maximised. This leads to 12 overall scenarios for global supply of biomass as shown in Table 2.5.

Table 2.5 Scenarios examined for global biomass supply

	Reference Global Biomass Demand		High Global Biomass Demand	
BAU	**Maximise Energy Crops**	**Maximise Biofuels**	**Maximise Energy Crops**	**Maximise Biofuels**
High Investment	**Maximise Energy Crops**	**Maximise Biofuels**	**Maximise Energy Crops**	**Maximise Biofuels**
Low development	**Maximise Energy Crops**	**Maximise Biofuels**	**Maximise Energy Crops**	**Maximise Biofuels**

Energy crops refer to woody biomass crops such as short rotation coppice; biofuels refers to all biofuel sources as used in the UK at present.

2.3 Price analysis

Oxford Economics has constructed a model that forecasts biodiesel, ethanol and biomass (wood pellets and wood chips) prices. The model uses economic inputs of energy supply and demand and the cost of feedstock inputs to produce the bio-energy price forecasts. The model estimates current drivers of bio-energy prices and assumes that these are (or in the case of solid biomass, will become) the main drivers of future prices.

The price forecasts are based around the supply scenarios described above. The central price scenario is based on the BAU supply scenario, assuming that production of 1G crops is maximised, and a reference demand for bioenergy. The ‘high’ and ‘low’ scenarios are based on the BAU-high investment scenario and the low development scenario respectively (with production of 1G crops maximised). The very high scenario is based on the BAU high investment scenario with the high biomass demand, used for demand figures. More details of the price analysis are given in Section 4.

3 Supply Resource Estimates

This chapter provides the results of modelling for the UK feedstocks and internationally traded feedstocks that could be available to the UK. For the UK feedstocks results are presented at a range of prices and with a range of constraints addressed. For the global biomass three scenarios of biomass trade development are considered that may influence availability to the UK.

The chapter is divided into three sections:

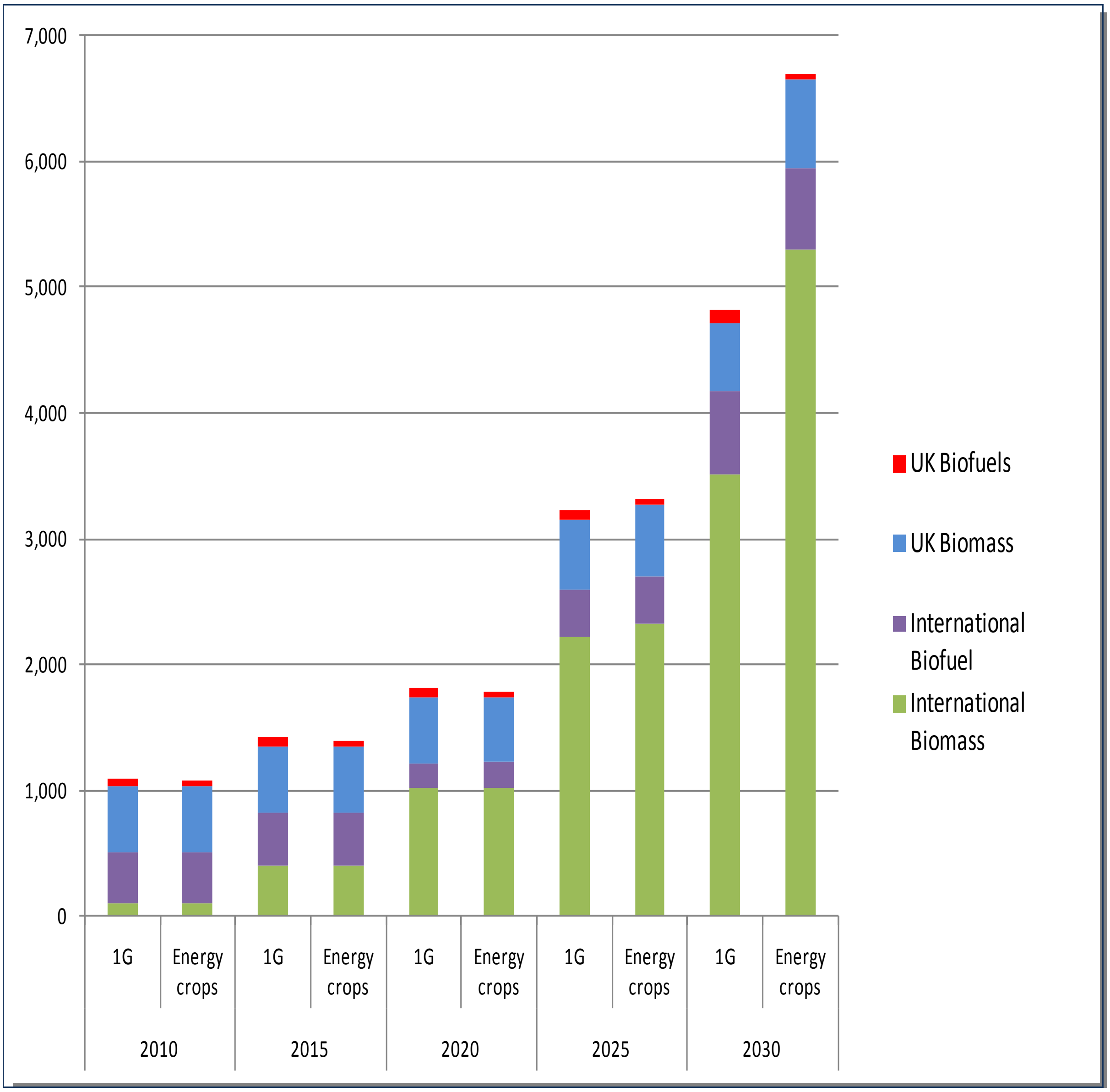
1. Headline results, which examines the total combined supply estimates
2. UK results, which provides estimates for each feedstock for the UK only, at a range of prices. This section presents the results of the constraint analysis and shows the impact of removing some of the constraints.
3. International results, which provides estimates for the four feedstocks examined internationally and for the international scenario analysis.

3.1 Headline results

The modelling of bioenergy supply suggests that by 2020, bioenergy supplied to the UK could be about 1,800 PJ or 20% of current primary energy demand in the UK[9] (Figure 3.1). This estimate is based on a price of £10/GJ for biomass feedstocks, assuming that all easy and medium constraints identified for UK feedstocks have been overcome, and a ‘business as usual scenario’ for international supply (with a ‘reference’ global demand for bioenergy). By 2030, mainly due to the development of energy crops globally, supply could rise substantially to between 4,800 and 6,700 PJ, or between a half and three-quarters of current primary energy demand in the UK. The range is due to assumptions about whether the production of energy crops or of 1G biofuels is maximised.

[9] Primary energy demand in the UK in 2009 was 9,211 PJ (Digest of UK Energy Statistics, 2010)

Figure 3.1 Biomass availability to the UK (at £10/GJ with easy and medium constraints removed, BAU for international resources) for land use maximised for first generation biofuels (1G) and for land use maximised for energy crops.



UK feedstocks provide about one-third of potential bioenergy supply in 2020, but by 2030 this has fallen to 10% due to the large increase in the international supply.

The increase in bioenergy supply over time is mainly due to more ex-agricultural land becoming available, which allows the planting of energy crops and 1G bio fuels feedstocks. However developments in infrastructure and the biomass market, which allow more of the potential resources to reach the market, also contribute to the increase. The reduction in transport biofuels supply in 2020 is because only some biofuels production is likely to meet the greenhouse gas saving criteria set in the Renewable Energy Directive (RED) (of 50%) which biofuels must meet in 2017.

There is little difference between the 1G biofuels and energy crops scenarios in Figure 3.1 up to 2020, mainly because the amount of energy crops is constrained up to 2020 by the rate at which energy crops can be planted rather than the amount of land available for energy crops.

3.2 UK Supply

Potential UK supply is summarised below. For each of the UK feedstocks a module is provided in the Annex report, which provides detail on the resource, constraints, the sources of these figures and more detailed results. A summary of these results is provided in Appendix 3 of this report.

The key results are shown in the graphs below.

Figure 3.2(a) summarises the availability of UK biomass, assuming that spare land is used whenever possible to maximise production of first generation biofuels. It shows three levels of availability:

- Low availability: £4/GJ (or low price for biofuels), easy constraints only addressed
- Medium availability: £6/GJ (or medium price for biofuels), easy and medium constraints addressed
- High availability: £10/GJ (or high price for biofuels), all constraints addressed; this represents the total accessible resource for the feedstock and so is the same regardless of price.

In this scenario the resource under low availability assumptions increases from around 425 PJ in 2010 to 500 PJ in 2030 (an increase of 18%). The graph shows the contribution of a variety of feedstocks in this scenario. Current feedstocks that dominate UK supply are landfill gas, dry agricultural residues and waste wood. In the future these are supplemented by increases in UK energy crops (from very little now to 65PJ in 2030), biofuel crops (from 16 PJ in 2010 to 66PJ/y in 2030), anaerobic digestion of food waste (from 6 PJ/y now to 33PJ/y by 2030) and the use of the renewable fraction of waste (from 12 to 35PJ/y by 2030).

Figure 3.2 (b) shows the same data, but assuming that any additional spare land is used to grow energy crops. For the low availability scenario (at £4/GJ) the dominance of similar feedstocks to those listed above can be seen, but with much lower first generation biofuel crops (from 6PJ in 2010 to 19PJ in 2030). The total resource increases from 410PJ in 2010 to 460 PJ in 2030 (a 12% increase). At this price energy crops are not planted because the price is not sufficient to overcome the costs and perceived risks to the agricultural sector. The situation improves under the medium availability assumptions (i.e. at £6/GJ), when the development of energy crops is estimated to approximately double compared to the scenario for maximised biofuel crops.[10]

The graphs also show the impact of meeting all constraints at £10/GJ (or high price for biofuels). Under this high availability scenario, for the scenario maximised for 1G biofuel crops there is an increase from 709 PJ in 2010 to 780PJ in 2030 and for the scenario that is maximised for energy crops there is an increase from 689PJ/y in 2010 to 883 PJ/y in 2030. The results show that landfill gas, agricultural residues and waste wood continue to dominate the picture, but that overall production has increased above that in the low availability scenario (at £4/GJ) by 70% in the maximised biofuels scenario and around 110% for the maximised energy crop scenario.

The overall results show increases in some key biomass resources between now and 2030. The following all increase with time and price:

- Waste wood
- Forestry residues
- Short rotation forestry (although this effect is only seen at £10/GJ)
- Anaerobic digestion (particularly of food waste and agricultural manures)
- Energy from the renewable fraction of waste
- Energy crops
- Biofuels (mainly bioethanol)

In every scenario landfill gas decreases over this time scale, due to the requirements for diverting biodegradable waste from landfill.

[10] The results for the two energy crop/1G scenarios show that, at medium (£6/GJ) and high (£10/GJ) availability the total supply of biomass for maximum energy crops is less than the amount produced for 1G crops until 2025, but that this situation changes by 2030. The yields from growing energy crops are higher (in energy terms) than 1G fuels, but the constraints on planting rate of energy crops limits this advantage until 2030. So the impact of the high energy yield is only seen in 2030.

Further details of these results are shown in the Annex report. Appendix 1 compares these results with those presented for technical supply in the E4Tech study (E4Tech 2008). This includes a discussion of the reasons for any differences between the results of the current study and the E4Tech study.

Figure 3.2 (a) Summary of results for UK biomass supply assuming maximum production of first generation biofuels crops on spare land. Supply is shown for low availability (£4/GJ easy constraints addressed), medium availability (£6/GJ easy and medium constraints met) and for high availability (£10/GJ all constraints met).

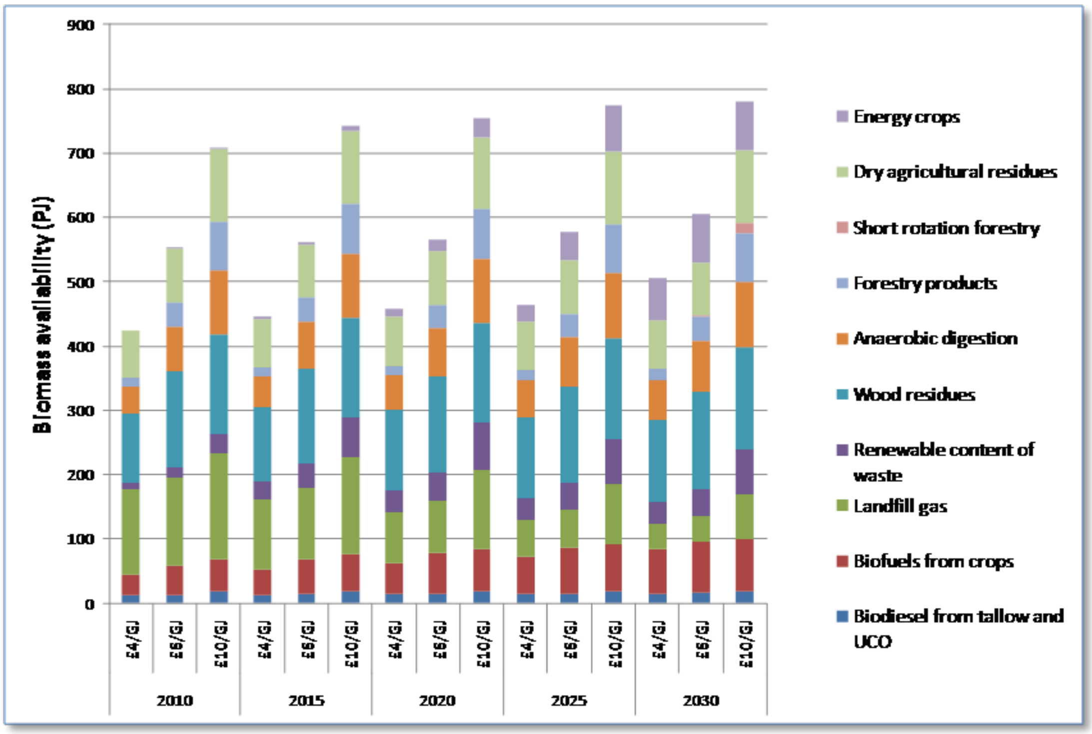
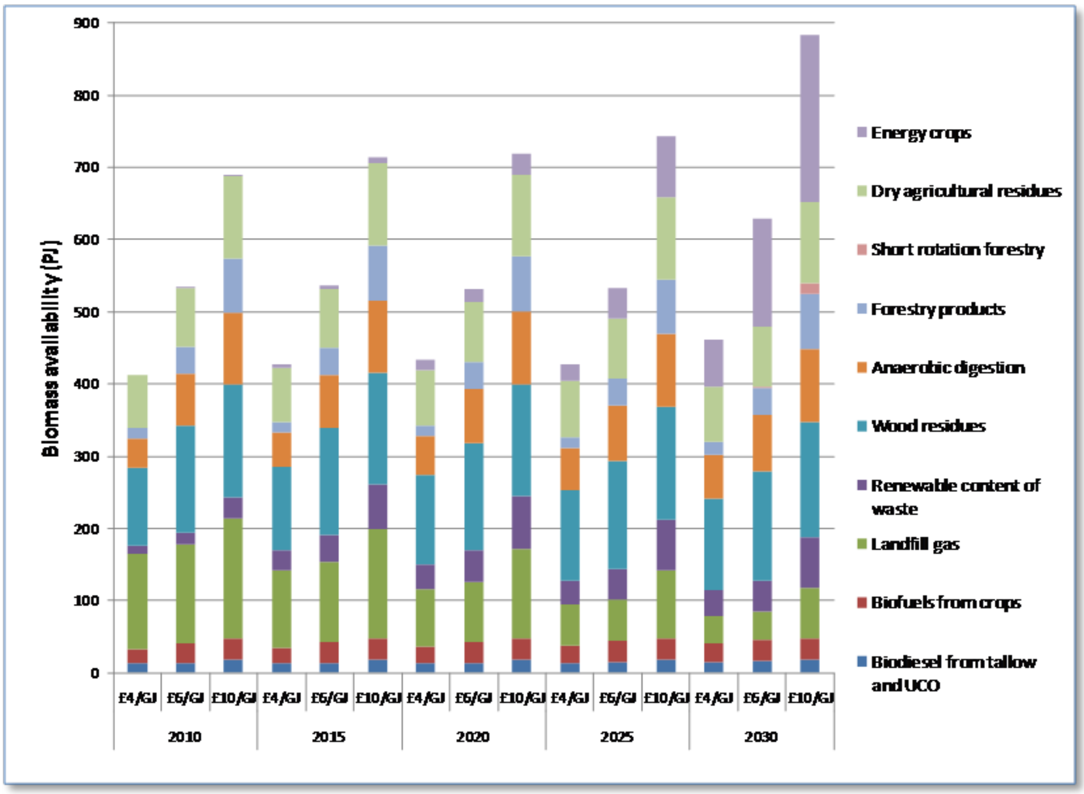


Figure 3.2 (b) Summary of results for UK biomass supply assuming maximum production of energy crops on available land. Supply is shown for low availability (£4/GJ, no constraints met), medium availability (£6/GJ easy and medium constraints met) and for high availability (£10/GJ all constraints met).



It is worth looking at the date for 2030 in more detail. At this date short rotation forestry and energy crops could become significant. At £4/GJ with no constraints overcome the UK could achieve 457PJ in 2030 (land use maximised for 1G crops) or 422PJ (land use maximised for energy crops), which would rise to 594 or 700PJ respectively at £10/GJ, a rise of up to 65%. This would rise by up to 7% to 638 or 742 PJ respectively at £10/GJ if easy and medium constraints are me. At £4/GJ it rises to 576 and 529 PJ respectively if easy and medium constraints are met, a rise of around 25% over the constrained potential at £4/GJ. This indicates a significant rise both due to increased prices and to meeting constraints, i.e. achieving the potential of bioenergy requires both (although this is complicated in that addressing many constraints will cost money). Constraints analysis – summary of results

Table 3.3 summarises the main constraints for each of the feedstocks examined for the UK. Full details on these constraints are presented in the model provided to DECC and a more detailed summary is available for each feedstock in the Annex report.

The analysis indicates that there are a number of common and important constraints:

- **Policy constraints** are common to most of the feedstocks. This is because bioenergy is not usually economic compared to fossil fuels without support from Government incentives. Consequently, policy stability is important to allow the development of the whole supply-bioenergy use chain, but it is particularly important to those feedstocks where considerable upfront investment is required to develop the resource, which includes (to a varying degree) many of the wood fuel feedstocks, the energy crops and feedstock for anaerobic digestion.[11]

- A second tier of policy constraints are also important – and we have included these as a catchall '**regulatory and policy uncertainty'**, although they are more complex than that. These are the policies that cut across areas (and often departmental responsibilities). For

[11] Upfront investment is required for these feedstocks to pay for the planting (of energy crops), the processing of energy crops and wood fuels and the collection, storage and transport of all of these feedstocks.

example: definitions of waste under Environment Agency regulation; definitions of biomass under Ofgem regulation; or land use policy as set for agriculture by Defra. Such policies do not necessarily prevent biomass feedstock supply from being developed but they do complicate the situation and may provide more complex constraints than the ones described above.

- **Market constraints** can also be significant. These are important because they affect the perception of the market by suppliers. Current markets for a number of biomass feedstocks are immature and result in uncertain and volatile prices. For other feedstocks this situation has improved, but demand is still dominated by a few key players, which makes farmers and the agricultural and forestry sector nervous of investment in supply. Long term contracts for supply are required by financiers of bioenergy plants, but many suppliers are nervous of signing such contracts because they fear they will not be able to take advantage of future price rises (including prices that affect their costs as well as price rises for biomass). These are all significant constraints for a number of feedstocks (particularly agricultural and forestry based feedstocks, where there are considerable upfront costs and risks to the supplier).

- Other market constraints are simply financial: even with the current incentives the returns are insufficient to develop the feedstock and make it difficult to obtain project finance for plant developers. This is true in areas where yields may be low, where the supply is too dispersed to justify collection or where the supply-use chain is complex and expensive to develop.

- Technical constraints have not been assessed as being as important as the above constraints for most feedstock – for some feedstocks there are no technical constraints. However, for feedstocks where use is perceived to be complex, they can be a significant barrier (e.g. on farm anaerobic digestion). In other situations where collection of the feedstock requires technical innovation (such as collection of residues from forests on steep or difficult terrain) technical constraints are a significant barrier. In these cases the technical constraint may be significant enough to make it impossible to achieve all unconstrained supply, even at £10/GJ.

- Infrastructure is important to supply. It includes the establishment of transport, storage, drying and processing facilities. Given the low bulk density of some fuels and the moisture content of others, transport over a large area is not cost effective for some feedstock, which also provides a constraint on use, particularly at lower feedstock supply prices.

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Table 3.3 Summary of constraints for each UK feedstock

For some of the feedstocks below there are significant competing uses. We exclude price independent competing uses from our constraints analysis and only comment on competition here where it results in price dependent constraints.

Feedstock	Constraints			Comments
	Most significant	Other key constraints	Difficult constraints	
Forest Residues	Technical: Harvesting site access and costs.	Need for drying and storage facilities Standards for fuel specification Low bulk density.	Terrain, cost of harvesting, risk of ground damage	• Significant resource very costly and difficult to harvest. • For remainder, the need to develop infrastructure for harvest, drying and storage and for transport is important. • Will require stable renewable policy to enable investment in infrastructure.
Small round wood	As for forest residues, terrain, site access and cost of harvesting are significant constraints.	Need for drying and storage facilities Standards for fuel specification and fuel testing facilities	Terrain, cost of harvesting, risk of ground damage	• Significant resource very costly and difficult to harvest. • For remainder, the need to develop infrastructure for harvest, drying and storage and for transport is important. • Will require stable renewable policy to enable investment in infrastructure.
Sawmill residues	Volume of sawlogs coming to mills.	Cost of certification for sustainability Incomplete or mature supply chain. Bark content[12]	Competition from other markets.	• Significant competition for resource will impact supply. • Supply constrained by sawlogs coming to mills. • Need for stable policy environment for investment. • Competition from other markets is significant.
Short rotation forestry	Lead time is long. Uncertainty about growing requirements, potential invasiveness and yields in	Possible planting rate.	Inertia; planting rate; need for research results before planting will begin	• Substantial long term investment; will require stable renewable policy • Research results required to give confidence to growers.

[12] Specifications for wood fuel frequently limit the bark content that is acceptable in the fuel supplied.

	different conditions.			
Arboricultural residues	Dispersed resource, low bulk density. Need to achieve fuel specification (e.g. chip size, moisture content)	Need to invest in collection and storage points. Insufficient returns and substantial upfront investment. Cost of sustainability certification	None.	• Need substantial upfront investment for storage and fuel preparation. • Sustainability certification will require investment in time and money. • Investment will only happen if renewable policy is perceived to be stable and reliable.
Dry agricultural residues	Feedstock often dispersed; location of plant crucial. .	Lack of collection and storage facilities Uncertainty in policy.	None, although it may require considerable increases in price to allow all remote resource to be developed.	• Need stable renewable energy policy to allow investment in plants and infrastructure. • Competition from other uses can be a significant price dependent constraint.
Energy crops	Land availability and alternative uses for land. Farmer perception Planting rates possible.	Good data on growing conditions, yields and impact on environment. Public perception. Costs associated with certification.	Perception of insecurity of market,	• Farmers need much more persuasion to grow energy crops instead of more familiar annual crops. • Crops tie up land • Perception that a few customers will dominate demand. • Need stable renewable energy policy to provide secure market; incentives to cover cost of planting; and an understanding that these crops compete with the potential use of land for conventional crops with which the farmer is more familiar and for which there is a more mature market.
First generation biofuels crops	Competition from cheap overseas feedstocks Public perception.	Lack of stability in policy environment,	Lack of processing facilities in UK for OSR. Concerns about impact on prices of other commodities. Concerns about public perception.	• Policy uncertainty and public perception are major constraints • Further constraints relate to lack of processing capacity in UK. • Competition from cheap overseas imports undermines UK production because it prevents the resource from being planted in the UK. This may not

				constrain overall availability of resource in the UK, but it does constrain the UK developed resource.
Other 1G biofuels feedstocks.		Lack of processing facilities in UK (tallow).	Immature supply chain for significant part of used cooking oil resource (i.e. municipal resource).	• UK policy stability important influence on investment decisions • Lack of processing facilities in UK for tallow. • Competition from other markets (tallow) may result in price dependent constraints.
Waste Wood	Location of feedstock compared with fuel demand	Requirement for substantial upfront investment. Lack of fuel standards	Lobbying from competing industries Lack of processing facilities for contaminated wood.	• Lack of collection and processing facilities. • Need for stable UK renewable energy policy to underpin investment.
Landfill gas			UK waste policy driving diversion of biodegradable waste from landfill.	• Production dictated by UK waste policy.
Renewable fraction of waste	Technical issues associated with proof of renewable content of waste and eligibility for renewable incentives.	Require investment in new facilities to take the residual fraction from recycling (‘solid recovered fuel’).	Public perception of waste combustion. Waste policy/waste contracts dictate what happens to waste, not energy policy.	• Local authorities and public are more concerned with recycling than energy recovery. • Public perception of energy recovery from waste is poor. • Difficult to demonstrate the renewable content of waste to satisfy regulator’s requirements. • Lack of facilities to burn solid recovered fuels.
Anaerobic digestion	The constraints on anaerobic digestion are considered for each of the relevant feedstocks below.			
Sewage sludge	Perceptions of complexity in market.	Returns insufficient at more remote/rural locations.	Cash flow issues relating to OFWAT’s regulation of the Water Treatment Industry. Remote location of some resource coupled with lack of transport infrastructure.	• Sewage treatment already developed for environmental and health reasons. The returns on investment can be insufficient to convert current treatment to AD in some locations. • Need stable policy environment to

				encourage development of further AD at sewage treatment plants.
Food and garden waste	Perception of risks, uncertainty and complexity of technology.	Lack of market experience in UK Lack of processing facilities for some waste streams (e.g. food waste from MSW)	Returns insufficient. Regulatory and policy uncertainty, relating to use of digestate as well as energy policy.	• Mis-perceived as complex feedstock supply chain. • Concern about insufficient returns and difficulty in obtaining project finance, unless the scheme is underwritten by secure contracts from local authorities. • Must be supported with clear, stable renewable energy policy and waste collection policies.
Farm slurries.	Perception of risks and uncertainty for farmers unfamiliar with digestion.	Lack of collection and storage facilities.	Integration into energy supply could be big problem for remote farms. Requires substantial upfront investment. Location of feedstock compared with energy demand,	• Need to demonstrate reliable technology in UK • Need for assistance with upfront investment • Need to understand the role of energy crops and co-digestion in obtaining good yields • Need to understand how energy can be integrated into energy supply infrastructure. • Need stable renewable energy policy to address investment risks.

3.2.1 UK supply - Summary and discussion

The results suggest that there is a large biomass resource in the UK, but its use is complicated by significant constraints. This means that it is not sensible to base UK biomass expectations purely on what is potentially available, but that constraints on the resource and methods to address these constraints must also be considered.

As an example, our scenarios suggest that in 2020 the UK resource:

- is 350PJ (1G maximised or energy crops maximised) at £4/GJ if no constraints are overcome (Figure 3.3a);
- rises by 14% to 400 PJ for 1G maximised or energy crops maximised at £4/GJ if easy constraints are overcome (Figure 3.3b);
- rises by another 18% for both scenarios (around 70PJ) if the price rises to £10/GJ (Figure 3.3c).

This demonstrates the importance of addressing the easy and medium constraints on UK resources; addressing these constraints could increase biomass supply more significantly than increasing the price paid for biomass.

Figure 3.3 (a) Estimated UK constrained biomass potential in 2020 no constraints overcome

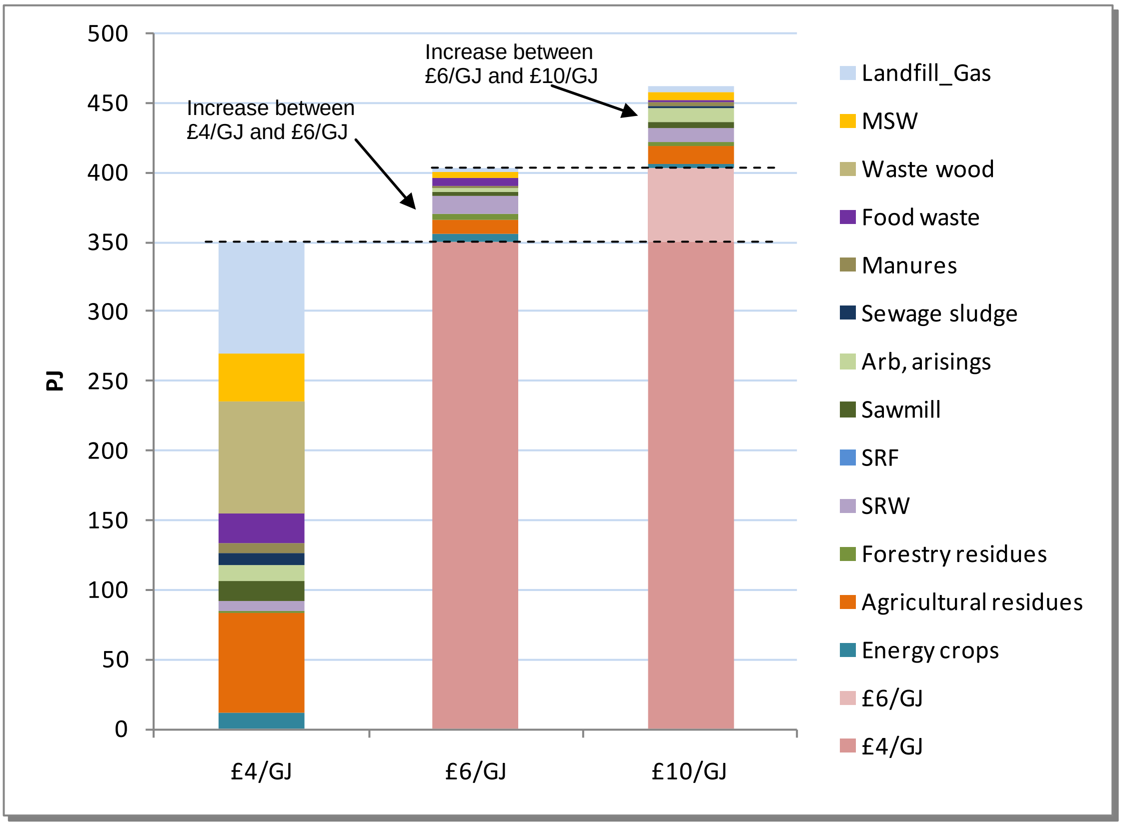
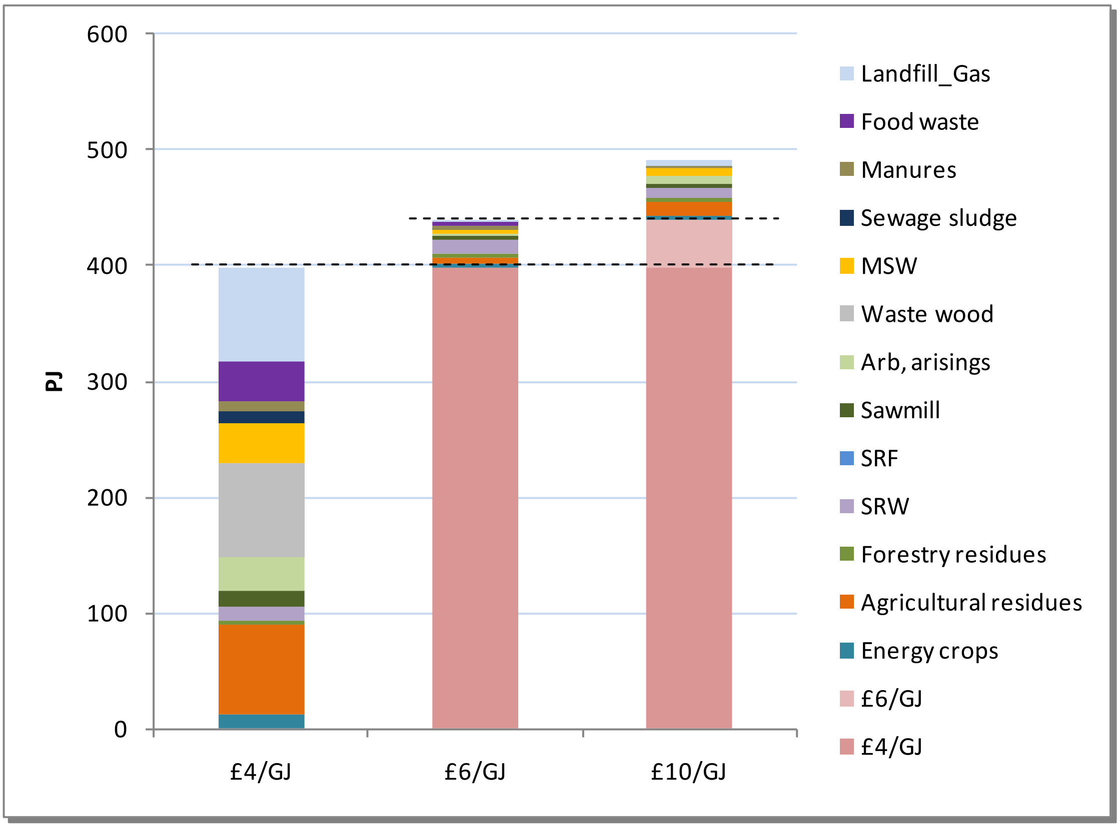
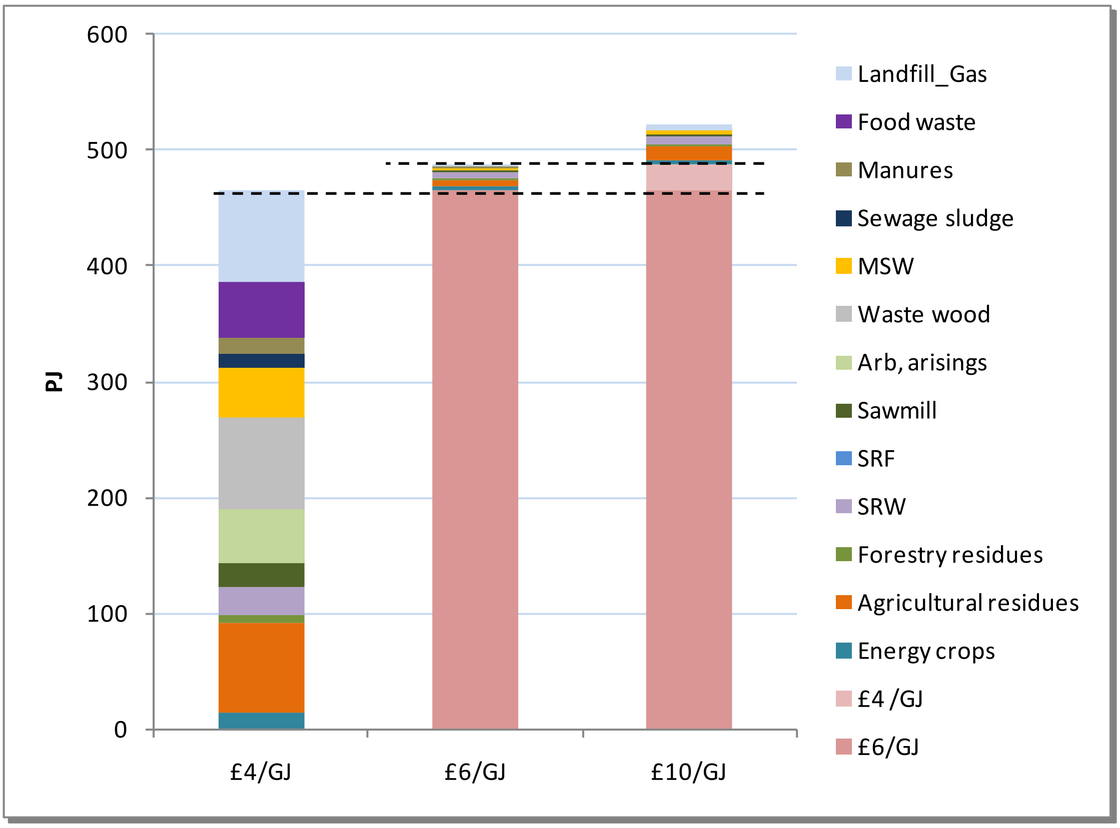


Figure 3.3(b) Estimated UK biomass potential in 2020, with easy constraints met.



Note: the graphs show the increases only for medium availability (£6/GJ) and high availability (£10/GJ). The resource that was already achieved at £4/GJ and £6/GJ is shaded one colour in the subsequent columns.

Figure 3.3 (c) Estimated UK biomass potential in 2020, with easy and medium constraints met.



Note: the graph shows the increases only for medium availability (£6/GJ) and high availability (£10/GJ). The resource that was already achieved at £4/GJ and £6/GJ is shaded one colour in the subsequent columns.

Many of the constraints can be overcome by investment in infrastructure or technology, if the perceptions of risks and uncertainty that hamper current investment are overcome. Some of these constraints can be addressed within the price of the feedstock – consistently higher prices could provide adequate margin to the supplier; some through time; and others through a clear and consistent investment and regulatory environment. Examples of these include investment in harvesting equipment for forestry that enables residues to be collected; planting equipment and material for energy crops; storage and processing facilities for many biomass sources (including waste). However, there remain significant constraints for some feedstock (those that require considerable upfront investment such as SRF, energy crops and anaerobic digestion feedstocks). In addition there are technical constraints that are almost impossible to overcome in the time period considered (e.g. the harvest of forest residues on difficult terrain).

For energy crops and short rotation forestry the whole question of land use and available land becomes important. In our analysis we have assumed that additional investment in yield increases for conventional crops increases the land availability for either first generation biofuels or energy crops without affecting the food supply. Thus investment in agriculture is also important to the development of biomass supply.

In summary, the main requirements to increase biomass supply from the UK are:

- A stable investment environment, which includes stable policy and good, long term contracts that recognised the risks to suppliers;
- Investment in infrastructure for the collection, storage and processing of feedstock, particularly for the more dispersed feedstocks;
- Addressing uncertainty and the perception of risk to overcome many of the market barriers, such as finance and inertia (i.e. reluctance on the part of the agriculture and forestry sectors to

invest in biomass). In part this can be addressed through some of the actions above, but more 'bankable' data is required to demonstrate that feedstock supply can work and there is a secure market. In addition public perception issues regarding the planting of energy crops; the harvest of residues from forests; and the processing of waste feedstock all need to be addressed;

- Investment in agriculture in general to increase yields of food crops and availability of land for bioenergy crops.

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3.3 Global Supply Resource Estimates

3.3.1 Introduction

The global supply estimates are presented for a 'reference' demand (as estimated by the IEA World Energy Outlook, see methodology) for three scenarios (Business as usual or BAU, High Investment and Low Development, see section 2.2). These results are presented below including only the biofuels that meet the Renewable Energy Directive (RED) sustainability criteria. Results for the high biomass demand scenario are also presented.

3.3.2 Summary of global results

The complete set of results for international bioenergy resources are provided in Appendix 4

Results for the reference energy demand scenarios, with sustainability standards applied.

Figures 3.4 and 3.5 show the results for 2020 and 2030 for the business as usual scenario. The international resource refers to the total estimated resource available. The surplus on the market is the amount that could go to international market, taking domestic (in country) use into account and taking competing uses for the resource into account. It is then assumed that 10% of this resource could be available to the UK. It should be noted that this is not equal to future imports, but provides an indication of what might be the level that could be imported if demand exists.

In 2020 the potential surplus on the market is estimated to be around 65% of the total international resource production. In 2030, the surplus on the market is estimated to be around 80% of the total international resource i.e. domestic demand is about 20% of the potential resource. The resource increases significantly between 2020 and 2030 in this scenario due partly to investment in infrastructure and development of the market, but mostly due to a significant increase in plantations of energy crops.

Figure 3.4 Results for global supply to the UK, Business as usual scenario, optimised for energy crop production.

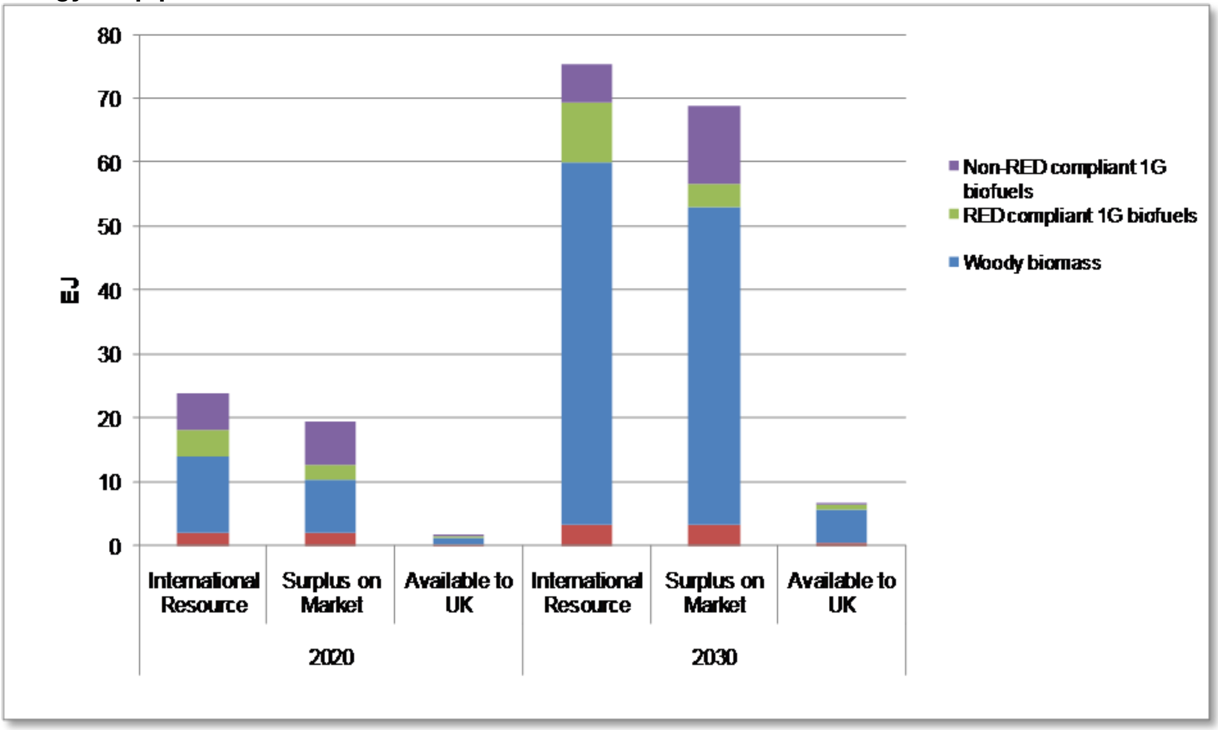
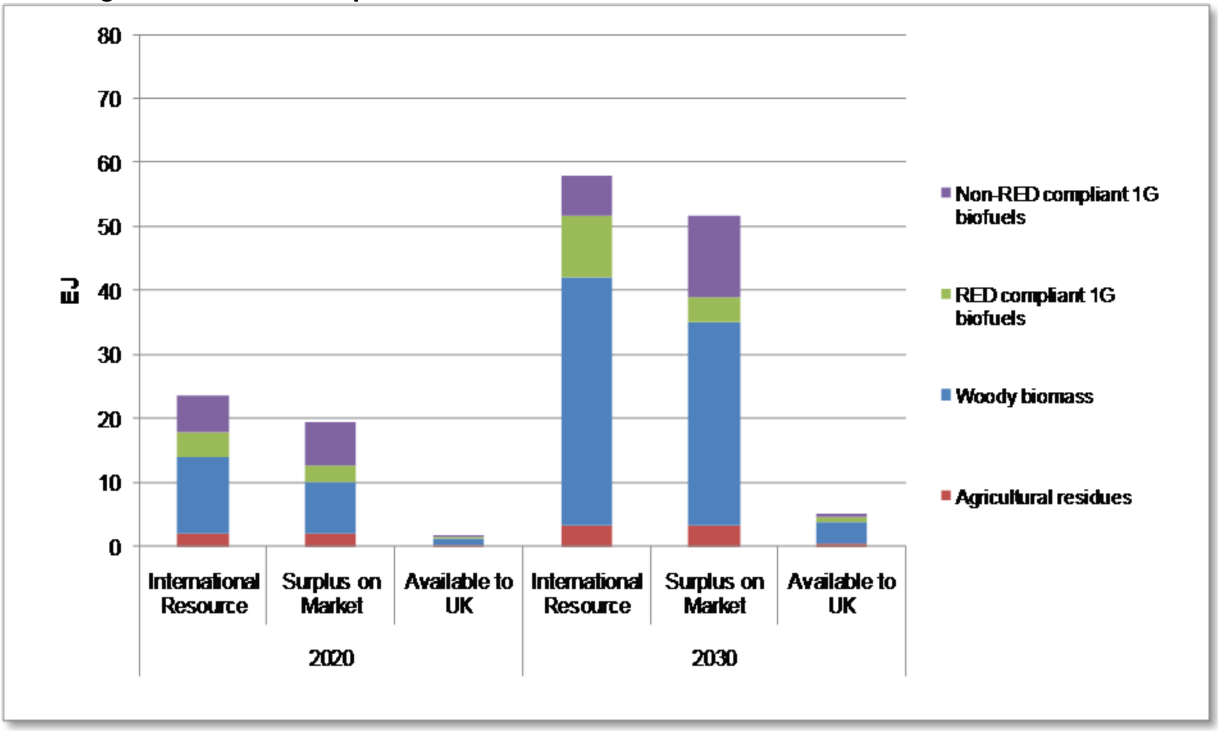


Figure 3.5 Results for global supply to the UK, Business as usual scenario, for 2020, optimised for first generation biofuels production



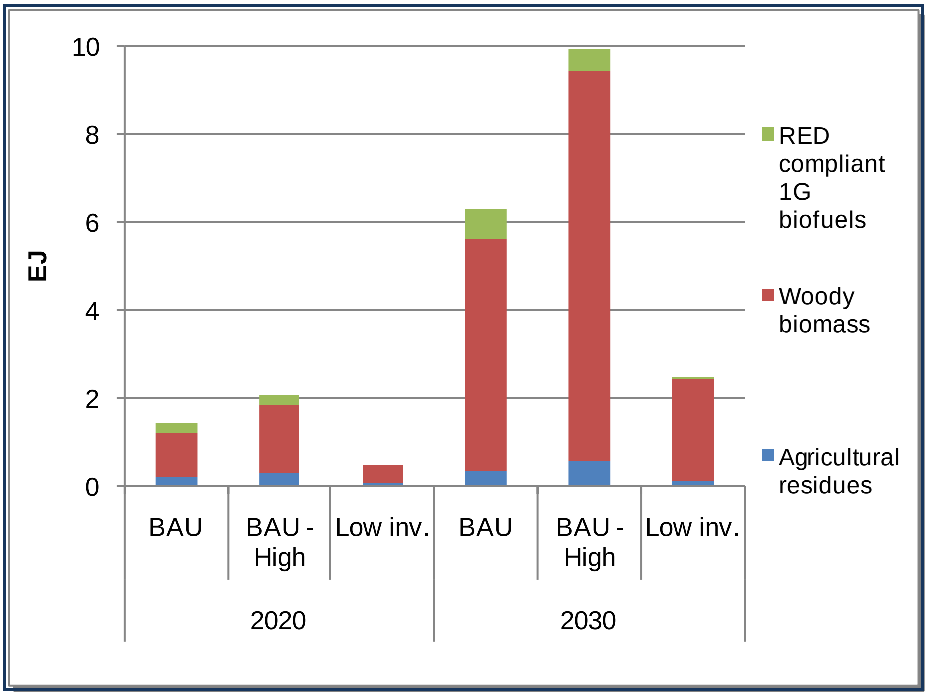
Figures 3.6 and 3.7 show the data for the amount available to the UK in 2020 and 2030 for all three development scenarios examined (Business as usual, BAU + high investment and low development). These graphs omit the non RED compliant biofuels, i.e. biofuels which would not meet the GHG savings criteria in RED. The graphs show that woody biomass (including energy crops) dominates supply.

The Figures also illustrate an important result for biofuels, showing that only a small amount of RED compliant biofuels are estimated to be available from first generation biofuels in 2020; particularly in the low development scenario. The small supply available is mainly comprised of bioethanol, as only very small amounts of biodiesel are judged to be able to meet the RED GHG savings criteria. For BAU and BAU plus high investment the quantities of biodiesel available to the UK from international sources that can meet the sustainability standards are low: only 42 and 48PJ respectively in 2030.

In 2020, the modelling indicates that there is not enough RED compliant biodiesel globally to meet the EU's demand for biodiesel. Within the model, biodiesel available to the UK is estimated as the global surplus, after other countries demands are met This means that within the model, when global supply cannot meet EU demand, then no biodiesel is available to the UK. However, this is an over simplification, and in reality, it is likely that the UK would obtain a proportion of any global supply that is available to the EU. Furthermore, it is likely that if there was a shortage of RED compliant biodiesel, then there would be a premium price for RED compliant fuels and producer countries that did not have sustainability standards for biofuels used domestically, would be likely to export the proportion of biofuel production which is RED compliant. There would also be a considerable incentive, particularly if RED compliant fuels attracted a premium price for biofuels producers to look at ways to reduce the greenhouse gas emissions associated with production in order to meet the RED criteria.

These factors mean that there is likely to be some availability of biodiesel to the UK in 2020. Global supply of RED compliant biodiesel is estimated to be 409 PJ in 2020 and 1243 PJ in 2030 (under the BAU scenario with 1G production maximised). If the UK were to obtain 10% of this global supply, then it would import about 41PJ of biodiesel in 2020 and 124PJ in 2030. For comparison, it is estimated that the quantity of biofuels required to meet the Renewable Transport Fuels Order in 2015 (of 5.2632% biofuels content by volume) is about 44PJ of biodiesel and 28 PJ of bioethanol.[13] Meeting the requirements of RED that biofuels use must equal 10% (by energy content) of road and rail transport fuel demand will require substantially higher quantities.

Figure 3.6 Global biomass available to UK, optimised for energy crop production



Figures 3.8 and 3.9 show the total solid biomass resource (i.e. excluding first generation biofuels) for 2020 and 2030 for the BAU scenario with 1G maximised, broken down into component fractions. These show the importance of wood energy crops to this resource and how they increase as a proportion of supply by 2030.[14] The planting of wood energy crops on the wide scale achieved in this scenario is by no means predictable. A lot needs to happen to enable this resource to be developed,

[13] Derived from ongoing study by AEA for the Department of Transport on the use of biofuels in transport.
[14] Similar results are obtained for the other scenarios, although the development of woody energy crops is lower in the low development scenario.

such as the development of suitable crops and the identification of suitable land where crops can be grown sustainably, which means that estimates of world supply contain a large amount of uncertainty.

Figure 3.7 Global Biomass available to UK, optimised for first generation biofuels production.

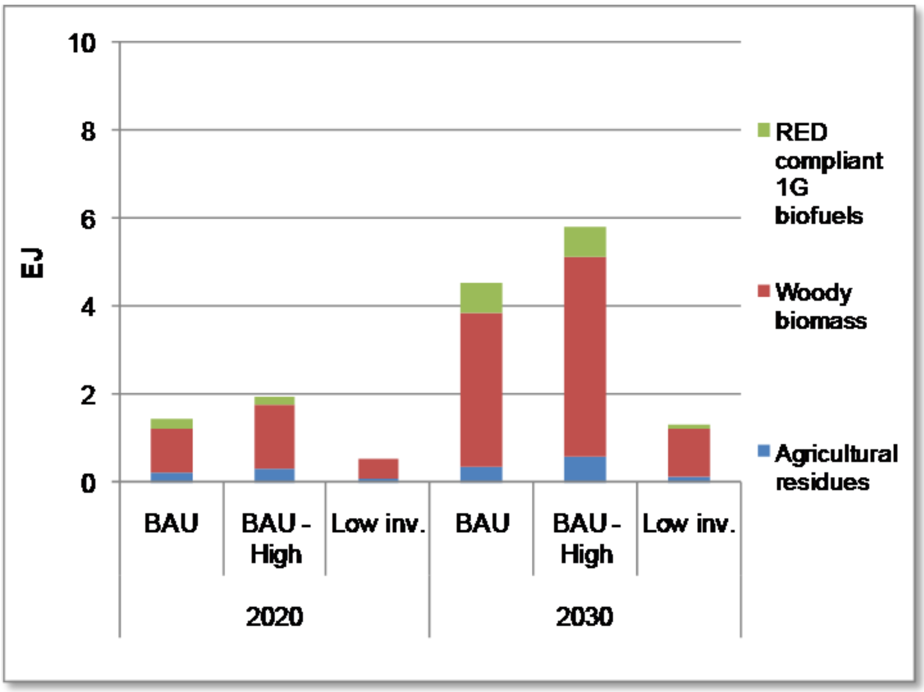


Figure 3.8 Global solid biomass resources in 2020 and 2030 in BAU (production of first generation biofuels maximised) (Total = 24EJ in 2020 and 58EJ in 2030)

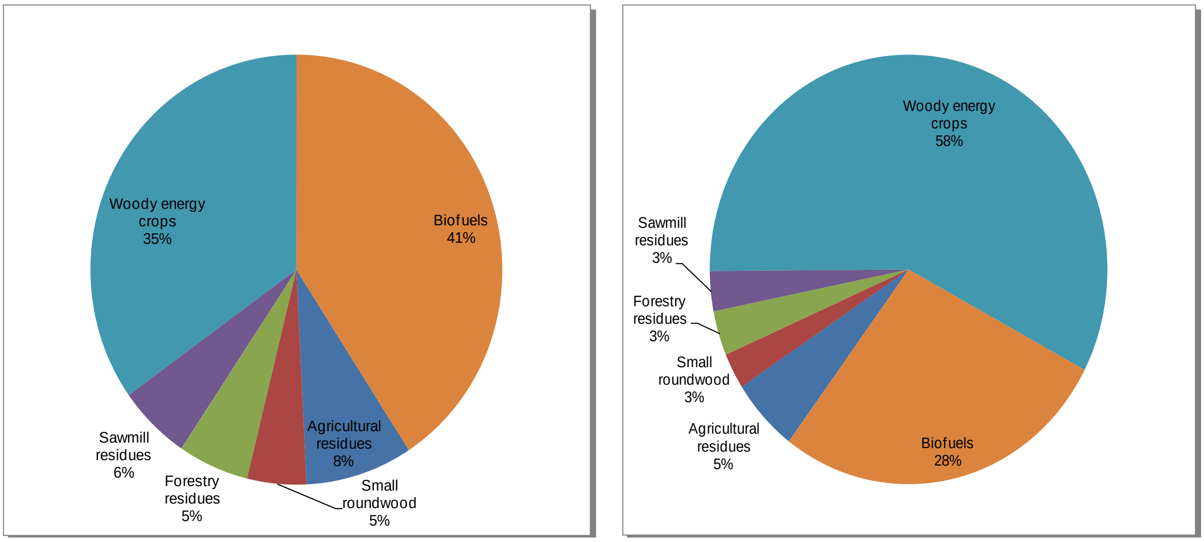
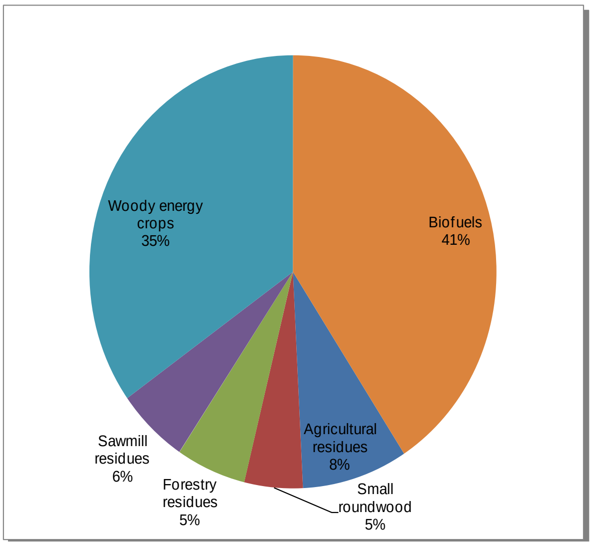
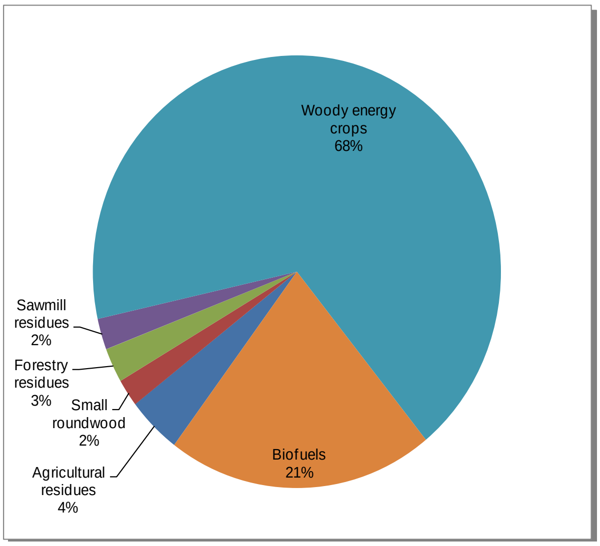


Figure 3.9 Global solid biomass resources (BAU) in 2020 and 2030 (production of woody energy crops maximised) (Total = 24EJ in 2020 and 75EJ in 2030)



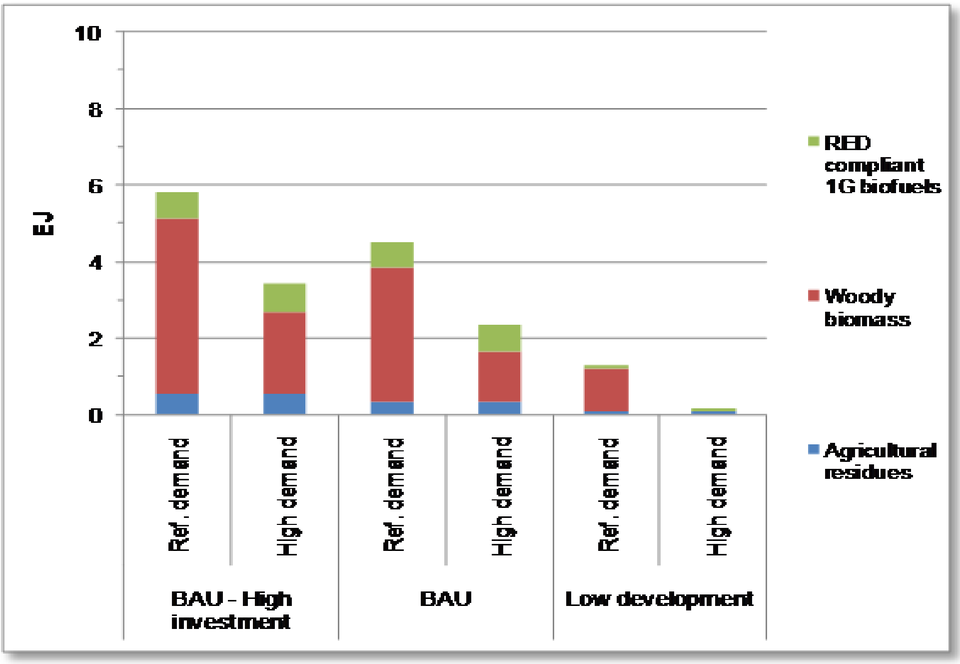


The impact of high biomass demand

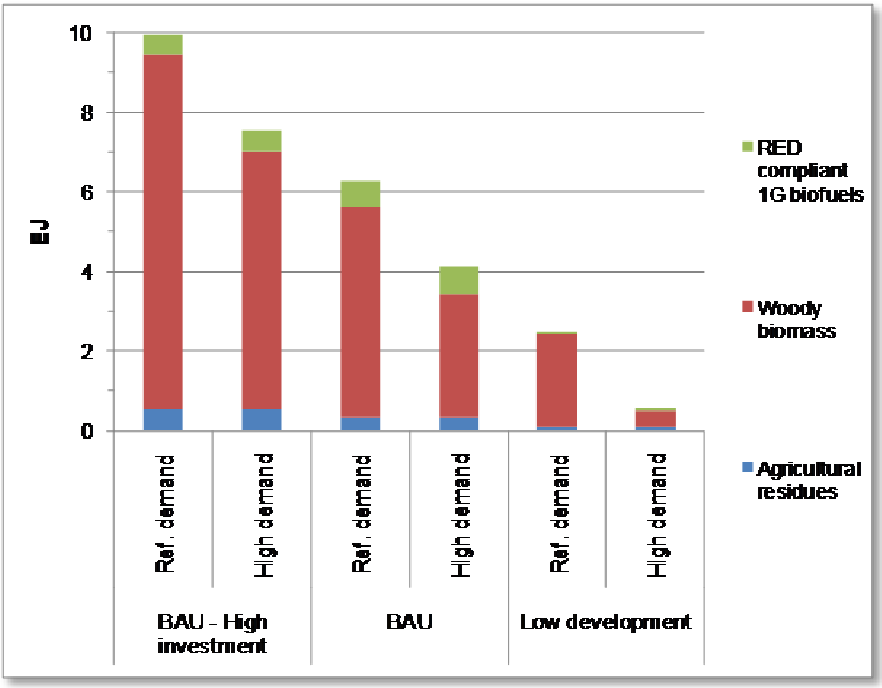
The high energy demand scenario showed significant decreases in availability of biomass to the UK (see Figure 3.10). For example, for BAU, maximised for 1G crops with sustainability standards applied, the amount of biomass available to the UK is estimated to decrease by around 23% in 2030 and by around 45% by 2030. The situation is slightly better for the high investment scenario and much worse for the low development scenario (the supply is decreased by 60% and 85% for 2020 and 2030 respectively). This demonstrates the importance of demand for biomass for energy elsewhere – and the importance of the level of investment in agriculture and biomass globally.

Figure 3.10 Impact of high biomass demand on the global supply available to the UK in 2030

(a) For 1G maximised scenario



(b) For energy crop maximised scenario



Location of Global Resources

The following figures show the origin of the main sources of RED compliant biomass available to the UK in the BAU scenario (1G maximised). These show the importance of the EU and North America to forestry resources; the importance of North and South America to first generation biofuels resources; but that energy crops would be more evenly spread around the world. Africa, and Asia (excluding China) are forecast to have low levels of supply of each of the resource, and while in the BAU-high investment scenario, there is more development of the resources in these regions, they still only account for 2 to 3% of global supply.

Figure 3.11 International forestry resources

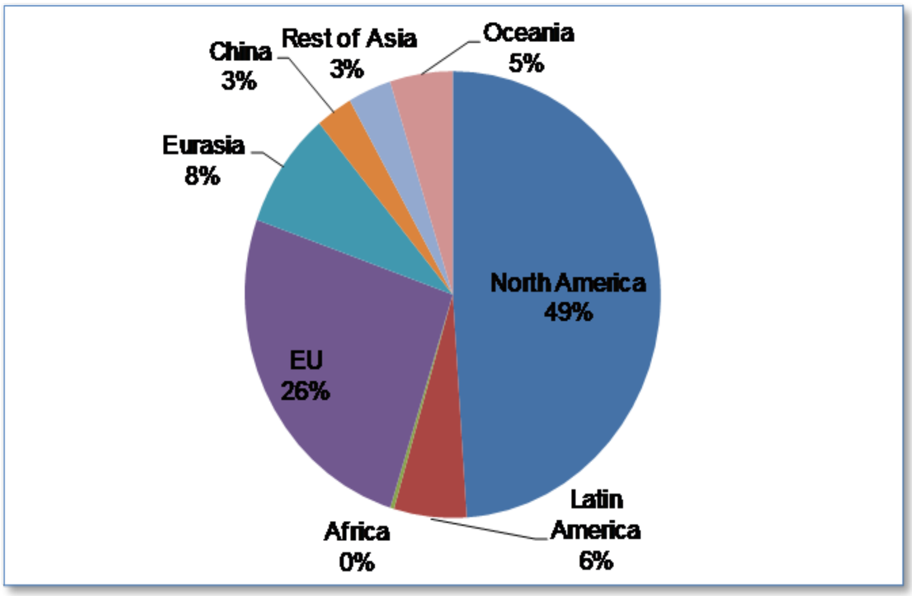


Figure 3.12 International energy crop resources

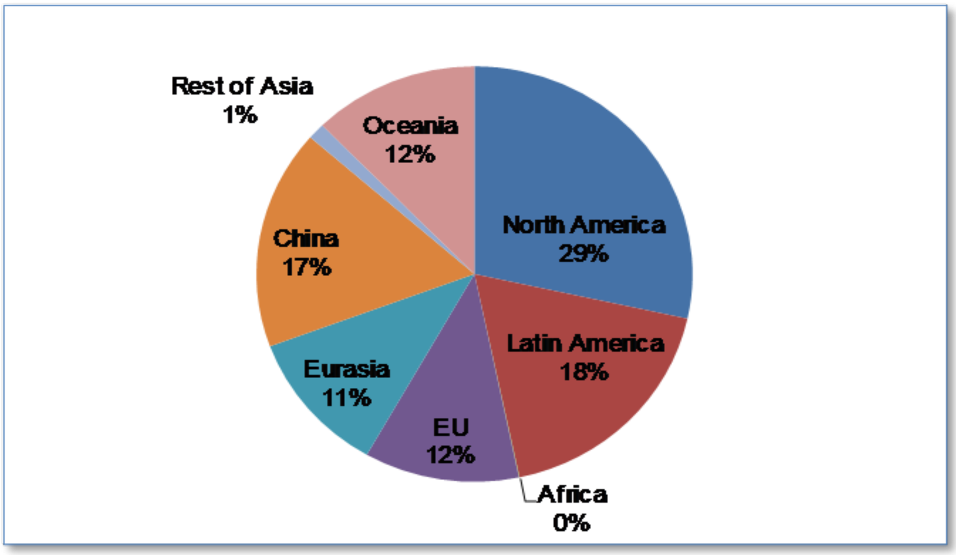
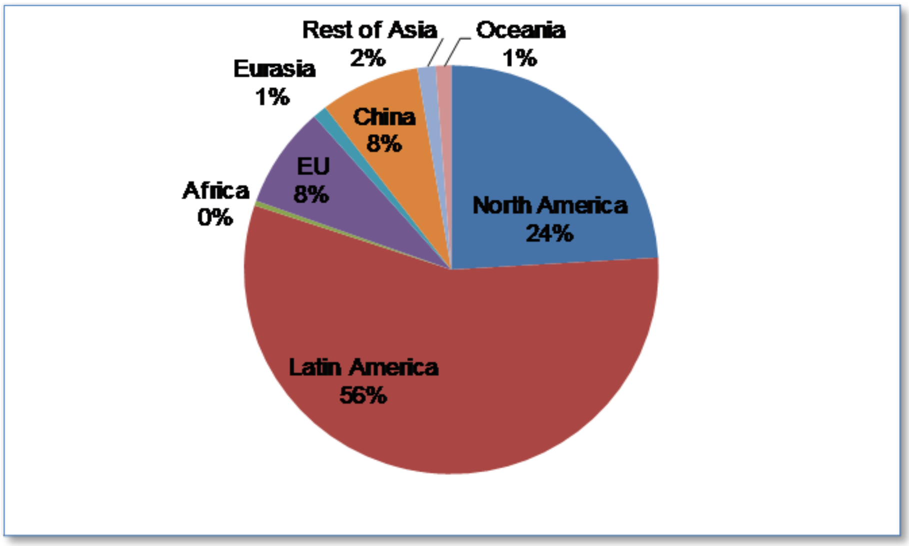


Figure 3.13 International sustainable 1G biofuels resource



3.3.3 Discussion of global results

Our analysis for global biomass resources show four key issues that are of immediate importance to UK bioenergy decision makers:

- International supply to the bioenergy market is predicted to grow, providing there is an international market to stimulate this. Currently this market is dominated by Europe, but by 2030 other key players, such as the USA and China will be important. Our analysis suggests that there is sufficient resource to meet UK demand, with the provisos below. As could be expected, growth in biomass supply is better in the high investment scenario; and it is significantly lower in the low development scenario, indicating the importance of investment in agriculture and forestry to the development of biomass.
- In our scenarios, the international supply is dominated by wood fuels, and wood fuels in turn are dominated by potential energy crops, which do not exist at the moment. Our analysis suggests that between around 60-75% of the global resource could be energy crops in 2030 (depending on the scenario), from virtually no supply now. Against a backdrop of increasing

demand for food from an increasing population there is a prospect that there will be increased investment in agricultural crops, which will improve yields and free up land for energy crops. However, this is by no means certain. Analysis by researchers at Utrecht University (e.g. Hoogwijk et al 2003, Hoogwijk 2005) shows that the regions of the world where most land is potentially available are situated in Sub-Saharan Africa, South America and Russia. There is no guarantee that these regions can be used to develop a significant energy crop resource for export and our analysis suggests a major increase in South America, and some resource in Russia (which is classified as part of Eurasia in Figures 3.11 to 3.13) but not in Africa. This partly because much of the potential land identified by Hoogwijk in this region does not become available until after 2030, and partly because the modelling assumes that there are significant infrastructure and market and trade barriers to developing resources in this region. Furthermore, the analysis undertaken to identify the availability of land is associated with high uncertainties, particularly in the interpretation of satellite data and assumptions about yield increases. Thus this part of the resource is by no means certain. How this resource is developed and supplied to the UK will be a major challenge and require considerable investment. This is reflected in the scenario analysis. Where there is increased investment, energy crops are more likely to be developed and the additional resource available reflects this. Conversely the low development scenario reflects the lack of international investment in the development of energy crops, as well as lack of investment in infrastructure such as transport networks, port facilities, processing facilities etc. There are also likely to be sustainability issues.[15] In our estimates issues such as water use, the need for feed crops to take precedent etc, are included. However, it will be important to ensure that such criteria are actually taken on board when the resource is developed.

- From the middle of the next decade to 2025 there could be a shortage of biofuels available to the UK that are compliant with the Renewable Energy Directive. This situation improves a little by 2030 in the BAU and high investment scenarios. It is most serious for biodiesel, which is predicted to be unavailable to the UK in the low development scenario. As discussed above this is because in the modelling only biofuels which were 'surplus' after other countries' demands had been met were considered as being available for import to the UK, and in the reality the UK would compete with other EU Member States for the available supply of biofuels which are compliant with RED and would therefore have access to some global biodiesel supply. The modelling does indicate however that due to the restrictions on supply the RED directive will impose (in terms of the requirement for biofuels to meet GHG savings targets), that the supply of RED compliant biofuels might not be enough to meet EU demand for biodiesel in 2020 .

- Agricultural residues could be a significant resource, but their harvest is unreliable and they are also used in the competing animal feed market. This will be important in years when harvests of crops used for animal feed are low. But it also means that agricultural residues may be used in quantity in years when there is a surplus and that UK bioenergy plants could be developed to be sufficiently flexible to take advantage of this surplus. In our analysis the agricultural residues resource increases with time in all scenarios, although the increase in much less apparent in the low development scenario. This is a reflection of investment in infrastructure and the opening of trading routes for bioenergy feedstock.

We have estimated that a significant amount of the resources produced go to meet national demand. This is more important if the potential for energy crop production is not realised – in this case the resources going to meet national demand represent a significant use of the remaining resource. In many potential supply countries wood is a significant source of energy because of its plentiful supply. For there to be an international resource available from such countries means that either their demand is met; or that the international price for wood based bioenergy feedstocks is higher than the domestic price and therefore it makes sense to supply to the international market.

There are two potentially important impacts on biomass supply which need to be considered:

- The impact of sustainability requirements on supply

[15] The large scale acquisition of land in South America and Africa for production of food or biofuels is causing concerns in local populations, particularly where it results in the displacement of small scale farmers (e.g. see articles on Ghana and Tanzania in http://allafrica.com/stories/200910051518.html and http://www.theeastafrican.co.ke/news/-/2558/667648/-/item/0/-/wst89uz/-/index.html). The way in which land is typically used to supply foreign markets and the nature of foreign investment is described in FAO (2008).

- The impact of increased international demand on supply to the UK

These are discussed below.

Sustainability

The analysis presented above includes the impact of the sustainability criteria in the RED on supply of biofuels. Application of these criteria makes a significant impact on biofuels availability to the UK, particularly for biodiesel from 2017 At this point there are insufficient biodiesel resources to meet UK targets, The situation is best in the high investment scenario, where significant biodiesel resources are available globally, but there will be international competition (at least within Europe) for these resources. This will mean increased prices to the UK supplier, which may, in turn stimulate increased production in the EU.

One concern for biofuels production is the indirect impacts that biofuels may have, particularly the land use impacts, more commonly referred to as indirect land use change (ILUC). More detail on ILUC is given in Box 3.1. The RED land use criteria are designed to overcome the issues described with regard to ILUC in Box 3.1. Whether they will, and whether ILUC will have further impacts is not yet clear. In addition the criteria in RED could be extended to solid biomass for heat and power. Depending on how this is done there may be significant impacts on this sector as well. Thus ILUC is very important to biomass supply and could be a potential show stopper, unless there is investment in understanding and preventing its impact; and in gaining international consensus on how it can be approached.

Box 3.1 Indirect and Direct land use change – definition

Land is required to grow energy crops. This land can be existing agricultural land, or land converted from another use. When the land is converted from another use for energy crops this is termed Direct Land Use Change (DLUC). DLUC occurs at the site of energy crop production, and is under the control of the energy crop producer. When existing agricultural land is used for energy crop production there is no DLUC. However, it is possible that the existing agricultural production will be transferred to another site, which may result in land use change at that site. This is termed Indirect Land Use Change (ILUC). ILUC occurs at another site which is potentially at any place in the globe. The original agricultural product may in addition by substituted by an alternative product. The substitute product and the amount, type and location of land used to produce it depend on a number of factors that interact and are cannot be predicted with certainty on a case by case. ILUC is therefore outside the direct control of the energy crops producer.

DLUC and ILUC are, however, equally important as they both lead to a range of possible environmental and social consequences. Many studies of the effects of land use change do not therefore distinguish DLUC and ILUC but speak simply of Land Use Change (LUC). For clarity DLUC can be defined as LUC that occurs locally, and ILUC as LUC that occurs remotely from the site of energy crop production.

The importance of land use change is related to the carbon stock of the land use that is displaced. If the established land use is of higher carbon stock than the crop that displaces it there is a one off release of carbon from that source, which may negate the carbon gain from the biomass crop that replaces it. One example of this would be the clearance of grassland or forest to plant energy crops. Many life cycle assessment tools do not currently include this use because of the difficulty of modelling it.

A lot of work is ongoing on ILUC, both to understand its actual impact and to provide a model that can be adopted within life cycle assessment. However, this work has yet to be completed. In the meantime the following can be concluded:

Box 3.1 continued.

- ILUC is a global issue that affects all land use sectors and can lead to GHG emissions, loss of biodiversity, water scarcity and land degradation, as well as impinging on local land rights.
- Bio-energy has a particular responsibility to minimise LUC, including ILUC, since the bio-energy sector sets out to reduce GHG emissions and encourage sustainable rural development.
- ILUC is potentially a show stopper for bio-energy. Current central estimates of GHG emissions associated with ILUC range from 30 to 103gCO_2eq/MJ biofuel produced. If substantial ILUC is attributed to energy crop production, then the GHG emissions savings benefits of bio-energy are substantially reduced or even negated. ILUC also has a negative impact on other sustainability indicators, but at present no quantified estimate is available.
- All major bio-energy players are currently reviewing their positions on ILUC, and there is considerable recent literature on the subject. However, to date no consensus has been achieved on the best approach to managing ILUC.
- In the short term action is required at the regional level to address ILUC in the context of current bio-energy policies. This is likely to include demonstration that ILUC is minimised and evaluation is likely to apply at individual project level.

In the longer term global co-operation is required to reach a consensus on whether any LUC is acceptable in energy crop production, what GHG emissions values and other sustainability indicator values are to be allocated to conversion of each land type, how LUC will be monitored, and how any penalties will be enforced.

Competing international demand for biomass

A number of countries across Europe and elsewhere have indicated that they think they will need to import biomass fuels to achieve their renewable energy targets. This includes countries such as South Korea and Japan in the Far East, where energy demand in general is likely to rise significantly. We have used the IEA WEO estimates to understand demand and to ensure that we examine supply using realistic estimates of competition. The UK's own demand for biomass will increase rapidly if all of the biomass plants in planning are developed (see Appendix 6 for a list of these plants). If European plants currently in planning are also developed it is likely that demand for biomass for heat and power plants will increase by 25 million odt above current demand.[16] This means that there are potentially significant increases in demand globally in the next five to seven years or so, which could both stretch biomass supply but also provide a strong incentive for the development of a viable international biomass market. The UK could be a significant player in this market, but it will require considerable investment in infrastructure to import and process the feedstock required and to ensure that phyto sanitary[17] regulations are met.

Interaction between UK and international supply

The development of international trade will depend on the development of international demand. There are two markets in which this has happened at the moment: the wood pellet and the biofuel market (see Box 3.2). Both of these markets have developed in response to European and other international demand. Prices on these markets are international and relate to international demand. Internal domestic prices are likely to be linked into this international market, because if a supplier can obtain a higher price on the international market, taking transport into account, compared to the domestic market, he is likely to consider trade in that market. It is possible to get historic data sets of the open market traded prices for these fuels (usually CIF or FOB prices). This leads us to suggest that in a mature international market we would expect international biomass feedstock prices to set the prices seen in the UK. However, currently for bioenergy feedstock where international demand is still to develop, historic price series are not available and trade usually takes place through bi-lateral

[16] Jaap Koppejan, IEA Bioenergy Task 32 leader, pers. comm. The European Biomass Association estimates current demand to be 13M odt in EU 27, which means demand could increase by 200%.

[17] Phyto sanitary regulations (Forestry Commission 2009) are those regulations that protect importing countries from the spread of pests and diseases on biomass from other regions. For this reason it is likely that the import of untreated brash and bark will not be allowed; and that wood chips will probably need to be subjected to some form of heat treatment before they can be imported. Further work is ongoing in this area, but any changes will need to be agreed at EU level (Forestry Commission 2010).

contracts and prices probably reflect the cost of production of the feedstock and the price of other feedstocks available to users.

Box 3.2 Development of the international pellets market

Pellets are a processed wood fuel, usually available at a moisture content of 8-10% and a bulk density of 650-750kg/m^3. They are most commonly made from residues from wood processing activities (i.e. sawdust and shavings from sawmills and furniture factories). They may also be made from roundwood, but this involves more processing and drying.

The advantage of pellets for wood energy supply lies in their storage and handling properties, which enable the fuel to be transported relatively easily and to be stored for periods of time, providing they are kept dry.

As a result pellets have been an important part of the expansion of the biomass heat market in a number of European countries; and they are becoming an increasingly important international fuel for the co-firing power generation market.

The development of the wood pellets market is charted by web sites such as pellet@las and www.propellets.at/ and further information is available in reports (e.g. VTT (2009) and (2007), Pöyry 2009). REN21 (2010) report a 25% increase in pellet use in Europe in 2008 and 20-27% increases in the use of pellets for heating in Italy, Germany and France. More recently, since 2006 in response to Government incentives large numbers of pellet heating plants have been installed in Britain and Ireland. In addition there has been an expansion of use and production in the USA and a large increase in production in Canada.

The price of wood pellets has been set by international demand for some time (since the early 2000s). Increased demand in 2005-6 caused a high price spike, but also stimulated large-scale investment in pellet production both in Europe and North America. Further production capacity and potential is available in Eastern Europe, around the Baltic and in Russia.

Potential growth areas in traded biomass

There are two other biomass resources that may become significant traded commodities in the future: waste wood and solid recovered fuel (SRF).

- There has been a rapid increase in re-processing of wood across the EU in recent years, stimulated by the increased incentives for bioenergy and recycling and by demand in the panel board industry. Most recovered wood is currently traded on bi-lateral contracts between the wood processor and bioenergy plant operators. In the UK new sources of good quality waste wood for combustion plants are becoming increasingly difficult to source. This issue is also hitting other countries in Europe, which is leading to the development of an international trade in Europe in waste wood suitable for combustion. It is likely that this market will become partially international in the future and that prices will be set internationally.

- SRF is being produced from the residue of mechanical and biological treatment of waste, but there is a shortage of capacity to take it in the UK at present. There are already indications that plants in Europe (the NL and Germany) may be interested in importing this fuel; and there is no reason why, if plants are developed in the UK, that SRF might not be imported to the UK. This means that in the long term an international market in this fuel may develop.

4 Price analysis

4.1 Overview

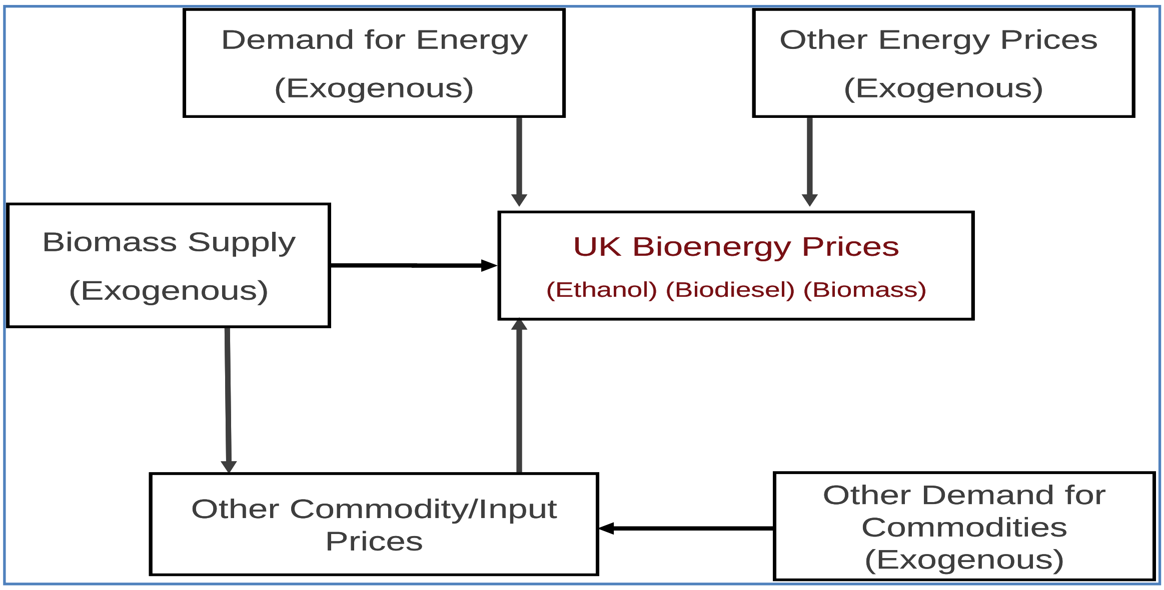
A model to forecast the price of internationally traded biodiesel, bioethanol, wood chips and wood pellets to 2030 was produced. The prices are for products traded on the international market in bulk, rather than products traded under bilateral arrangements. The latter is currently the case for a large part of wood chip and wood pellet supply to generators in the large scale power sector, but as the biomass market develops, it is likely to be internationally traded market which sets the price.

The analysis models the drivers of current international prices for bio-energy and assumes that these are or, in the case of solid biomass, will become the main drivers of future bio-energy prices. It uses economic inputs of energy supply and demand and the cost of feedstock inputs to produce the bio-energy price forecasts. Forecasts have been produced for a base case and two alternative scenarios, which are consistent with the biomass supply scenarios described in Section 3.

4.2 Summary of the Price Model

The model forecasts bio-energy prices by looking at both costs and underlying supply and demand factors. In each case changes in the price of the bio-energy product being modelling is assumed to be primarily determined by the price of the underlying feedstocks used to produce that product. For example in the case of ethanol the key feedstocks are corn, sugarcane and some other agricultural products. Changes in the prices of this feedstock are in turn determined by the overall supply of the feedstock, by energy and non-energy demand for the feedstock and by other energy prices. Bio-energy prices are assumed to be determined as a weighted combination of these feedstock prices. In addition other energy prices such as the oil price and coal prices and also overall energy demand also have an impact upon price. Figure 4.1 summarises the key relationships in the model.

Figure 4.1 Stylistic figure of the Bio-energy price model



There are three price models in total, all of which forecast annual prices for a type of bio-energy. Energy demand (both for bio-energy and other forms of energy), bio-energy supply, other energy prices and other demand for feedstocks are all determined outside the model. All prices are modelled in real terms and are then translated into nominal prices. Prices are all forecast on an annual basis. The three models contain the following specific factors.

Bio-diesel model: the key feedstocks for bio-diesel are oil, rapeseed, sunflower and palm oil.

Changes in these prices are determined as a function of total agricultural demand and supply, biodiesel demand and other energy prices. The supply and demand elasticities for each feedstock, which are a crucial driver of the model are based upon past studies, have been collected from the website of the Food and Agricultural Policy Research Institute (FAPRI website). The feedstock prices are weighted together (using weights based upon FAPRI data) to produce a total input price. Bio-diesel prices are then determined as a function of this weighted feedstock price. Other factors that also have impact on prices are other energy prices and total energy demand. Unfortunately as biodiesel production has only been existence for a relatively short space of time a key concern with this model and indeed with each of the price models described here is that coefficients are by necessity based upon a very short time series. This needs to be borne in mind when assessing the robustness of any of the results that are reported here.

Ethanol model: this has the same basic framework as that for bio-diesel prices. The relevant feedstock prices here are corn, sugar cane, sugar beet, wheat and barley. These prices are again determined by demand and supply for them plus other energy prices and total energy demand. The ethanol price equation is driven by feedstock prices plus other energy prices.

Biomass model: this model has been particularly difficult to build because the market is in its infancy and so very little data exists on either biomass prices or on the costs or quantities of the key inputs. The model that has been set up is very similar to those for other bio-energy prices. It is assumed that an international market for these products will develop overtime. As a result it is deemed sensible to forecast prices based upon global trends in supply and demand for biomass.

The most important determinant of future changes in biomass prices are changes in the prices of the key feedstock inputs. The prices of the inputs are in turn assumed to be impacted by changes in their supply and the demand. The key feedstock inputs in these cases are agricultural, forestry and wood residuals. Their prices will rise if the available supply of the feedstock goes down relative to current demand for that feedstock. Similarly prices of these feedstock will rise (or fall) if the demand for that feedstock goes up and total supply is unchanged. Demand for the feedstock is assumed to come from a combination of its use in biomass production and “other sources” “of demand. Increases in the price of the underlying feedstock will, all other things being equal, produce a proportionate rise in biomass prices.

Biomass prices are also assumed to be impacted by other factors. So an increase in “other” energy prices (all other things being equal) will lead to a rise in biomass prices. Also increases in total energy demand (brought about by example by faster global GDP growth) will (all other things being equal) lead to a rise in biomass prices.

The numbers for current and forecast supply of agricultural, forestry and wood residuals used in the modelling are consistent with the estimates described elsewhere in this report. Alternative demand for these materials other than for the purpose of producing energy is assumed to grow in line with output growth in industries that have traditionally made use of these products.

It is a key assumption of the model that biomass prices will be increasingly determined as if they were traded in a competitive market. This doesn’t necessarily mean that all prices are actually determined in this way. Indeed the market (like that for other types of commodities) is likely to be one that has a combination of some biomass being traded in markets and some traded via bilateral contracts. However, even if that is the case, it is still likely that the market price will influence the other prices. Indeed, it is likely to become increasingly the case that the market will provide the price information that will be used to inform negotiations in setting up other forms of contract.

In using the models it is possible to change the following variables to gauge their impact upon bio-energy prices–

- Total energy demand
- The proportion of bio-energy in total energy demand
- The total supply of all feedstocks
- The proportion of the demand for these feedstocks that are accounted for by bio-energy and other non bio-energy uses
- Price of other forms of energy

It is also possible to vary the supply and demand elasticities for all crops. In preparing both the base forecast and the alternative scenario care has been taken to ensure that the exogenous inputs used are consistent with the modelling of biomass supply which has been undertaken.

It was noted earlier that, given the lack of historic data, there must be a fairly wide confidence interval around forecast numbers. Tests suggest that the forecasts are particularly sensitive to the selected assumptions about demand and supply price elasticity. A set of base forecasts have been created based upon “mean estimates” of price elasticity drawn from the FAPRI database. The alternative scenarios then use these same elasticities.

4.3 Price Scenarios Modelled

Table 4.1 outlines the key assumptions in the three alternative scenarios for bio-energy prices which have been modelled. The price scenarios draw on the global bioenergy supply scenarios described in Section 3.

Table 4.1 Assumptions for Price Modelling

Price Scenario name	Bioenergy Demand scenario	Supply scenario	Max energy crops or 1G	Other assumptions
Central	Reference	BAU	Max 1G	Higher total energy demand and other energy prices
High	Reference	BAU – high investment	Max 1G	Lower total energy demand and other energy prices
Low	Reference	Low development	Max 1G	Lower total energy demand and other energy prices
Very High	High Biomass demand	BAU – High investment	Max 1G	Higher total energy demand and other energy prices

The central case is based upon the “business as usual” scenario for global biomass supply. This uses the following inputs for the exogenous variables –

- Other energy prices are taken from the Oxford Economics forecast.
- Total energy demand is taken from the IEA WEO forecast (reference demand case in the bioenergy supply modelling).
- Supply and demand forecasts for other agricultural products are from FAPRI supplemented with Oxford Economics estimates for later years.
- Wood residue and forestry residue figures based upon Forest Research CARBINE results as used in the global supply modelling.
- Estimates for demand for competing uses are derived from Oxford Economics industry forecasts.

Each of these inputs can be varied to derive alternative scenarios.

In the alternative scenarios we model the impact of changing three assumptions –
- Biomass supply
- Overall economic growth and so energy demand
- Other energy prices

There are three alternative scenarios –
- Low development – this is a scenario of weaker economic growth and lower energy prices but it also has a lower level of investment in biomass supply than in the base case, and hence lower levels of biomass supply
- High investment – this is a scenario of stronger global economic growth and higher energy prices but also has higher level of investment in biomass supply than in the base case.
- Very high energy demand – this is a scenario of very strong economic growth and high biomass demand coupled with the assumptions on biomass supply contained in the “High Investment” scenario.

4.4 Results

The results for the base case are given in Table 4.2; all numbers are expressed in £/GJ at 2010 prices. A range of estimates are presented because of the difficulty of determining current market prices (i.e. in 2010). In the case of wood pellets, prices estimates are given for pellets supplied in bulk and bagged to represent different users – largely expected to be in the heat sector, as well as an overall price, which is the average of these two. In the case of wood chip prices, we provide estimates of both commercial/industrial heat sector prices and domestic heat sector prices. These alternative prices are estimated by assuming that current price differentials are maintained by the market throughout the forecast period. It is however possible for the user to relax this assumption in the model if so required.

In the base case, wood pellet and wood chip prices rise by just under 10% in real terms between 2010 and 2020. After 2020, prices level out and remain roughly unchanged in real terms. This is because the price of the underlying feedstock, other energy prices and the overall demand for energy are forecast to grow only slowly. In particular, prices of underlying feedstocks grow more slowly than price inflation as a whole. While this has generally been the case for the last few decades, this may prove to be an overly conservative assumption in the future if the demand for this feedstock both for bio-energy and other uses continues to rise strongly.

The price differential between biomass and other forms of energy remains roughly constant overtime in real terms. This may be considered surprising, given how low bio-energy prices currently are when compared to other energy prices. This result occurs because bio-energy prices have so far been driven much more by their feedstock prices than they have by other energy prices. However, it is possible that as bio-energy becomes a closer substitute for other forms of energy then prices may move closer to other energy prices. Of course if this does take place then it may also have a downward effect on other energy prices.

Table 4.2 Bioenergy price forecasts for wood pellets (£/GJ) *2010 prices*

	Current			2020				2030			
	Low	Central	High	Low	Central	High	Very High	Low	Central	High	Very high
Bulk	11	12	13	12	13	15	17	11	13	15	18
Bagged	13	15	17	15	17	19	21	13	16	19	23
Overall	12	14	16	14	15	18	20	12	15	18	21

Table 4.2b Bioenergy price forecasts for wood chips (£/GJ) *2010 prices*

	Current			2020				2030		
	Low	Central	High	Low	Central	High	Very High	Low	Central	High
Domestic (inc. VAT)	6	7	9	6	7	10	11	6	8	11
Industrial/ commercial (exc. VAT)	4	6	7	5	6	7.5	8	5	6	8

Table 4.2c Biofuel price forecasts (£/GJ) *2010 prices*

	Current	2020			2030			
		Low	Central	High	Low	Central	High	Very High
Biodiesel	24	27	28	30	23	27	31	48
Bioethanol	16	14	15	16	12	13	16	23

Source: Oxford Economics

Prices in the alternative scenarios are impacted by a number of factors that in some cases have a partially offsetting impact on the price forecasts. The scenarios then should be seen as a range of alternative forecasts rather than a simulation of the impact of changing a single assumption. However, it is easily possibly to conduct such simulations on the model. The forecast numbers from the alternative scenario are presented in Table 4.3

Table 4.3 Assumptions used to create the Alternative Scenarios

	Per annum change from base (%)		
	Biomass supply	Energy demand	Other energy prices
Scenario:			
High Development	0.2	0.75	1.00
Low development	-0.10	-0.50	-0.75
Very high energy growth		1.5	

Source: Oxford Economics

Low development scenario – In this scenario investment in biomass production is considerably lower than in the central case. This in isolation might be expected to restrict the supply of biomass and so raise prices. However, the low development is assumed to occur in part because global economic and global energy demand is lower (by about 0.5% a year) when compared to the central case. As a result the level of total global energy demand is assumed to be about 5% lower in 2020 when compared with the central case. The overall effect is for the level of biomass prices to be about 16% lower by 2020 (in real terms) than they are in the central case. Prices of wood pellets and wood chips are forecast to rise by about 6-7% in this scenario between 2010 and 2020.

High Investment scenario – In this scenario investment in biomass production is considerably higher than in the base case. This by itself might be expected to increase the supply of biomass and so lower prices. However, the high investment is assumed to occur in part because global economic and global energy demand is more buoyant (by about 0.75% a year) than in the central case. The overall effect then is for biomass prices to be about 15% higher in this scenario by 2020 than they are in the central case. Prices are forecast to rise by about 12-13% in this scenario between 2010 and 2020.

Very high energy demand – This scenario is a variant on the previously described high investment scenario. It models the same levels of investment in biomass but it has higher demand for biomass energy (consistent with the high biomass demand scenario in the biomass supply modelling). It also has stronger global economic growth and so higher total energy demand (1.5% pa when compared to the central case). This is the scenario in which biomass prices are at their highest level. In this scenario biomass prices are about 27% higher by 2020 than they are in the central forecast. Here prices are forecast to rise by about 25% between 2010 and 2020.

4.5 Prices for Large Scale Electricity

The price analysis developed above is for traded biomass products, and applicable largely to the heat sector. The large scale electricity sector is different because it is not transparent as many contracts are negotiated directly between power generators and suppliers so there is no open market for many of these trades. Analysis was undertaken of this market, based on existing academic literature, information on agricultural prices, price collection services as well as information provided by suppliers and generators.

Prices for biomass in the large scale electricity sector vary by feedstock and depend on factors such as processing and handling costs, transport, storage, contract conditions and exchange rate fluctuations. Our analysis suggests a spread of current prices in this sector as follows:

Table 4.4 Current prices for biomass fuels in the large scale electricity sector (prices delivered to power station gate)

2010 prices £/GJ	Low prices	Mid prices	High prices
Prices for large scale power generators			
UK wood feedstocks	6	7	8
Imported wood feedstock	7.5	8.5	10
Energy crops	3.5	7	8
Agricultural residues (UK)	0.5	2.5	4.5
Mixed solid wastes	-12	-8	-4
Waste wood	-2	1	3
Solid recovered fuel (SRF)	-6	-2	1
Wet feedstocks for anaerobic digestion	-10.5	5	11

Notes

Source: Endex, Argus Media, EUBionet III, The UK Forestry Commission, WRAP; and discussions with suppliers and users in the heat and large-scale power sector.

[1] Includes price of transport to plant and processing for use. Lowest prices are for chips; higher prices are for processed fuels such as wood pellets. Prices are from generators, EUbionet III (2010), Argus Media (2010), Endex (2010), and AEA own information.

[2] This covers a range of different feedstocks: higher prices cover costs of pelleting for co-firing, central prices reflect straw products and lower prices chicken litter.

[3] Assumes calorific value of 9GJ/t. All prices are negative to represent gate fees. High price represents more recent incineration facilities. Medium price is between that for old and new facilities. The prices vary because the prices for the more recent incinerators include the higher capital and development costs of these facilities. For new facilities WRAP gives a medium price of £10.2/GJ. None of these prices include hazardous waste. Figures are from AEA experience and WRAP (2010).

[4] Waste wood prices depend on grade of waste wood (i.e. level of contamination in wood).

[5] Unlikely to achieve positive price at present in UK as there is no ready market in UK. Figures assume calorific value of ~12GJ/t, although the calorific value could be as high as 16-19GJ/t for some SRF. Figures are estimated AEA experience on cost of producing SRF and likely market for the residue rather than real market prices.

[6] The large range of prices for wet feedstocks for anaerobic digestion is due to the range of feedstocks available. The prices range from gate fees for food waste to prices for slurries that include the transport of these slurries to a central plant. The prices also include the cost of growing energy crops such as maize for some plants. As the way in which AD will be adopted across the UK is not yet clear we have included the range of prices. However, it is likely that developers could treat a range of these feedstocks in any one plant.

The prices provided in Table 4.4 are based on prices seen in the market in 2010. Box 4.1 discusses these in the context of the price analysis undertaken to examine the impact of price on constraints in Section 3.

Box 4.1 Comment on price ranges used for the constraints analysis in the context of actual prices for biomass feedstocks.

To examine the impact of price dependent constraints, a price range of £4/GJ, £6/GJ and £/10/GJ was used to assess potential availability for all of the biomass fuels considered. These prices were used to illustrate what might happen to supply if users were willing to pay a higher price for the fuel.

For virgin biomass fuels (such as wood chips and pellets, agricultural residues),energy crops and imports this range is realistic in view of current market prices shown in Table 4.4. For some of the residues, £4/GJ is sufficiently attractive for access to the whole resource.

The same price range was applied for mixed waste fuels to understand the impact of investment on availability. Because users generally receive a disposal fee for such fuels, as is indicated in Table 4.4, the price of £4/GJ provides an indication of how much of the waste resource is available at negative or low prices. The £6/GJ and £10/GJ levels examine how much additional resource could be pulled out of the waste stream should there be investment in the infrastructure to enable more waste to be accessed for energy technologies. Such investments might include additional segregation technologies, source separation schemes and transport for wet wastes. More detail on this approach is provided in the Annex report.

Commentary and Trends

Our analysis shows that the current market for biomass products is disparate, with prices varying by feedstock, processing and transport costs, and ability of generators to secure long-term contracts. Therefore the market is characterised by a range of prices, and generators may hold different supply contracts with different prices at any given time. This has made the analysis of prices difficult and means that it is more sensible to think of ranges of prices rather than a single estimate.

As the above table shows there is a clear distinction between prices for waste products and other biomass, with prices for the former being driven by gate fees. Gate fees vary geographically, by type and grade of waste, and by demand and supply of the waste feedstock. Prices will also depend on landfill tax and the gate fee for incineration. Recent increased demand for example for waste wood from the energy sector and by other sectors that take re-processed wood, have resulted in lower gate fees and, at the high end, to positive prices.

Our analysis found the following key trends in this market:

- Biomass power plants currently being planned are increasing in size, which means that the fuel cannot all be obtained on the spot market. This means that feedstocks are likely to be purchased through bilateral contracts with suppliers around the world. This means the generators negotiate prices on a year by year basis within the terms of the contract. This supply is likely to be delivered in bulk, generally implying they are able to purchase supplies at lower prices than heat users. Power generators have indicated that they access biomass across a range of markets, UK and imported.

- Larger power generators may be in a position to develop their own supply e.g. through investment in local farms, developing plantations abroad, negotiating with farmer co-operatives or forming joint ventures with processing and supply companies. This investment is aimed at securing long term supplies, rather than focused on de-risking prices alone.

- Long-term contracts increase security of supply, but many suppliers are reluctant to sign fixed price contracts because this exposes them to long term risks, particularly related to changes in their costs or opportunities, which may not be recognised in the contract. Negotiation of long term contracts is essentially negotiation of mitigation of risk for both the supplier and generator; and this increases the price. It is more likely that parties will negotiate an upper and lower limit to supply prices to provide certainty regarding the range of price, but that prices will be negotiated on an annual basis, subject to some type of price indexation, which may be simply related to the RPI; or it could take a variety of factors such as general energy price, foreign exchange factors, RPI in various regions etc. This reflects the type of contract in use in for raw material the paper and pulp sector.

- Many biomass feedstocks are produced by labour and energy intensive processes and therefore the cost of production is influenced by the cost of labour and energy. However, feedback from electricity generators is that the effect of logistics – processing, transport/shipping and storage – has an even bigger impact on prices. In addition, for some regions there are political risks – for example the decision by Russia to impose tariffs on unprocessed timber exports.

- For large-scale users who can take advantage of waste wood fuels prices are likely to be low or negative, but they may face additional costs in ensuring their plants meet Waste Incineration Directive requirements. Waste fuels (such as solid recovered fuels) are likely to be available at much lower prices (i.e. at a gate fee) but will require considerable investment in preparation and emissions clean up.

- Small scale power generators taking local supply only may have access to feedstock at low prices. For example, anaerobic digestion plant designed to treat wastes or residue feedstocks available at low or negative prices. In this case the major costs facing developers is the high capital cost rather than the fuel supply.

- Theoretical estimates for energy crops put supply in the range of £3.0 - £5/GJ (e.g. Nix 2011), but the perceived risk constraints need to be overcome. This price would make them attractive to small, medium and large-scale users, although for small-scale users who require processing of the fuels into pellets, prices would be higher to reflect the cost of additional processing (by an additional £1/GJ).

Future Trends

The way in which this market develops in the future is difficult to predict. If the market becomes more transparent and competitive, with several different biomass sources essentially becoming substitutes, then it is possible that the market will develop towards one that looks more like the traded market for chips and pellets discussed in 1.3 above, rather than the current situation described above. If this happens then future prices will be more driven by demand and supply fundamentals, and possibly linked to fossil fuel prices. This is likely to mean rising future prices, a view supported by generators who were consulted in this work. This view is based this on potential increases in demand for biomass globally and the cost of developing the resource for the international market.

Waste wood re-processors are predicting that prices will increase and that gate fees could become a thing of the past. This is because of the level of demand for the cleaner grades of waste wood. Even if more waste wood could be taken out of the mixed waste sector, there is a finite source of waste wood in the UK which means that there will eventually be a limit to supply. Generally the sector expects this price to rise to around £3/GJ.

Mixed waste gate fees for incineration are generally increasing related to the landfill tax and to increased capital costs. The trend towards processing of waste for recycling and recovery means that there will be increasing quantities of residues for which there is no alternative to energy recovery. These residues are termed solid recovered fuel (SRF) and there is a very limited market for SRF in the UK at present. However, if the UK follows German experience plants that burn SRF may be build, particularly if the biomass content of the input fuel can be demonstrated to be more than 90% of the calorific value, making it eligible for ROCs.

5 Conclusions

This report examines potential biomass supply in the UK to 2030, both from UK feedstocks and imported feedstocks. It examines the impact that supply side issues have in constraining the available resource, but does not consider constraints on the conversion and use of biomass. Global supply was considered under 3 scenarios: business as usual; high investment; and low development.

Key findings of this analysis are:

1. A wide range of feedstocks make up the potential UK resource. These include wood, crop and waste resources representing a range of chemical and physical characteristics that will need to be taken into account in their exploitation.
2. By 2020, the UK could have access to about 1,800 PJ of bioenergy supply; this is equivalent to 20% of current primary energy demand in the UK,[18] and would meet the level of demand estimated in the UK Renewable Energy Strategy (DECC 2009). This estimate of supply is based on a price of £10/GJ for biomass feedstocks, assuming that all easy and medium constraints identified for UK feedstocks have been overcome, and a 'business as usual scenario' for international supply (with a 'reference' global demand for bioenergy). By 2030, mainly due to the development of energy crops globally, supply could rise substantially to between 4,800 and 6,700 PJ, or between a half and three-quarters of current primary energy demand in the UK. The range is due to assumptions about whether the production of energy crops or of 1G biofuels is maximised.
3. UK feedstocks provide about one-third of potential bioenergy supply in 2020, but by 2030 this has fallen to 10% due to the large increase in the international supply. The increase in bioenergy supply over time is mainly due to more ex-agricultural land becoming available, which allows the planting of energy crops and 1G bio fuels feedstocks. However developments in infrastructure and the biomass market, which allow more of the potential resources to reach the market, also contribute to the increase. There is a reduction in biofuels supply by 2020, because only some biofuels production is likely to meet the greenhouse gas saving criteria set in the Renewable Energy Directive (RED) for 2017.
4. These levels of supply are dependent on the development of energy crops both in the UK and abroad and the import of a significant quantity of biomass to the UK, most notably energy crops, but also wood from the forestry sector, agricultural residues, and biofuels (either as finished fuels or as feedstocks). For the biofuels, it is also dependent on the development of sufficient supplies that meet the sustainability requirements included in the RED. To achieve this supply will require considerable investment in land, crop development and equipment. A stable investment environment will be necessary to achieve this.
5. Our analysis shows that a number of constraints could significantly restrict the supply of biomass both within the UK and internationally. Higher prices for biomass will overcome some constraints and that time will address others, but there are intransigent issues that remain very hard to address, particularly terrain and location issues. This means that any analysis based on potential supply alone, without taking constraints into consideration, may be misleading in the amount of bioenergy that can be achieved.
6. Different end use sectors (heat, electricity and biofuels, small, medium and large-scale) have different feedstock specifications and purchasing strategies. They also differ in their need for, and ability to invest in the infrastructure for storage, processing and handling biomass. This means that, although there may be some competition for the raw feedstock, different sectors have different abilities to control the price they pay. This results in sectors experiencing different market conditions. For example, small scale users tend to use logs, pelleted, or bracketed fuels, purchased on the spot market in relatively small quantities, which can expose this sector to high prices (often over £8/GJ). Larger-scale users have more access to long – term contracts, bulk purchase and the ability to use less processed feedstocks, all of which lowers the price per tonne (to £4-£8/GJ for some large scale users). At large-scale users may also be able to use plant with more flexible feedstock specifications. This difference is important to the level of uptake of biomass in the UK.

[18] Primary energy demand in the UK in 2009 was 9,211 PJ (Digest of UK Energy Statistics, 2010)

7. There are interactions between the UK and the international market which become more significant when either suppliers or users can access this market. There are already established international markets in biofuels and pellet fuels and these markets tend to influence the price in the UK market for these fuels. While at present, bulk purchases by large end users are typically done under bilateral contracts with the supply, we consider that in time international trade is also likely to dominate this bulk purchase market and that prices seen in the UK will be set by the international market. Thus international demand will influence the availability and price of biomass used in the UK.

Further details on these key conclusions are:

8. Analysis of constraints within the UK shows that several key constraints have a significant impact on supply and it will be important to address these if we are to optimise supply. The most significant constraints on supply are:
    a. Infrastructure for (and the cost of) drying, transport and processing of feedstocks. Increased prices would allow for this investment.
    b. Policy uncertainty, which is a key constraint for all bioenergy sectors. This applies not just to support for renewable energy but also to other environmental and agricultural policies. For example, it is not certain what impact the use of land for energy crops may have on Environmental Stewardship for farmers; and uncertainties related to the definition of a feedstock as a waste continues to be important for the cost of developing some waste derived fuels.
    c. Perception of risk, which affects bioenergy plant development, notably project finance (both obtaining finance and the interest charged) can be a significant constraint.
    d. Perception of risk is also important for farmers and the forestry sector. This relates to market dominance by a few key players and the need for considerable upfront investment in some cases. The experience of farmers in other markets influences these perceptions. Developers of plants need to take these concerns seriously and take steps to address them.
9. In addition to the above constraints, we identified a number of threats to the UK supply:
    a. Rises in demand for biomass resources for competing uses;
    b. Growing concerns about sustainability;
    c. Rises in bioenergy targets overseas

    There is a need to be aware of these developments and their impact on UK bioenergy supplies
10. There are potential conflicts between the use of biomass for heat and power and their use for biofuels:
    a. The feedstocks used for the heat and power sectors and the biofuels sector are currently different, but there are potential conflicts in land use for energy crops or first generation biofuels. In our analysis we have compared maximum use of available land for energy crops with maximum use for 1G crops. The analysis shows that in *primary* energy terms the energy potential is greater if the land is planted with energy crops. However, energy crops represent a considerable investment and risk to the farmer; and the planting of crops that could be used for biofuels appear to represent lower risk to the agricultural sector (depending on demand side issues).
    b. The situation is further complicated by the development of second generation/advanced biofuels after 2020. This would result in lignocellulose resources (such as wood or agricultural residues) becoming suitable feedstock for transport biofuels, as well as heat and power and could result in competition between sectors for feedstock.

    Our analysis does not address these conflicts. Further work is needed to understand which is the best use for specific resources.
11. Energy crops represent a significant part of the bioenergy resource, both in the UK supply and internationally – over 85% of the international wood based resource is estimated to come from energy crops in 2030 and 11-28% of the total UK resource is estimated to be energy crops in

2030. However, there is little sign of wide scale planting in the UK or abroad at present. There is a need to monitor the development of this resource given its importance in overall supply.

12. In assessing the availability of land for bioenergy crops (woody energy crops and first generation biofuels feedstocks -oil, sugar and starch crops) in the UK and overseas we assumed that land currently used for food (and feed) production will not be available for bioenergy crops. Only land released from agricultural production as yields increase (which means that less land would be needed to meet food and feed demands) is assumed to be available for bioenergy planting. This means our estimates of energy crops and 1G crops for 2030 is dependent on yields for food and feed crops improving and increasing land availability for bioenergy crops.

13. A new resource being explored in the UK is short rotation forestry (SRF). The potential of SRF is not well understood at present, particularly the investment required; environmental impacts; growing conditions; and yields, although trials are ongoing. Further information is needed on these aspects of short rotation forestry. SRF is a potentially important source of biomass, but it is also a long term crop, with rotations of up to 20 years, that will not be developed unless there is long term stable investment environment in place to support its use.

14. There is a need to be aware of international developments and their impact on the UK market:

    a. The UK will be one of a number of countries importing biomass and there will be competition in the international market. We have taken this into account by assuming that only 10% of biomass potentially available in this international market would be available to the UK.[19] We have assumed that in country demand and alternative uses for biomass will be met first before biomass is supplied for energy. The results show that, providing energy crops can be developed, there will be adequate resource available to the UK to meet its demands by 2030 and particularly so under the high investment scenarios examined. In practice it is likely that demand for energy and non-energy uses of biomass will complete with each other.

    b. The market for chips and pellets is still immature and sensitive to short term supply side shortages or periods of high demand. Current estimates of future demand show that there is considerable potential for increased demand for biomass in the EU over the next five to seven years. The impact of this is difficult to predict. This could lead to sudden increases in demand and prices, at least in the short term that affect the whole market in Europe and may affect the quality of the fuels supplied.

15. Not all biomass supply is directly substitutable in all conversion plants. For example, some technologies, such as anaerobic digestion, biofuels plants and biomass combustion plant are designed to take specific types of biomass, and have tight specifications with regard to composition, particle size and dry matter content of the feedstock. Thus the type of biomass resource needs to be matched with particular conversion pathways suitable for that product

16. The development of anaerobic digestion (AD) is important to the use of wet biomass resources that are expensive to dry and transport. It may also be an important technology for the organic fraction of solid waste. In addition, there is currently increased interest in the potential to inject upgraded biomethane into the gas grid. However, there are a number of constraints on the development of AD in the UK, including cost and the wide dispersion of many of the potential feedstocks. Studies have indicated that for medium AD scale plants there remain important constraints relating to integration with the energy network. These include the development of cost effective upgrading plant for methane injection to the grid or the cost of power connection for biogas power generators. Although these are not supply side constraints, for AD development of the supply is closely integrated with the development of local plants to take the feedstock.

17. There are considerable uncertainties in the assessment of future bio-energy resource and prices. Therefore we developed a scenario based approach under which key insights into

[19] The 10% figure is based on examination of the modelling results that indicate that in the time period being considered, the EU is both one of the regions with the highest demand for biomass, and also that it will need to import significant amounts of biomass to meet this demand. We therefore believe that the EU is likely to be one of the key players in the international biomass market in this time period and that the UK will be competing with other EU countries to secure biomass supply. Overall the UK accounts for about 10% of EU energy demand and this value has therefore been chosen to allow an estimation of how much biomass supply the UK might secure. This situation could change if other regions increase their biomass demand.

drivers and constraints to future supply can be derived. The estimation of the impact of constraints examined in this report is a matter of expert judgement and there is uncertainty associate with these figures. All estimates should be used as a guide based on particular assumptions rather than precise forecasts.

18. The bio-energy price model uses economic theory to model and forecast UK bio-energy prices. A key constraint on the accuracy of both the modelling itself and the results that it produces is that data in this area is very limited. The model attempts to make the best possible use of existing information and as such the forecasts can be seen as a good guide to future price developments. However, it is possible that the conclusions may have to be revised as better information becomes available.
19. The model suggests that in future biomass prices are likely to move more in line with the prices of other energy sources than they have in the past. However, some differences will continue to be observed as biomass prices will be influenced by factors that are unlikely to impact on other energy prices, such as changes in the price of agricultural feedstock. Moreover, bioenergy is likely to continue to offer a price discount compared to other energy sources.
20. Price forecasts have been provided for a range of scenarios. In the base case wood pellet and wood chip prices rise by just under 10% in real terms between 2010 and 2020, and then remain roughly unchanged in real terms. This is because the price of the underlying feedstock, other energy prices and the overall demand for energy are forecast to grow only slowly. In particular prices of underlying feedstocks grow more slowly than price inflation as a whole. The price differential between biomass and other forms of energy remains roughly constant overtime in real terms.
21. Prices in the alternative scenarios are impacted by a number of factors that in some cases have a partially offsetting impact on the price forecasts. The scenarios then should be seen as a range of alternative forecasts rather than a simulation of the impact of changing a single assumption.
22. There is considerable variation in biomass price:
    a. Prices vary considerably depending on the time of the year the purchase is made, the growth in demand for the fuel and the amount of biomass purchased (i.e. whether it is bagged or bought in bulk). Bulk supplies often come on a discount compared to bagged fuel. Thus **there is no one biomass price, but a range of prices** within the market place, complicating calculations of the cost of bioenergy. Lower prices (in our case modelled as £4/GJ) tend to be for bulk delivery of chips. The cost of pelleting and bagging increases the price for biomass and means that pellets tend to be available only at much higher prices (often £10/GJ delivered or more).
    b. Different sectors of the biomass market use different biomass resources. For example, the small and commercial heat sector tends to use prepared wood fuels (chips, pellets and logs for the domestic market). Large-scale power generation can be more flexible: plants in operation use solid waste fuels, agricultural residues and wood fuels. The co-firing sector is the most flexible at present. Many plant operators co-fire a variety of fuels, depending on what is available. This means that some plant operators are restricted to specific fuels; and others can substitute fuels depending on price and availability. Consequently the domestic sector, using logs and pellets bought on the spot market, faces high prices and greater uncertainty than large-scale power generation, where plant operators can sign long term supply contracts and buy in bulk, often with the flexibility to buy at times of the year when supplies are cheaper. Commercial plant operators, such as local authority and hospital CHP operators generally sign long-term supply contracts and probably see prices between the high domestic and lower large-scale power supply contracts. This **difference in ability to access feedstock at different prices means that different sectors will be faced with different costs**.

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6.1.1 References

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Appendices

Appendix 1
Summary of differences between E4Tech results (E4Tech 2008) and our results

Summary of the difference between the results presented in E4Tech (2010) and the results presented here for the UK only.

E4Tech (2010) examined the technical potential for biomass feedstocks for the UK. This is where our report starts, but we then derive availability under different constraints. The table below discusses any difference between our results and £4Tech (2010). However, some of their estimates (reasonably) subtract existing (competing) uses from the resource, so a true comparison between our unconstrained resource and their technical potential is not always possible.

Feedstock	E4Tech estimate (PJ)	Our estimate (PJ) – Available resource for 2030	Reason for difference
Agricultural residues	69	Unconstrained resource: 211 Available resource 113	E4Tech resource refers to straw resource only. Our resource includes straw, seed hulls and husks and chicken litter. (Note: Our estimate for straw available resource is 84.4PJ: the difference could be partially explained because we estimated the resource by pooling results from a number of sources and then made specific assumptions regarding the sensitivity of competing use to price, which may have been different to E4Tech's assumptions).
Forest residues	19 (2020)	18	
Small round wood	4.5 (2010) to 17.5 (2020)	Unconstrained resource: 63 Accessible resource: 58	In this work Forest Research resource estimates were used as unconstrained resource. E4Tech used data from Forestry Commission softwood forecast (2005) plus pers comm from the Forestry Commission and subtracted existing uses. There is no quoted available (unconstrained resource). When our figures are constrained there is an estimated resource between 3 and 28PJ in 2010 rising to 11-31PJ in 2030. This indicates that our constrained resources are in the same range as E4Tech's competition constrained resource.
Arboricultural arisings	6.1 to 7.8 in 2020	Unconstrained resource: 44 (2010) to 50 in 2030.	We used recently updated estimates (ADAS (2008)), which consider a greater potential resource (road side verges and urban open spaces) not included in the sources available to E4Tech.
Sawmill residues	2.4 (2008) to 19.5 (2020)	Unconstrained resource: 30	E4Tech used earlier set (2008) and included competition in their resource. Our constrained resource is 13-21PJ (2010) rising to 16-21PJ in 2030, which is in line with E4Tech's estimates.
Short rotation forestry	Not included	Unconstrained resource: 0	Forest Research figures.

		(2010) to 15 (2030)	
Energy Crops	Not given. Discussed in terms of land area planted only.	Resource in 2030, 75.9-282.15PJ	Resource dependent on land availability assumptions. We assumed 296-1100 kha available in 2030; E4Tech assumed 4 scenarios ranging from: 634kha (2008)-2534kha (2030) available and 1083-2213kha planted (constrained by planting rate).
Wet manures	4.2 (2008) – 91.9 (2030)	Unconstrained resource: 25 Accessible potential: 23-24	Unable to explain difference
Sewage sludge	15.2 (2008) – 24.6 (2030)	Unconstrained resource: 14-16 Accessible resource: 13 (2010) – 15 (2030)	We assume higher growth rate for sewage sludge production, but that less is treated by anaerobic digestion. Overall this results in a lower estimate of available resource. Other differences may lie in the assumed methane yield; and because we have assumed that some treatment works are too remote and small to support anaerobic digestion.
Food and green waste	50 (food waste only)	Unconstrained: 80; Accessible resource: 63	Our estimates based on updated data, which shows that there may be greater quantities of food waste than E4Tech predicted. Garden waste accounted for 9PJ, of which 90% is assumed to be achievable by 2030. Our constrained resource is 19-46PJ in 2030.
Waste wood	19 (2008) to 149 (2030)	Unconstrained resource: 85.3 Available resource: 67	Our figures come from updated WRAP (2009) and Defra (2009) reports. These provide lower estimates for total wood waste arisings based on discussions with the wood reprocessing industry and with suppliers of waste wood. These have resulted in our decreased resources for 2030.
Landfill gas	63 (2008) to 15 (2030)	Unconstrained resource: 235 (2010) - 243 (2030) Constrained resource: 166 (2010) - 69 (2030)	Difficult to explain differences as E4Tech's calculations were not provided. 2008 estimate is current LFG usage, not available resource. They assume no new gas capture and no sites currently flaring LFG switch to energy generation. They also assumed that no new waste would be landfilled from 2008. These assumptions were to prevent double counting of the biodegradable resource. We have divided the waste resource into the fractions that are likely to go to the different options, including recycling, incineration and anaerobic digestion. In addition we have assumed that landfilling of biodegradable waste will only decrease in line with Government targets, which means that we assume that there will continue to be a new landfill gas resource generated for some time, in contrast to E4Tech.
Renewable content of solid waste	40	Unconstrained resource: 330 (2010) – 342 (2030) Available resource 35 (2010) to 70 (2030)	Constrained resource potential: 12-17 PJ in 2010 rising to 35-42PJ in 2030. Our results are based on residue available for energy from waste. The available resource includes the likely rise in recycling and other recovery to 2030. E4Tech results represent the energy content of the relevant fractions of MSW. These figures appear to take recycling into account, but the exact calculations are not provided.

Appendix 2 Summary of factors considered in International Biomass Demand

This appendix provides more information on the feedstock considered for global supply. The Table below provides information on the characteristics of the market. This is then considered further in terms of international demand for these feedstocks.

Characteristics of current market for international feedstocks.

Biomass Feedstock	Characteristics of current market
Forestry feedstock (residues, small stem wood, chips and pellets)	Wood feedstocks available for energy are often associated with (and dependent on) the established market for timber and pulp, in which there are established traders and key players. Bioenergy feedstock is the lowest value product produced in forestry and some suppliers claim to make poor margins from fuel (or a loss). It is unlikely that forests will be felled for energy demand alone in the near future. Thus, globally traded wood fuels are, on the whole, currently produced as a by-product of the established wood product market and dependent on it. In our analysis we have used results from the Forest Research Carbine model, which assumes historic trends continue in the future. If bioenergy demand becomes sufficient this situation may change and plantations may be established for the production of bioenergy feedstock as a primary market, but this is not explicitly considered in our model, beyond any predictions built into the Forest Research Carbine model. Trade in chips and pellets are treated as a sub-set of the overall biomass resource available from forestry and forestry residues and we do not consider them separately in the supply-constraint analysis. Note: The development of wood biomass in the future will be linked to demand for wood, which is likely to increase in the future, particularly in the emerging economies. There is a potential to increase plantations to meet these demands e.g. in Australia, where there is a history of establishing new plantations to meet demand for chip and pulp in the Chinese and Japanese markets. The Asian markets will be important in determining the availability of wood resource from this region of the world. We have used assumptions in Carbine, which are based on historic trends and do not assume a growth in plantations or forestry beyond these trends.
Agricultural residues	Agricultural residues traded for bioenergy are associated with the production of other agricultural products such as oil, food, feed and ethanol. The availability of these resources is a function of crop planted, harvest, climatic conditions and agricultural processing. Much of the resource is widely dispersed and the quality is liable to deteriorate rapidly. In addition existing uses present significant competition. Many agricultural residues have established markets in the animal feed sector or as feedstock for other agricultural commodities. Trade is often dominated by a few key players and supply may be constrained by annual harvests. In our analysis we assumed that the animal feed market dominates international trade and takes precedent over international bioenergy trade in agricultural residues. Thus the international supply of bioenergy feedstock from agricultural residues is the residual of what is left after local use and demand for feed. There is a large amount of DDGS produced by bioethanol production, which may be used as an animal feed (the USA exports some 1Mt/y of these residues to the European feed market). We have not included this in our analysis. In the future this may be used for second generation biofuels, but it is not included here. The use of agricultural residues for bioenergy is increasing rapidly in some countries (O'Connell *et al* 2009). We have anticipated this in our analysis.
Biofuels	The development of an international biofuels market is relatively new and

	dominated by a few countries. However, more countries are examining biofuels potential and more biofuels production is likely to be stimulated as the market develops. In this analysis we consider that many countries will produce biofuels for internal use only and that the main international market will continue to be dominated by a few key players (although more than at present). We have only considered the production of these countries as available for international trade. Demand for biofuels was taken from the IEA WEO analysis (2009).
Energy Crops	Although they show much promise and there is a lot of interest at national level in energy crops in a number of countries, there is very little established energy crop at present. Consequently for this analysis we have relied on estimates of potential land availability for energy crop production available in the literature and looked at constraints on the availability of this land as well as the constraints preventing bioenergy crops being planted. Energy crops are also likely to be constrained by the ability of the agricultural sector to establish the crops, which is dependent on availability of planting material (e.g. rhizomes for some energy grasses or suitable cuttings for wood energy crops) and the availability of planting machinery. These constrain the establishment of energy crops significantly at the moment, but their development could be accelerated in the future. Information about the planting rates assumed in each scenario is given in Section 2.2.3, with detailed information supplied in the Annex report.

Biomass is expensive to produce, collect, harvest and store. In general it is not produced without an established market for the output. The Table below summarises the demand for energy from biomass; some of the feedstocks of interest to energy are also used for animal feed, timber, pulp and paper. These established markets have been taken into account in our model.

Summary of international biomass demand

Column 1 shows whether there is a RE target, obligation or grant system.

Column 2 if there is a biomass heat and power target, mandate or grant system. A bracket represents development of a policy or a related policy or programme; or, on a regional basis that some countries within the region have policies, but not all of them do.

Column 3 if there are biofuels mandates

Column 4 shows the current status of biomass use: low (i.e. very little used); Dom only (cook stoves and domestic heat only); Agri-ind (agricultural /processing residues dominant); sig: significant (current high level of use or programme of stable increase, including power, heat or CHP); rapid: rapid increase (programme of rapid increase above significant).

Column 5 shows the current status of biofuels use: none; low (i.e. very little used); significant (current use is significant proportion of fuel use); increase (programme of stable increase); rapid is rapid increase (programme of rapid increase above significant).

Column 6 shows what the key sources of biomass in the region are at present or are being planned: wood from forestry and processing (wfp), agricultural and food processing residues (ag), crops (c), waste (w), biogas (AD), fuel wood for domestic use (dom); all = all of the above.

Column 7 shows whether or not the region is net import, net export or reliant on own biomass only. Sig (meaning significant) is included if the region is a major player.

Region	RE policy	Biomass heat and/or ?	Biofuels mandate ?	Biomass use	Biofuel use	Key biomass used	Net import/ export?
USA		•	•	Rapid	Rapid	All, particularly WFP and AD.	Export
Canada	•		•	? Significant	Increase	WFP, AG, AD	Sig. Net export
Mexico		•		Significant growth	low	AG	Self reliant.
EU	•	•	•	Rapid	Increase	All	Sig. Net import
Eastern Europe	(•)	(•)	(•)	Agri-ind	Low	WFP, Ag, C	Net export
Russia			(•)	Dom	Low	Dom	Sig. Net export
Brazil			•	Agri-ind/Dom	Significant/rapid	Agri-Ind, Dom, WFP, C	Sig. Net export
Other central and South America		(•)	•	Agri-ind/Dom	Rapid	Agri-Ind, Dom, WFP, C	Sig. Net export
Middle East	•		(•)	Dom only	Low	W	Neither.
North Africa	•			Dom only (Agri ind?)	Low	? (Agri-ind)	Neither.
Sub Saharan Africa	(•)		(•)	Dom/Agri-Ind	Low/increase	Agri-Ind, Dom, WFP, C	Self reliant/sig.net export
China	•	•	•	Rapid	Increase/Rapid	All	Net import
Indonesia and Malaysia	•	•	•	Agri-Ind/Dom.	Rapid	Agri-Ind, Dom, C	Net export
India	•	•	•	Rapid	Rapid	All	Self reliant
Other Asia	(•)	(•)	•	Agri-Ind/Dom	Increase/rapid	Agri-Ind, Dom, WFP, C	Self reliant.
Japan	•	•	•	Agri-Ind	Low	Agri-Ind, W, WFP.	Self reliant/net import.
Australia and New Zealand.	•		•	Increase	Increase.	WFP, Agri-Ind, C, W, AD	Net export.

Notes: *Further information on the specific growth of bioenergy is available from REN21 (2010); Spelter and Toth (2009) outline the growth in pellet production and demand in North America; Egger and Oehlinger (2009) outline pellet production and demand in Europe; and Pöyry (2009) provide predictions of global demand in wood pellets to 24Mt by 2015.*

Appendix 3 Summary of results for UK biomass supply showing two land use scenarios (first generation biofuels maximised and energy crops maximised).

Summary of results for UK bioenergy feedstocks showing two land use scenarios (first generation biofuels maximised and energy crops maximised).

Scenario: 1G feedstocks maximised

	Bioenergy feedstock	Constrained potential at £4/GJ (PJ)					Constrained potential at £4/GJ - Overcoming Easy constraints (PJ)					Constrained potential at £4/GJ - Overcoming Medium Constraints (PJ)					Constrained potential at £4/GJ - Overcoming all Constraints (PJ)				
		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
£4/GJ	Bioenergy	279	320	350	352	391	381	393	398	390	420	470	473	465	454	483	641	665	671	682	680
	Biofuels	16	28	41	53	66	44	52	61	73	85	58	67	75	84	93	68	77	84	93	100
	Total	***295***	***347***	***391***	***406***	***457***	***425***	***446***	***459***	***463***	***505***	***528***	***540***	***540***	***538***	***576***	***709***	***742***	***755***	***774***	***780***

Scenario: Energy crops maximised

	Bioenergy feedstock	Constrained potential at £4/GJ (PJ)					Constrained potential at £4/GJ - Overcoming Easy constraints (PJ)					Constrained potential at £4/GJ - Overcoming Medium Constraints (PJ)					Constrained potential at £4/GJ - Overcoming all Constraints (PJ)				
		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
£4/GJ	Bioenergy	279	320	350	352	391	381	393	398	390	420	470	473	465	455	486	641	665	671	695	835
	Biofuels	12	17	23	27	31	32	34	36	38	41	42	42	42	43	43	48	48	48	48	48
	Total	***291***	***337***	***373***	***379***	***422***	***413***	***427***	***433***	***428***	***461***	***512***	***514***	***507***	***497***	***529***	***690***	***714***	***719***	***744***	***884***

Scenario: 1G feedstocks maximised

	Bioenergy feedstock	Constrained potential at £6/GJ (PJ)					Constrained potential at £6/GJ - Overcoming Easy constraints (PJ)					Constrained potential at£6/GJ - overcomming Medium constraints (PJ)					Constrained potential at £6/GJ - Overcoming all Constraints (PJ)				
		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
£6/GJ	Bioenergy	350	379	403	414	444	431	438	440	445	467	494	494	488	490	510	641	665	671	682	680
	Biofuels	31	43	57	69	82	46	57	68	79	91	59	68	77	87	96	68	77	84	93	100
	Total	***382***	***422***	***460***	***484***	***526***	***477***	***494***	***508***	***524***	***558***	***553***	***562***	***565***	***576***	***606***	***709***	***742***	***755***	***774***	***780***

Scenario: Energy crops maximised

	Bioenergy feedstock	Constrained potential at £6/GJ (PJ)					Constrained potential at £6/GJ - Overcoming Easy constraints (PJ)					Constrained potential at £6/GJ - Overcoming Medium Constraints (PJ)					Constrained potential at £6/GJ - Overcoming all Constraints (PJ)				
		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
£6/GJ	Bioenergy	350	379	403	414	518	431	438	440	444	541	494	494	488	489	584	641	665	671	695	835
	Biofuels	23	28	32	36	39	34	36	39	41	43	42	42	43	44	45	48	48	48	48	48
	Total	***373***	***407***	***435***	***450***	***557***	***465***	***474***	***479***	***485***	***584***	***536***	***536***	***531***	***533***	***629***	***690***	***714***	***719***	***744***	***884***

Scenario: 1G feedstocks maximised

	Bioenergy feedstock	Constrained potential at £10/GJ (PJ)					Constrained potential at £10/GJ - Overcoming Easy constraints (PJ)					Constrained potential at £10/GJ - Overcoming Medium Constraints (PJ)					Constrained potential at £10/GJ - Overcoming all Constraints (PJ)				
		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
£10/GJ																					
	Bioenergy	430	453	470	503	500	479	487	490	522	518	524	526	521	548	541	641	665	671	682	680
	Biofuels	51	62	74	85	94	54	64	75	85	94	63	72	80	89	97	68	77	84	93	100
	Total	***481***	***515***	***544***	***587***	***594***	***533***	***552***	***565***	***607***	***612***	***587***	***598***	***602***	***637***	***638***	***709***	***742***	***755***	***774***	***780***

Scenario: Energy crops maximised

	Bioenergy feedstock	Constrained potential at £10/GJ (PJ)					Constrained potential at £10/GJ - Overcoming Easy constraints (PJ)					Constrained potential at £10/GJ - Overcoming Medium Constraints (PJ)					Constrained potential at £10/GJ - Overcoming all Constraints (PJ)				
		2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
£10/GJ																					
	Bioenergy	430	453	470	516	655	479	487	490	535	672	524	526	521	562	696	641	665	671	695	835
	Biofuels	37	39	42	44	45	39	41	43	44	45	44	45	45	46	46	48	48	48	48	48
	Total	***467***	***492***	***512***	***560***	***700***	***518***	***528***	***533***	***579***	***717***	***568***	***571***	***567***	***608***	***742***	***690***	***714***	***719***	***744***	***884***

Appendix 4 Results to modelling of international supply.

Sustainability standards applied; reference energy demand (a) land use maximised for first generation biofuels crops production (b) land use maximised for production of energy crops

Results from modelling of international supply. Sustainability standards applied (a) land use maximised for first generation biofuels crops production

International resource suitable for trade (before domestic demand)

	BAU					BAU - high investment					Low development				
	Maximise Production 1G Feedstocks					Maximise Production 1G Feedstocks					Maximise Production 1G Feedstocks				
	2010	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**
Agricultural residues	854	1,419	1,984	2,602	3,220	854	1,968	3,083	4,334	5,585	854	833	812	915	1,017
Small roundwood	729	911	1,093	1,327	1,561	729	1,111	1,493	1,539	1,585	729	849	969	1,003	1,037
Forestry residues	905	1,109	1,313	1,625	1,937	905	1,327	1,749	1,853	1,956	905	1,059	1,213	1,284	1,356
Sawmill residues	1,154	1,252	1,349	1,546	1,743	1,154	1,263	1,371	1,569	1,767	1,154	1,184	1,213	1,343	1,472
Woody energy crops	0	2,475	8,268	20,237	33,506	0	2,866	10,474	24,908	41,603	0	1,200	4,190	10,123	13,145
Total solid biomass	***3,642***	***7,166***	***14,008***	***27,337***	***41,966***	***3,642***	***8,535***	***18,170***	***34,203***	***52,497***	***3,642***	***5,124***	***8,397***	***14,667***	***18,027***
Bioethanol - RED compliant	5,146	5,772	3,559	5,657	8,441	5,146	5,797	3,618	5,734	8,557	3,978	3,521	1,523	2,090	2,749
Biodiesel - RED	953	1,277	409	758	1,243	953	1,302	459	813	1,305	974	1,106	289	448	600
Bioethanol - Non-RED	0	866	4,214	4,514	4,716	0	866	4,214	4,612	4,937	0	560	2,497	2,526	2,482
Biodiesel - Non-RED	0	73	1,482	1,550	1,568	0	73	1,482	1,566	1,605	0	51	1,104	1,027	900
Total biofuels	***6,099***	***7,988***	***9,664***	***12,479***	***15,967***	***6,099***	***8,037***	***9,773***	***12,725***	***16,405***	***4,952***	***5,239***	***5,413***	***6,090***	***6,731***

Potential surplus on global market (i.e. after domestic demand removed)

	BAU					BAU - high investment					Low development				
	2010	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**
Agricultural residues	854	1,419	1,984	2,602	3,220	854	1,968	3,083	4,334	5,585	854	833	812	915	1,017
Woody biomass	119	2,597	8,177	19,649	31,913	119	3,417	11,240	24,783	40,079	119	1,141	3,737	8,666	10,177
Total solid biomass	***973***	***4,016***	***10,161***	***22,251***	***35,133***	***973***	***5,385***	***14,323***	***29,117***	***45,664***	***973***	***1,974***	***4,549***	***9,581***	***11,194***
Bioethanol - RED compliant	3,612	3,655	2,022	3,720	6,248	3,612	3,680	2,081	3,797	6,365	2,456	1,404	-9	159	563
Biodiesel - RED	467	515	-506	-164	421	467	540	-456	-110	483	488	344	-626	-474	-222
Bioethanol - Non-RED	0	626	2,557	2,908	3,409	0	626	2,557	3,006	3,630	0	321	835	914	1,168
Biodiesel - Non-RED	0	63	1,258	1,315	1,354	0	63	1,258	1,331	1,391	0	41	880	792	687
Total biofuels	***4,079***	***4,860***	***5,331***	***7,779***	***11,432***	***4,079***	***4,909***	***5,440***	***8,025***	***11,869***	***2,944***	***2,111***	***1,080***	***1,390***	***2,195***

International supplies available to UK (based on UK accessing 10% of global supply)

	BAU					BAU - high investment					Low development				
	2010	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**	**2010**	**2015**	**2020**	**2025**	**2030**
Agricultural residues	85	142	198	260	322	85	197	308	433	559	85	83	81	91	102
Woody biomass	12	260	818	1,965	3,191	12	342	1,124	2,478	4,008	12	114	374	867	1,018
Total solid biomass	***97***	***402***	***1,016***	***2,225***	***3,513***	***97***	***539***	***1,432***	***2,912***	***4,566***	***97***	***197***	***455***	***958***	***1,119***
Bioethanol - RED compliant	361	366	202	372	625	361	368	208	380	636	246	140	0	16	56
Biodiesel - RED	47	52	0	0	42	47	54	0	0	48	49	34	0	0	0
Bioethanol - Non-RED	0	63	256	291	341	0	63	256	301	363	0	32	84	91	117
Biodiesel - Non-RED	0	6	126	132	135	0	6	126	133	139	0	4	88	79	69
Total biofuels (RED compliant	***408***	***417***	***202***	***372***	***667***	***408***	***422***	***208***	***380***	***685***	***294***	***175***	***0***	***16***	***56***

Results from modelling of international supply. Sustainability standards applied. (b) Land use maximised for production of energy crops

International resource suitable for trade (before domestic demand)

	BAU – Maximise Production of Energy Crops					BAU - high investment – Maximise Production of Energy Crops					Low development – Maximise Production of Energy Crops				
	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
Agricultural residues	854	1,419	1,984	2,602	3,220	854	1,968	3,083	4,334	5,585	854	833	812	915	1,017
Small roundwood	729	911	1,093	1,327	1,561	729	1,111	1,493	1,539	1,585	729	849	969	1,003	1,037
Forestry residues	905	1,109	1,313	1,625	1,937	905	1,327	1,749	1,853	1,956	905	1,059	1,213	1,284	1,356
Sawmill residues	1,154	1,252	1,349	1,546	1,743	1,154	1,263	1,371	1,569	1,767	1,154	1,184	1,213	1,343	1,472
Woody energy crops	0	2,502	8,310	21,293	51,466	0	2,927	11,599	33,837	84,713	0	952	3,782	10,875	25,214
Total solid biomass	***3,642***	***7,194***	***14,051***	***28,393***	***59,927***	***3,642***	***8,596***	***19,295***	***43,132***	***95,607***	***3,642***	***4,876***	***7,989***	***15,419***	***30,096***
Bioethanol - RED compliant	5,146	5,772	3,559	5,657	8,309	5,146	5,797	3,618	5,734	6,903	3,978	3,521	1,523	2,090	2,559
Biodiesel - RED	953	1,277	409	758	1,221	953	1,302	459	813	1,139	974	1,106	289	448	566
Bioethanol - Non-RED	0	866	4,214	4,514	4,467	0	866	4,214	4,612	4,594	0	560	2,497	2,526	2,212
Biodiesel - Non-RED	0	73	1,482	1,550	1,513	0	73	1,482	1,566	1,378	0	51	1,104	1,027	833
Total biofuels	***6,099***	***7,988***	***9,664***	***12,479***	***15,510***	***6,099***	***8,037***	***9,773***	***12,725***	***14,013***	***4,952***	***5,239***	***5,413***	***6,090***	***6,169***

Potential surplus on global market (i.e. after domestic demand removed)

	BAU					BAU - high investment					Low development				
	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
Agricultural residues	854	1,419	1,984	2,602	3,220	854	1,968	3,083	4,334	5,585	854	833	812	915	1,017
Woody biomass	119	2,624	8,219	20,704	49,874	119	3,477	12,365	33,711	83,189	119	893	3,329	9,418	22,246
Total solid biomass	***973***	***4,043***	***10,203***	***23,307***	***53,094***	***973***	***5,446***	***15,448***	***38,046***	***88,774***	***973***	***1,726***	***4,141***	***10,333***	***23,263***
Bioethanol - RED compliant	3,612	3,655	2,022	3,720	6,117	3,612	3,680	2,081	3,797	4,711	2,456	1,404	-9	159	372
Biodiesel - RED	467	515	-506	-164	399	467	540	-456	-110	317	488	344	-626	-474	-256
Bioethanol - Non-RED	0	626	2,557	2,908	3,160	0	626	2,557	3,006	3,286	0	321	835	914	899
Biodiesel - Non-RED	0	63	1,258	1,315	1,299	0	63	1,258	1,331	1,164	0	41	880	792	620
Total biofuels	***4,079***	***4,860***	***5,331***	***7,779***	***10,975***	***4,079***	***4,909***	***5,440***	***8,025***	***9,478***	***2,944***	***2,111***	***1,080***	***1,390***	***1,634***

International supplies available to UK (based on UK accessing 10% of global supply)

	BAU					BAU - high investment					Low development				
	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030	2010	2015	2020	2025	2030
Agricultural residues	85	142	198	260	322	85	197	308	433	559	85	83	81	91	102
Woody biomass	12	262	822	2,070	4,987	12	348	1,236	3,371	8,319	12	89	333	942	2,225
Total solid biomass	***97***	***404***	***1,020***	***2,331***	***5,309***	***97***	***545***	***1,545***	***3,805***	***8,877***	***97***	***173***	***414***	***1,033***	***2,326***
Bioethanol - RED compliant	361	366	202	372	612	361	368	208	380	471	246	140	0	16	37
Biodiesel - RED	47	52	0	0	40	47	54	0	0	32	49	34	0	0	0
Bioethanol - Non-RED	0	63	256	291	316	0	63	256	301	329	0	32	84	91	90
Biodiesel - Non-RED	0	6	126	132	130	0	6	126	133	116	0	4	88	79	62
Total biofuels (RED compliant	***408***	***417***	***202***	***372***	***652***	***408***	***422***	***208***	***380***	***503***	***294***	***175***	***0***	***16***	***37***

Appendix 5: Proposals for use of biomass in large scale plants in UK

The proposed large scale biomass plants in the UK will mainly use wood chips, although some propose to use small amounts of pellets, straw and energy crops. Proposed figures are:

Proposed plant	Fuel (Mt/y)	Comments
Drax – Heron*	300MW using 1.4Mt/y biomass	Drax say: It is intended that the plant will operate with a wide variety of biomass fuels, including purpose grown energy crops, forestry and agricultural residues as well as potentially recycled timber and recycled paper… Fuel will arrive at the Renewable Energy Plant in numerous physical shapes and sizes, for example; chips, pellets, meals, cakes, briquettes, logs and bales
Prenergy, Port Talbot	2-3Mt/y	Imported wood chip
MGT Teeside	1.2Mt/y	Wood chip, sourced from North and South America, Europe and the Baltic States
MGT Tyne	1.2Mt/y	
E.ON, Bristol	150MW, 1.2Mt/y	Wood chip
EPRL	40MWe, 313,000t/y	Recycled wood
Tilbury		
Scottish and Southern	4x 100MW (total), each 1.3 Mt/y	Plants at Dundee, Leith, Rosyth and Grangemouth. Most fuel – clean wood chips, short rotation forestry, agricultural residues and recovered biomass materials. Fuel will arrive at the Renewable Energy Plant in numerous physical shapes and sizes, for example; chips, pellets, meals, cakes, briquettes, logs and bales.
Ferrybridge multi-fuel power station	93MW, up to 800,000t/y	Mixed solid recovered fuel, waste wood and clean wood chips
Anglesey Biomass	299MW Assume supply would be ~3Mt/y at least.	Imported wood chips and pellets and other biomass such as agricultural feedstock including sunflower husks.
Helios Avonmouth	100MW 850,000t/y	Imported and UK wood, agricultural residues (from cereal and oil seed crop production) and energy crops. Supplied as loose material, chips, pellets and briquettes
Total fuel demand	**17.3-18.3Mt/y**	

Data source: Environmental statements for proposed plants.
* Drax are proposing two other 300MW plants and to convert one of their 660MW units to biomass.

In addition to the above RWE Innoy are building a large pellet plant in Georgia, USA to produce 750,000t pellets for co-firing at the Amer coal power station in NL. Dutch demand for biomass fuel is predicted to be around 6Mt/y. Increased demand for biomass due to plants in planning or development is thought to be over 25Mt/y, not including waste to energy and solid recovered fuel plants.

Annex
Detail on assumptions for UK feedstock supply
Data and assumptions for International feedstock supply

This is supplied as a separate report.

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