THE AVAILABILITY OF SUSTAINABLE BIOMASS FOR USE IN UK POWER GENERATION

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Foreword

The world's population is growing rapidly and so are our individual aspirations and resulting demands on the world's resources. Coupled changes in the environment, climate and public attitudes are driving new legislation and technological innovations.

The biomass sector is part of that change. Biomass energy, humanities' oldest source of heat and light, continues to be used extensively across the world but there is the potential for a significant increase in its usage into the future as a renewable, and low carbon, energy source.

However, such an expansion cannot be uncontrolled. Whilst there are huge benefits in the increased use of biomass, there are equally large risks of unanticipated negative effects. We have already seen this in the bioliquid sector where the combination of environmental, biodiversity and social impacts coupled to a knowledge vacuum triggered a public outcry leading to legislative controls and constraints. The need to define and implement sustainable biomass supply chains that are verifiable, closely monitored and implemented in ways that are compatible with the local communities is paramount for the supplier as well as the end-user.

So, whilst we stand at the brink of a major expansion of biomass in the UK and beyond, we have to ensure that companies spearheading its increased use understand, and are prepared for, the need to demonstrate sustainability in its production and use. As this report indicates, there is a substantial global resource available for some time into the future but it should only be accessed by those responsible companies which put sustainability at the heart of their biomass procurement programmes. Indeed, the eventual scale of the biomass resource may end up being defined by the wholehearted engagement of these companies in the emerging systems and standards being developed to underpin sustainable development.

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Executive Summary

The aim of this report is to provide a short overview of the issues and potential opportunities for the use of biomass as a contribution to the Department of Energy and Climate Change (DECC)'s Bioenergy Strategy, as well as to the Committee on Climate Change (CCC)'s Bioenergy Review. This document assesses the availability and sustainability of biomass for power and heat generation within the next few decades, exploring biomass potential, sustainability issues and the benefits of using biomass in the energy sector. The report reflects the short term requirements of the UK's 2020 Renewable Energy Strategy targets and the decarbonisation of the UK power sector, as well as the longer term implications of developing Carbon Capture and Storage (CCS) and next-generation biofuel technologies. These considerations are of particular importance when considering DECC's 2050 Pathways Analysis and the UK Bioenergy Strategy.

Bioenergy is a central element of a number of major global and national scenarios for meeting the International Panel on Climate Change's 2℃ (450ppm) target, the International Energy Agency's scenarios and the UK's 2050 Pathway Analysis being developed to guide the UK Government's renewable energy portfolio and underlying policies. The likely future availability of biomass to make a meaningful contribution to global energy provision and the impacts of making such a contribution remain topics of active research and policy development.

The fundamental basis of the increased use of biomass for energy is an understanding that when properly and carefully managed, the use of biomass for energy:

- is renewable;
- can be sustainable – if managed appropriately, it need not adversely affect other demands on land e.g. for food production, the provision of ecosystems services or the communities along the supply chain;
- is plentiful – it is the world's fourth largest energy resource after oil, coal and gas; and
- is geographically diverse and flexible– it comes in many forms from many places.

Many studies have been published in recent years assessing the potential of biomass for energy showing a wide range of potential outcomes, dependent on the assumptions made about production and sourcing of feedstock, technology development and modelling techniques employed. The recent emergence of the biofuels sector and the anticipated acceleration of advanced biofuels, which would employ the same lignocellulosic biomass feedstocks as those used for electricity and heat generation, challenges the future expansion of the biomass power sector, owing to the potential competition for the feedstocks and concerns about the sustainability of feedstock to meet anticipated demands. At the same time, a global debate has developed concerning the indirect impacts of using conventional crops as feedstocks for bioenergy, suggesting that the sustainability of any future expansion of the bioenergy sector is very likely to attract intense scrutiny in terms of its sustainability impacts.

It is concluded that there is a significant biomass potential for electricity generation with the ultimate longer-term goal for the UK being the development of biomass plant linked to CCS which would provide negative carbon emissions - the only technology to do so. It is likely that, without significant volume of biomass coupled to CCS, meeting the UK's 80% greenhouse gas (GHG) emission reduction target by 2050 will be almost impossible.

In addition, the use of traditional bioenergy could be progressively replaced by modern bioenergy worldwide in order to increase energy use efficiency, reduce adverse health impacts, promote the environmental and social components of sustainability and reduce waste. This is an important challenge especially for developing countries that still demand technology transfer, market regulation, funding and public policies to equitably realise this modernisation potential. The foreign investment in biomass supply chains, resulting from UK-based modern biomass demand, could assist with the transition from traditional to modern bioenergy in developing countries, if carefully implemented.

Contents

Introduction

Over the last five years or so, a ‘perfect storm’ of events in the UK and abroad has brought the current and future projected use of biomass for energy (and food) into stark relief. Simple calculations show that with existing energy use efficiencies and trends in demand, indigenously grown biomass cannot play a really significant role in the provision of the future energy services needed by the UK’s population, particularly for the provision of low or zero-carbon emission fuels. Thus, the likely future scale, practicality, environmental and social impacts, the share of biomass supply being directed to the different forms of bioenergy and the share of indigenous against imported biomass (either as raw feedstocks or final fuel product) remains the source of an intense debate.

The intention of this report is to provide a short overview of the issues and potential opportunities for the use of biomass for energy as a contribution to the Department of Energy and Climate Change (DECC)’s Bioenergy Strategy and the related work by the Committee on Climate Change (CCC) on its Bioenergy Review. This document assesses the availability and sustainability of biomass for power generation in 2020 as this is when the most immediate and concrete targets exist for the adoption of renewable energy in EU. It includes evaluations of the biomass potential, sustainability issues and the benefits and risks of using biomass in the UK power sector. It addresses many of these issues from the perspective of the UK’s largest electricity production plant which is currently embarked on a transition from coal to biomass. The aim of Drax Power Ltd (Drax) is to be predominantly fired by biomass in the next decades by progressively increasing the share of biomass that is co-fired with coal. This experience is coupled here with the national and international life cycle analytical capabilities and expert knowledge of modelling for biomass availability of LCAworks Ltd.

Using the UK’s 2020 Renewable Energy Strategy targets as the basis for the analysis, the report assesses the potential to use the UK Government’s main policy instruments to drive the use of biomass for energy into the energy supply mix and to ensure that the supplies of that biomass are sustainable, focusing on:

- The Renewables Obligation (RO)
- The Renewable Transport Fuels Obligation (RTFO)
- The Renewable Heat Incentive (RHI)

The report re-evaluates the role of large-scale biomass electricity production in the light of new work on the long term availability of sustainable biomass and on the potential to rapidly (and relatively cheaply) transform existing coal plant to burn large quantities of biomass. Governments across the EU are now much more optimistic than previously on the role of large scale biomass and, in particular, the role of utilising existing coal plant to provide an efficient, flexible and economic contribution to power sector decarbonisation and compliance with tough requirements on renewable energy use by 2020.

In the UK, the RHI will also encourage the use of biomass in the domestic and industrial heat markets.

These developments open up the further potential for power generators and industrial heat users, as well as biomass suppliers, to invest in the supply chains necessary to deliver consistent quantities of sustainable biomass over the next few decades in significantly larger volumes than hitherto seen. This development of increased biomass generation capabilities will require the construction of complete supply chains, from biomass production through new processing, handling and transport, involving the integration of additional port terminal facilities, storage developments and new biomass rail wagon assets, to existing plant operations.

Provided that the UK Government remains supportive of the potential of biomass in the short term, the drive towards the ultimate longer-term goal for the UK - to develop biomass plant linked to Carbon Capture and Storage (CCS) becomes realistic. Biomass CCS is the most prominent technology capable, even if still relatively expensive, of providing negative carbon emissions.

Chapter 1- The use of biomass for energy

1.1. Introduction

There is considerable agreement amongst governments across the world to move to a low carbon global economy although the timing to achieve proposed targets remains the subject of debate, particularly between the emerging and industrialised countries. The UK Government has been heavily involved in the discussions around the optimum means of achieving this objective and has adopted a lead role in setting extensive greenhouse gas (GHG) emission reduction targets. The current national strategic goal is to ensure an 80% reduction in GHG emissions (from a 1990 base) by 2050, with several intermediate targets needing to be realised before this overarching target can be met. The most relevant intermediate targets to achieving this goal are the need to ensure that 15% of the UK's energy demand is provided by renewable energy by 2020 and the aim of essentially decarbonising the power (electricity) sector by 2030. These are ambitious targets and represent a four-fold increase in renewables between now and 2020, and significantly more by 2030. The Committee on Climate Change (CCC, 2010), which provides independent advice to the Government, has indicated that there is scope for even further penetration of renewable energy, reaching 30 to 45% of all energy consumed in the UK by 2030.

All these targets pose a significant challenge to the UK energy industry as they must be reached in less than two decades. They have major implications for the fuel supplies and technology mix and, therefore, more investments will be necessary as existing power generating infrastructure is retrofitted or replaced and new investment in transmission assets is commissioned. Given the highly ambitious levels and the inevitable uncertainty about introducing new technologies and market structures at such a rapid pace, there is no case for identifying a single technology solution and in fact, diversity within the renewables mix is preferable. It is evident that an increasingly wide range of technologies and feedstocks is essential and this includes the extensive use of biomass for power, heating and transport.

Biomass is abundantly available and is the world's fourth largest energy resource after oil, coal and gas. Many studies concur that the sustainable biomass fuel resource is vast, with potential both domestically and internationally through well managed forests, new plantations and energy crop establishment. It is estimated that by 2050 sustainable sources of biomass could supply the world with 20% to 50% of its primary energy requirements (IEA, 2009) from its current supply of 10% of the world's energy demand. In a recent report commissioned by DECC, AEA Technology (AEA, 2011) concluded that by 2020 the UK could access 1,800PJ (1,800 x 10^{15}J) of sustainable biomass (equivalent to 20% of the UK primary energy demand) and that by 2030 this could more than double or even treble.

However, in the UK, biomass has to date only been used in a limited way. The Biomass Task Force and the Government's (Biomass Strategy) response to it (DTI, 2007) confirmed that it was an under-utilised resource, particularly as a source of renewable heat. It stated that *"Biomass will have a central role to play in meeting the EU target of 20% renewable energy by 2020"* even though it only focused on using the fairly limited UK biomass resource base. Some actions emerged from this work, including recommendations to source from the UK, an additional 1 million tonnes of wood from under-managed woodlands, increasing the amount of energy crops to 350,000 ha by 2020 and increasing the use of organic wastes. This ambitious increase in domestic supplies has proven difficult to realise under the existing land use and agricultural markets in the UK and progress has been mixed, with the only real positive change being the significant encouragement of anaerobic digestion as a means of utilising wet biomass wastes. The Strategy noted that *'biomass imports would continue to be a significant source of biomass feedstocks for co-firing'* even though it is difficult to understand the potential for the use of biomass for energy in the UK without developing a perspective on the share of indigenous versus imported biomass relative to the global demand and supply balance.

1.2. The UK situation: policy drivers for bioenergy generation

In the UK, the Renewables Obligation (RO) started to incentivise the use of biomass for power generation in 2002. Some dedicated biomass plants have been built and most, if not all, of the existing UK coal plant have since co-fired biomass (and still have the capability to continue to do so). However, the path towards the use of large scale biomass co-firing has not been easy. The original policy intention was for co-firing to be a transitional technology, being the means of establishing large scale UK energy crop production by 2006 and dedicated biomass plant by 2016. It became increasingly clear that this intention was infeasible in practice, partly because of a lack of confidence in the long term value of the technology given the likely lifetime of coal plant and the perception that sufficient biomass was not available, particularly from the UK, to satisfy such large scale needs. In addition, the regulations around biomass (and particularly biomass co-firing) were frequently modified and indeed in 2005-6, Government policy significantly constrained biomass co-firing, resulting in little biomass consumption that year. At the same time, some environmental non-governmental organisations (NGOs) opposed the use of co-firing technology, interpreting it as a way of increasing the profitability of fossil plant and thereby somehow slowing the transition away from the use of fossil fuels.

Despite these concerns, in 2006 Woods et al., (2006), examined the sustainability and CO_2 benefits of biomass for co-firing for DTI/BERR and concluded, inter alia, that "*from an avoided greenhouse gas perspective, the co-firing of biomass with coal represents one of the most effective uses of biomass resources for energy".* In 2009, following the setting of tight, legally-binding, targets (15% renewable energy by 2020), the Renewable Energy Strategy (DECC, 2009) started to quantify the implications of such a target indicating that about 30% of the electricity demand, 12% of the heat demand and 10% of the transport demand could originate from renewables. The Strategy further estimated that around 30% of the overall UK target could come from bioenergy, rising to 50% if biofuels for transport were included, thereby confirming the importance of this resource in the UK's energy future. The analysis at the time optimistically indicated that there could be '*sufficient biomass resource potential in the UK to meet the demand for heat and power in 2020*' although it also noted, without quantification, that '*imported biomass products are likely to continue to play a role in the UK use of bioenergy'.*

The Strategy also noted that heating accounted for 47% of all UK final energy consumption, although at the time only 1.5% was from renewable sources. The Renewable Heat Incentive (RHI) (DECC, 2011b) has subsequently committed the Government to an ambition that, by 2020, 12% of the country's heat would be from renewables, much of this being from biomass.

The July 2011 UK Renewable Energy Roadmap (DECC, 2011c) identified eight key technologies which could deliver between them, around 90% of the generation necessary to meet the UK's 2020 target. These were classified as significant because of the combination of their cost effectiveness, potential level of deployment and importance to the UK's 2050 energy mix. These are shown in Table 1 and essentially confirm the 2009 analysis indicating that biomass and biofuels might together account for around half of the national renewable requirement.

The Roadmap suggested that in 2010 the UK had around 2.5 GWe of biomass electricity capacity, accounting for 11.9 TWhe of output, thereby making the single largest contribution to the UK's renewable electricity generation. 62% of this capacity came from waste/landfill gas, although co-firing contributed 21% and dedicated plant 17% of the total. By 2020, biomass could, on the central DECC scenario, deliver up to 6 GWe or 32-50 TWhe of renewable energy, an increase of 3.5 GWe over current levels. Much of the projected increase in biomass electricity to 2020 is anticipated to be in dedicated biomass or plant converted to biomass from coal, providing an additional 20-38 TWhe of biomass power in 2020 and requiring an additional 12-23 million tonnes of biomass (at 35% conversion efficiency using biomass of 17 GJ/t) per year.

The bioelectricity production is complemented by a biomass heat requirement in the Roadmap of around 24-38 TWhe requiring an additional 7 to 10 million tonnes (assuming 80% efficiency) of biomass. In addition, these figures suggest a demand of 7 to 15 million tonnes of biomass for transport fuels. Hence, the central scenario implies that, unless the UK can significantly increase the extent of its biomass production , the country will need to develop an import capacity of up to 18-33 million tonnes of biomass per year.

DECC also noted the potential for output increases above the levels indicated in Table 1, provided that enough sustainable feedstock can be made available

This analysis clearly indicates the need for industry to invest in the international supply chains necessary to deliver consistent quantities of sustainable biomass over the next few decades, in considerably larger volumes than hitherto possible.

Table 1. Technology breakdown of renewable energy provision (TWhe; DECC Central view) from UK Renewable Energy Roadmap (2011) and estimates of biomass demand (million tonnes dry biomass)

	Central range for 2020 (TWhe)	**Biomass demand (Mt/yr)**
Onshore wind	24-32	
Offshore wind	33-58	
Biomass Electricity	32-50	16 to 22
Marine	1	
Biomass heat	36-50	5 to 10
Air source and ground source heat pumps (non-domestic)	16-22	
Renewable transport	Up to 48	7 to 15
Others including hydro, geothermal, solar and domestic heat	14	
Estimated 2020 target	234	28 to 47

1.3. Conclusions

The 2011 DECC Renewable Energy Roadmap indicated that biomass is considered one of the key technologies for the UK in terms of cost effectiveness, potential level of deployment and importance to the 2050 energy mix.

Recent Government statements on biomass have promoted the development of a more positive view of the strategic role of biomass in the UK, with up to one half of the country's 2020 renewable energy target being met by biomass in the form of heat, power or transport fuel. This reflects raised confidence in the extent of the UK biomass resource and on the long term availability of biomass which can be imported into the UK.

DECC's projections imply that unless the UK can increase the extent of biomass production, the country will need to develop a considerable import capacity and require power generators and large heat users, as well as biomass suppliers, to invest in the overseas supply chains necessary to deliver large quantities of sustainable biomass.

Chapter 2. The value of biomass for power generation

2.1. Biomass for power generation up to 2030 - overview

It is anticipated that by 2020 over 20 GWe of the existing UK power plants (mainly coal and nuclear) will have closed. The introduction of the EU Emissions Trading System (EU ETS), and the Large Combustion Plant Directive (LCPD) (now replaced by the Industrial Emissions Directive (IED)) are already imposing significant additional economic pressures on the operation of fossil-fired plant.

Over the next decade or so, the UK will therefore need to invest in new generation capacity to replace closing plant and to meet expected increases in electricity demand. The CCC highlighted, in their fourth budget report (CCC 2010), the need for effective power sector decarbonisation by 2030 and set out a range of scenarios for investment in low-carbon generation capacity, proposing a planning scenario in which average emissions from the generation sector are reduced from current levels of around 500 gCO_2/kWh to around 50 gCO_2/kWh in 2030. However, the nature of the replacement plant will fundamentally change the UK system's technology mix since the current expectation is that it will move from a relatively predictable base built around large scale coal and gas plant to one dominated by small scale, intermittent, seasonal and unpredictable generators such as wind, solar, and hydroelectric. National Grid (2011), estimated that in 2020, around 28% of the transmission connected generation will consist of wind and other intermittent technologies, thereby introducing a requirement for a significantly higher, and more variable, operating reserve. Thermal plant will therefore be expected to operate in a much more flexible manner (Poyry, 2011) with a potential for wind output to be curtailed at times, in order to ensure that sufficient thermal capacity is always available to meet the operating reserve requirements. By 2020, the extreme hour-to-hour changes in demand net of wind output have been estimated to be as much as 17 GWe, which is a significant increase from the maximum variation of 5 GWe in 2009. The position in 2030 could be even more extreme.

Coal-fired generation currently provides security of supply benefits in terms of availability, reliability and flexibility and co-firing biomass at a coal-fired power station can take on these important security of supply characteristics, as can larger scale dedicated biomass electricity plants. Hence, unlike any other large scale renewable technology, biomass-fired generation can respond flexibly and quickly to changes in electricity supply or demand and can provide large scale, reliable, predictable, power. Many current energy mix projections, such as the CCC renewables report (CCC, 2011), have not fully recognised this potential benefit and have assumed that, in 2030, a significant amount of Combined Cycle Gas Turbine (CCGT) or Open Cycle Gas Turbine (OCGT) plant will be needed to provide the flexible operating reserve. If, however, biomass plant are built in the numbers anticipated in the recent DECC Renewable Energy Roadmap, the need for such fossil plant will be considerably reduced.

In addition, conversion and enhanced co-firing biomass plant (and hence plant using existing transmission assets) will reduce the need for significant transmission investment required to connect other low carbon developments at more extreme locations on the network.

The recent Arup report for DECC (Arup, 2011) considered a range of different options for biomass usage, including dedicated biomass plant as well as existing coal plant in a variety of regimes: the maintenance of the existing co-firing regime using low levels of biomass; an 'enhanced co-firing' regime for higher throughput; and a potential to fully convert a coal station to biomass-only. Arup indicated that, even if significant quantities of biomass are used for co-firing and coal plant conversion, there is significant potential for constructing new dedicated plants. They recognised that small biomass plant (<50 MWe) would tend to use locally sourced fuel delivered by road, such as forestry residues, small round wood, sawmill residues, arboricultural arisings and short rotation forestry. Arup estimated that the UK could host 50-60 of these small, dedicated plant distributed around the UK, probably configured as Combined Heat and Power (CHP) and competing for fuel with the small scale domestic and commercial, heat-only biomass sector which is being encouraged through the RHI. In addition, large plant (50-350 MWe) would also be constructed, often located near ports specifically to access a wide range of imported fuels.

Arup also considered the potential for the conversion of co-firing generation to biomass generation, concluding that conversion could offer *"up to 1.8 GWe of high capacity factor, low planning risk, deployment up to 2030 with low levels of capex and opex".*

The Renewable Energy Roadmap of July 2011 (DECC, 2011c) confirmed this view, indicating that *'conversion of coal plant to biomass is a major new development'*. DECC also indicated that options for coal plant conversion '*offer considerable scope for additional generation'.* Table 2 provides the Renewable Energy Roadmap levelised costs of generation, excluding the additional transmission costs of connecting intermittent sources and the costs of building and operating any thermal reserve needed to maintain system security.

Table 2: Levelised cost ranges (DECC Central view) from UK Renewable Energy Roadmap, 2011.

Sector		**Levelised costs (£/MWh)**
Onshore wind		71-122
Offshore wind		102-176
Biomass electricity	Dedicated plant	120-156
	Co-firing	93-110
	Converted coal plant	106-127
Marine		162-340
Biomass heat (non-domestic)	Boilers	40-99
	District heating	61-156
Heat pumps (non-domestic)	Air source	44-55
	Ground source	62-75

As can be gathered from Table 2, the required capital investment for modifying plant in this way can be lower per MW than the investment required for other renewable generation facilities such as offshore wind. The indirect costs are also significantly lower as the output is more reliable and predictable, requiring little back-up capacity. These factors are proving attractive to DECC in developing its strategy for compliance with the UK's 2020 RES requirements and 2030 ambitions for decarbonisation of the electricity generating sector. Thus, enhanced co-firing and conversion could provide a cheaper and more secure option in complying with the UK's 2020 renewable targets than other renewable energy technologies, particularly when taking into account the reduction in transmission costs and the benefits in system security.

2.2. Increasing the co-firing throughput

Limited co-firing can be achieved in most UK coal plant with little modification to the plant, by pulverising the coal and biomass simultaneously in the existing coal mills, a technique usually termed 'co-milling' (or 'through-the-mill') which allows size reduction and drying of both the biomass and coal prior to the two fuels being burnt together in the furnace. However, in order to consistently increase the throughput in a given boiler, techniques which require greater modification, such as "direct injection" can be employed. These involve the introduction of the biomass to the boiler, or individual burners, in a separate stream to the coal and provide several advantages over co-milling, the most significant being that the biomass does not affect the flow, milling and classification of the coal, thereby avoiding the unit load limitations that can occur when co-milling low calorific value biomass. As an example of this, Drax has now applied this direct injection technology across all six generating units of the power station and its recently (2010) commissioned co-firing facility and supporting systems now represents an operational 500 MW biomass co-firing capability (or 12.5%) throughput on each unit. This could deliver up to 3 TWhe of renewable energy per year, reducing CO_2 emissions from the plant by over two and a half million tonnes each year.

It is now considered that co-firing at rates of 20-50% biomass throughput (or more) is possible. It is even anticipated that, with further modifications, complete conversion of a coal boiler to biomass may be feasible and, although there is little experience in the UK beyond short term trials, some European generators have fully converted coal boilers. This is not yet a proven technology at large scale (>500 MW) since the use of biomass on an operational plant introduces several constraints. Biomass typically contains substantially more volatile matter than the bituminous coals normally used in coal-fired plant in the UK, with significant associated handling and safety implications. In addition, there are uncertainties about the operational and economic compromises which may need to be made to facilitate increased biomass throughput. For example, the flue gas and ash from dedicated wood firing have different fouling and corrosion characteristics than those from coal firing.

There is, however, confidence that the technical challenges in increasing biomass throughput can be overcome. Many generators have concluded that large volumes of biomass can be successfully sourced, transported and burnt in conventional power stations, replacing coal. Current co-firing/conversion programmes are now focusing on setting up supply chains capable of sourcing and transporting biomass in larger volumes than hitherto seen in the UK or Europe. The implications of the widespread use of this technology are profound, although little work has been done to date on the potential for this technology to impact on the European power market. The prospects for exploitation of this potential to enable the transformation of some UK's existing coal plant into substantial renewable generators depend both on the technical capability of the UK coal fleet and the introduction of regulatory and economic incentives to encourage high levels of co-firing and potentially full conversion.

Another important co-firing technology is the use of bioethanol in natural gas power plants, in either combined or conventional cycles i.e. in a Brayton cycle associated with Rankine cycle, or only in a Brayton cycle, respectively. This is a relatively new technology and is still under investigation. Petrobras, for example, is testing this technology in an existing natural gas power plant, in commercial scale, in Juiz de Fora city, State of Minas Gerais, Brazil. In this project the company is testing ethanol in a natural gas turbine, in a co-firing flex-fuel system. The technical results so far have been quite positive, but the economic viability of this technology is still its main challenge, as recently reported by Conti (2011).

2.3. Role of biomass to 2050 - Carbon Capture and Storage

Several studies have attempted to ascertain the optimum means of meeting an 80% reduction in UK emissions by 2050, confirming the importance of maintaining a significant role for sustainable bioenergy as a vital part of a low carbon energy system (DECC, 2010). There are several areas, such as industrial high grade heating, road freight, agriculture and aviation, where electrification is unlikely to be practical and sustainable bioenergy appears to be the main way forward, The debate is still on-going as to whether the highly flexible characteristics of biomass should be used to best effect for transport, heat or power although, if electrification of the road transport system is viable, then the value of biomass as a vector for liquid fuels becomes less important in a long-term scenario.

Irrespective of the outcome of the debate, it is clear that the use of bioenergy with CCS (BECCS) is important, this being the only technology currently envisaged as generating 'negative carbon emissions' (Strapasson and Dean, 2011). The technical potential for BECCS is significant and various studies have indicated that it could supply 10% of global electricity demand in addition to substantial associated negative emissions. For example, a recent study by Ecofys for the IEA (IEA, 2011) assessed the potential for combining biomass and CCS technologies in power generation and transport fuel applications in the period up to 2050. They calculated that savings of up to 10 Gt of negative carbon dioxide emissions across the globe annually might be possible, a substantial proportion of global energy-related emissions in 2010 of around 31 Gt CO_2eq. For the electricity industry, various technology routes were considered, including pulverised coal with direct biomass co-firing, circulating fluidised bed combustors (CFBC) dedicated biomass, integrated gasification combined cycle with co-gasification of biomass, and biomass integrated gasification combined cycle.

The UK's Energy Technologies Institute (ETI) has recently commissioned several studies on biomass with one of them evaluating the potential for BECCS to provide the UK with a mechanism, by 2050, to remove 50 to 100 Mt CO_2 from the atmosphere annually and generate 80 to 120 TWhe per year. The cost at which this option can be developed and deployed, compared to the alternatives, will be a critical parameter in determining its value in assisting the UK to reach its 2050 emission targets.

Studies of this type suggest that any new UK coal-fired plant, which will be eventually fitted with CCS technology, should also be designed with a co-firing capacity. The current energy sector development envisages coal CCS demonstrator plants within the next few years, deploying post-combustion/pre-combustion or oxy-fuel technology. Biomass is not specifically targeted but, if biomass CCS is to be developed long term, then early coal demonstrators should be capable of co-firing. Initially these could operate at low levels of biomass throughput but could increase the share until a substantial fraction of the generation is from biomass, leading to overall negative carbon emissions.

New dedicated biomass plant i.e. those built up to 2020, will mostly be <300 MW and therefore will not be obliged to be carbon capture-ready (CCR). However some plant, probably all CFBC, may be built over the next decade in excess of the 300 MW threshold and these could form an additional component of any CCS demonstration programme.

Figure 1 shows a scheme for the development of negative emissions in biomass and coal plants, indicating that the use of enhanced co-firing, fully converted coal plant and dedicated biomass could be viewed as transitional technologies towards the ultimate goal of BECCS, by establishing the sustainable biomass markets and expertise which will be required to exploit future CCS technologies. Provided that a mechanism for incentivising 'negative carbon' is introduced, testing of these new build CCS plant with increasing levels of biomass is practicable in the 2020s.

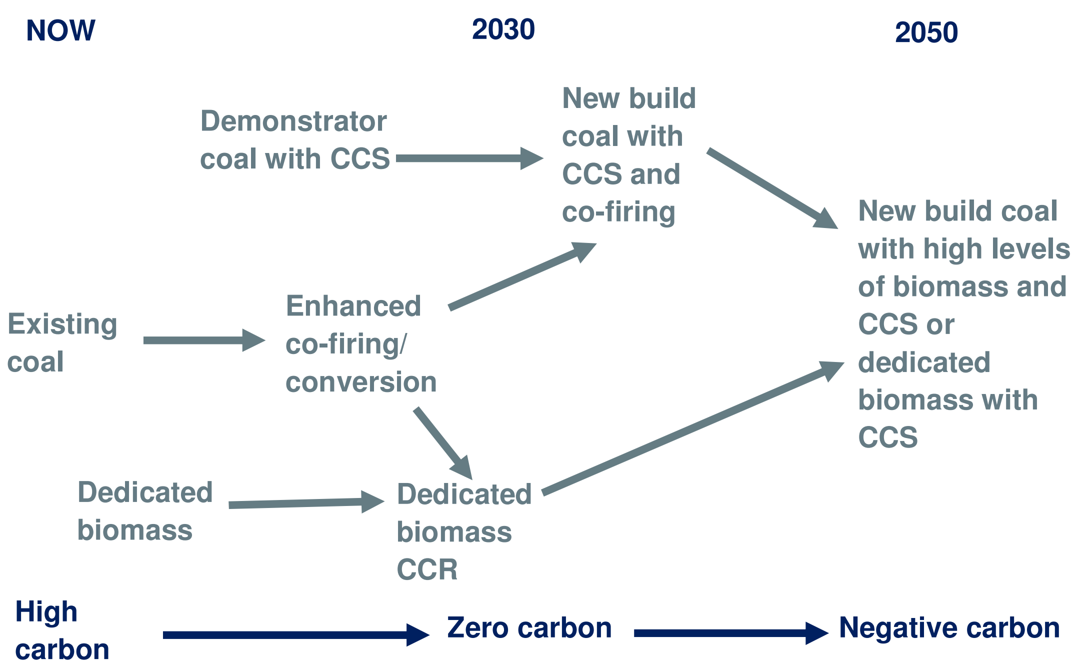


Figure 1. A potential route to negative carbon emissions using existing coal and biomass plant as transitional technologies.

There are many expectations for BECCS technology but its success relies on developing a demonstrably sustainable biomass supply chain. The existing bioenergy plants and CCS testing systems (Strapasson and Dean, 2011; McGlashan et al, 2010) have shown favourable results. The CCC (2011) conclusion was that, without CCS, biomass would probably be of more value when used outside the power sector although if CCS were available, biomass use in the power sector may be more attractive. However, the recent DECC banding review however emphasises the role of biomass electricity to meeting the 2020 target, through co-firing and dedicated biomass use..Moreover, changes will need to be made to the legal framework towards BECCS, since it is not properly regulated by either the EU ETS or United Nations Framework Convention on Climate Change (UNFCCC) (Strapasson and Dean, 2011). Identifying and implementing suitable market stimuli for the expansion of this technology are key for its successful deployment.

2.5. Chapter conclusions

There is a high level of confidence that existing coal plant could utilise large quantities of biomass, either through enhanced co-firing or through full conversion to biomass, thereby providing an economic contribution to power sector decarbonisation and compliance with the UK's tough targets for expanding renewable energy use in 2020. Besides, the efficient use of biomass (as a source of thermal energy, like natural gas and coal, but in this case renewable) for industrial and domestic heat uses, presents also a high potential for GHG emission reductions per unit of useful energy.

In this regard, the UK has a unique opportunity to increase the share of biomass in its energy mix which would have significant benefits. There is an opportunity for the UK to play a major role in Europe, in terms of innovative sustainable biomass technologies, renewable heat industry, domestic biomass production and use of waste fuels i.e. the UK could become a major biomass trading hub, facilitate exportable skills in the conversion and operation of biomass power stations.

Work needs to continue in developing biomass CCS in co-fired configurations with coal. Current development programmes in the EU are focused on the use of coal (with co-firing), but, once the integration of the capture, transport and storage technologies has been achieved, steadily increasing the share of biomass seems logical. The technical potential for biomass CCS is significant and various studies have indicated that it could be fitted to the supply of approximately 10% of global electricity production, in addition to substantial associated negative carbon. However, the regulatory regimes need to be put into place to incentivise its use.

Chapter 3. Understanding and implementing biomass sustainability

3.1. Introduction

The progress made to date on the co-firing, conversion and dedicated biomass options has laid the foundations for further expansion in UK biomass generation. However, the long term development of the technology depends critically upon the availability of adequate sustainable feedstock (fuel). This not only makes sense from a business perspective, that is, longevity and security of feedstock supply, but it is also essential for environmental, economic and social reasons.

One of the attractions for the use of biomass resources as feedstock for bioenergy is that they are considered carbon neutral in terms of energy generation (IPCC, 2006). In other words, the combustion of biomass emits the same quantity of CO_2 as is captured by its growth. However, understanding of the production of biomass is developing in terms of more comprehensive analysis addressing environmental impacts over the whole lifecycle. This lifecycle approach considers the harvesting, processing and transportation of biomass, as well as whether the production of biomass causes changes in land use and carbon stocks. This has been put into practice in the liquid biofuel sector under various policies in different countries, including the UK Renewable Transport Fuels Obligation's (RTFO) Carbon and Sustainability reporting methodology and the Renewables Obligation's (RO) guidance on sustainability criteria for bioliquids and solid biomass (currently under stakeholder consultation), used in the generation of electricity.

On-going areas of concern in the production of liquid biofuels are the impacts of changing land use and the loss of land areas with high biodiversity, the potential conflict of growing crops for energy rather than for food, the impacts on indigenous populations and the methodologies used for calculating GHG reductions (relying on methodological decisions and assumptions which significantly affect the outcomes). Several NGOs and independent organisations, such as the Nuffield Council on Bioethics (Nuffield, 2011), have written extensively on these subjects (Pilgrim and Harvey, 2010; Nuffield, 2011; ActionAid UK, 2011). Such has been the concern about the negative aspects of the biofuels industry, the original policy under development for the RTFO was reviewed (Gallagher Review, 2008) and the targets for inclusion of biofuels were reduced and timelines extended to allow for better understanding of the impacts of the developing industry.

The RTFO development of sustainability criteria follows a 'meta-standard approach' for biofuels and as supply chain specific sustainability assessment methodologies have been developed, they have been benchmarked and incorporated into the reporting methodology (e.g. the Round Table on Sustainable Palm Oil (RSPO), Bonsucre, Round Table on Responsible Soy (RTRS). IEA Task 40 has reviewed over 70 schemes and policies which include the sustainability assessment of biomass for bioenergy supply chains (Junginger et al. 2011; van Dam, 2009). Legislation has now been enforced in the EU for liquid transport biofuels, through the Renewable Energy Directive (RED) and The Fuels Quality Directive (FQD) and it is anticipated that the biomass for bioenergy industry will follow the same route, starting with the changes made under the 2011 RO Order in the UK.

The precedent set by biofuel policies and the developing industry has greatly influenced thinking in the solid biomass arena, which at this time considers that a wider range of biomass feedstocks will be used for heat and electricity provision. The European Commission (EC 2010) concluded that, whilst much of the European sourced biomass is sustainable in that it is produced under national agricultural or forestry certified schemes, at the global level deforestation and illegal logging continue and the extent and coverage of sustainability assurance is limited. Sustainability at the policy level has been, and continues to be, defined through stakeholder consultation and will require a broad range of principles to address the wide, diverse range of feedstocks, which might be sourced from almost any country in the world.

It is also worth noting that in contrast to the bioliquid sector, the great majority of biomass currently (and probably for some time into the future) used in the UK and Europe for electricity generation is derived from wastes, residues or by-products for a variety of reasons such as the availability, price, handling and combustion characteristics. Sustainability concerns about these materials are reduced, but not eliminated entirely, from the use of these feedstocks

Over time, the UK's aspirations for biomass-based generation will require the use of significant amounts of biomass as discussed in Chapters 1 and 2. As a result, the UK has been seen as a leader in the responsible and economic evolution of sustainability in biomass power generation, driving the introduction of sustainable biomass practices through fuel procurement activities. Under the RO, the concept of mandatory sustainability reporting has been introduced for biomass used in the generation of electricity in plants over 50 kWe. The current requirements are that generators will have to demonstrate a minimum of 60% GHG emissions savings for electricity generation using solid biomass, relative to an average EU fossil fuel use (not lifecycle based),and that restrictions will be applied to materials sourced from land with high biodiversity value or high carbon stock (including primary forest, peatland, and wetlands). DECC have developed a GHG calculator for use by generators and more detailed draft guidance for sustainability reporting for biomass feedstocks has recently been issued by Ofgem (Ofgem, 2011). Changes in carbon stock due to forestry management will also have to be taken into account in the GHG calculations. Following two years of mandatory reporting, in April 2013, the issuance of ROCs will be tied into compliance with criteria set for the reporting of sustainability of biomass.

3.2. Industry sustainability policy

The clear message from stakeholders and policymakers is that the key risk to the development of large biomass usage is the use of biomass which does not provide the anticipated GHG benefits or that has unwanted negative impacts (directly or indirectly). This is of particular concern when biomass is sourced from regions where extraction is not regulated to the same level as in the EU. This risk will only be effectively mitigated by compliance with strict sustainability standards which are comprehensive, legally binding and well and demonstrably implemented, so that public and NGO concerns can be allayed and sustainable biomass accepted in the energy mix. The implementation of sustainability criteria across the bioenergy sector therefore depends on gaining credibility for monitoring and verification systems across the full length of the supply chain, with both suppliers and end-users developing the necessary management and auditing systems. Eventually, the same principles must be applied to the whole energy sector and beyond.

There is, therefore, a need for credible sustainability standards to be applied by all biomass users (large or small, heat or power) and implemented into solid biomass fuel procurement activities. Clear, well defined principles, criteria and methodologies to define, monitor and verify sustainability performance and to calculate GHG emissions are also required.

In 2008, in the absence of recognised and suitable standards for the procurement of sustainable biomass, Drax developed its own programme of sustainability standards and implemented comprehensive sustainability criteria into its biomass procurement activities with the aim of assuring both the availability and sustainability of biomass supplies. These include a set of high level principles committing the company to progressively improving the sustainability performance of its suppliers against net GHG savings, biodiversity protection and improvement, social factors, avoiding use of food and building materials and encouraging good agricultural and forestry practices. The Drax procurement process is designed to ensure that the production and delivery of biomass will:

- Significantly reduce greenhouse gas emissions compared with fossil-fuelled generation and give preference to biomass sources that maximise this benefit.
- Not result in a net release of carbon from the vegetation and soil
- Not endanger food supply or communities where the use of biomass is essential for subsistence (for example, heat, medicines, building materials).
- Not adversely affect protected or vulnerable biodiversity and where possible give preference to biomass production that strengthens biodiversity.
- Deploy good practices to protect and/or improve soil, water (both ground and surface) and air quality.
- Contribute to local prosperity in the area of supply chain management and biomass production.
- Contribute to the social well being of employees and the local population in the area of the biomass production.

These procurement programmes cover all supply chain stages, including, where applicable cultivation and harvesting, transforming and processing, and transportation. Implementing this policy has required the development of a lifecycle GHG model, as well as development of documentation and an audit programme against which suppliers are measured to demonstrate compliance. The policy guidelines are designed to encourage those suppliers who can demonstrate that their biomass supply chain provides both direct and indirect positive economic benefits and/or contributions to the local community. Certified forest management plans, audit reports and other supporting documentation may be used to help demonstrate good practice in maintaining below and above ground carbon stock, encouraging biodiversity, requiring mechanisms for public outreach, education, and involvement related to forest management and affected indigenous people. The social aspects of biomass production are important, particularly in countries with a developing industrial base and are based around the International Labour Organisation (ILO) rules, which address issues such as wages, child labour and working conditions.

In the absence of globally co-ordinated sustainability criteria, each generating company will need to set up systems of their own to manage their sustainability risks. In Drax's case, the aim has been to test developing sustainability criteria and standards and to work towards formally implementing them in all bioenergy procurement activities. Since 2008, suppliers have had to comply with sustainability criteria as a condition of contract, whilst recognising that some need a period of adjustment to ensure that their supplies could be managed under any future international sustainability standard.

The Drax approach has two components; the first to ensure that all supplies pass a set of criteria which screen out 'unsustainable' biomass; and the second to encourage all suppliers to improve both data provision and the sustainability of their biomass to the Drax performance requirements. Before any biomass contract is signed, suppliers have to provide sufficient data to enable an assessment of the origin and likely sustainability issues associated with the fuel. The intention is that fuel which is clearly unsustainable will not be purchased and contracts will only be signed for material which is or is working towards demonstrable sustainability.

Overall, supplier response to this process has been positive and most have worked with Drax to implement this robust sustainability policy. Audits were introduced in 2009 to supplement the high level policy and to assess the sustainability information provided by the supplier to Drax, in order to identify whether it was factually correct and whether data were available to support the supplier's questionnaire returns.

The public debate on the potential consequences of unsustainable bioenergy has become a key and determinant factor in its future development. While the development of sustainability criteria and certification systems started largely as a theoretical exercise, they are currently being put into practice, and thus have a direct effect in the development of bioenergy, creating new challenges which need to be tackled quickly and adequately by industry, policy makers and academia alike. Any large scale development of bioenergy should require the development and implementation of schemes to ensure that the feedstock is extracted sustainably. Gaining stakeholder confidence in the acceptability of large scale bioenergy projects is critical, not just for the interested public and environmental NGOs but also for investors and banks who have an interest in the longevity of the fuel stream. The use of bioenergy certification schemes, combined with increased transparency of operation, could provide a major benefit in this area. In many countries forestry regulations are already well established and since the 1990s (when concerns about the use of wood products from deforested areas came to the notice of consumers and NGOs) a number of certification schemes have been developed to provide assurances for the furniture, and pulp and paper industries.

There are many forestry certification schemes available, but the most important accreditation agencies are: the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) of the Canadian Standard Association (CSA). FSC and PEFC represented in 2010 respectively 52% and 31% of the world certified forests (FSC, 2011). Several agricultural products are covered by schemes such as the UK's Red Tractor Farm Assurance Combinable Crops & Sugar Beet Scheme (formerly ACCS). Also in the UK, the Forestry Commission's Sustainability Scheme (Woodland Assurance Scheme, UKWAS) has set out rigorous criteria for the extraction and use of wood.

The IEA Bioenergy Task 40 has done an overview of worldwide issues dealing with sustainability certification of biomass (Bioenergytrade, 2011). Despite a very large number of studies, undertaken by academics, private institutions and NGOs, there is not, as yet, any global model for assessing the impacts of sustainability and certification on international bioenergy trade. IEA Tasks 40 and 43 are currently carrying out a study on “harmonisation of sustainability certification of bioenergy”, with the aim of evaluating how stakeholders are affected, quantifying the anticipated impact on worldwide bioenergy trade and making pertinent recommendations (the first draft of the study is expected in November 2011 and the final report by May 2012). Another important initiative is the Global Bioenergy Partnership (GBEP), which is a governmental forum created by G8+5 countries, which also assembles many other countries and United Nations institutions, such as the Food and Agriculture Organization (FAO), United Nations Convention Against Torture (UNCAT) and United Nations Environment Programme (UNEP).

It is anticipated that, as sustainability criteria become more established across the industry, existing schemes may evolve and new ones emerge to reflect both bioenergy market expansion and increasing demands for transparency and consistency in sustainability implementation. Some sustainability criteria are actually integrated in legislation as a mandate, so all market actors dealing with biofuels and bioenergy for the specific market where the legislation is valid will be confronted with the practical implementation of these requirements. The main example is the EC Renewable Energy Directive (2009/28/EC), which puts sustainability requirements to biofuels for transport and liquid biofuels (for stationary bioenergy) marketed in the EU. For solid and gaseous biomass for electricity, heating and cooling, so far most sustainability certification initiatives are voluntary systems.

NGOs are increasingly setting the standard for commercial companies to match, as witnessed by the WWF’s New Generation Plantations Project (NGPP), which aims to identify, promote and communicate better practices for plantation design and management. Recognising the need to expand land to provide for the global population’s material needs (the WWF Living Forest Report (2011) predicts 4-6 million hectares per year to 2050), the NGPP also recognises the contribution that well managed and effective plantation production can make in preventing on-going deforestation and forest degradation. The principles of the NGPP are: maintaining ecosystem integrity; protecting and enhancing high conservation values developed through effective stakeholder involvement process; and contributing to economic growth and employment. Working with private forestry companies and government agencies, the project takes a pragmatic and proactive approach to plantation and resource management, highlighting examples of well-managed and appropriately located plantations that form part of healthy, diverse and multi-functional forest landscapes, compatible with biodiversity conservation and local social needs. Some of these examples are the following case studies (WWF, 2011):

- Fibria, a company situated in Brazil, which has a carbon management programme, using the Chicago Climate Exchange (CCX), the Investor Carbon Disclosure Project (CDP) and the Brazilian stock exchange (BM&F-Bovespa);
- Veracel Celulose, a joint venture of Fibria and Stora Enso groups, which is working with forest restoration, carbon storage and income generation in the Pau Brasil Ecological Corridor project in Monte Pascoal, State of Bahia, Brazil. Veracel is also supplying renewable electricity to the national grid using by-products from the pulp-making process;
- China Green Carbon Foundation, which is a partnership between the Chinese Government and the private sector in a bioenergy plantation in Yunnan. The foundation is using carbon offset funding to develop forests for bioenergy;
- Masisa (Nueva Group), a company which is situated in Chile, Argentina, Brazil and Venezuela and has a methodology for carbon capture quantification in forest plantation;
- UPM Tilhill, which is a private forestry industry in Scotland and is using a the voluntary carbon offset market to fund native woodland creation. The company is also developing sustainable stump harvesting guidelines for the UK;
- Forestry Commission Great Britain, which is developing a woodland carbon code; and
- Forestry Commission Wales, which is promoting the sustainable management of biomass and is supporting a proposal of biomass electricity generation from the Western Bio Energy Ltd.

Whilst the direction of travel is clear, it is necessary to recognise that an overregulation of the bioenergy market could damage its development, both in the UK and potential supplier countries, especially as this is a non-commoditised market. If the sustainability criteria are not practical and realistic, and not properly implemented, they could seriously impede rather than promote bioenergy. Modern biomass is an emerging business worldwide and the sustainable requirements must advance progressively. This is especially important for developing countries where the efficient use of biomass for bioenergy has real potential to benefit communities on many levels (e.g. by providing employment opportunities and infrastructure to provide access to services), if implemented appropriately. However, the demand for feedstock for biofuels and biomass, promoted by the EU RED policy has already been blamed for 'land-grabbing' and the abuse of the rights of local populations in various countries (ActionAid 2011; Oxfam 2011). As part of Drax's commitment to its sustainability policy, for potential supply chains in countries where environments and/or local populations may be considered vulnerable or at risk, more effort and emphasis is placed on better understanding of local conditions before contracts are signed, to ensure that the policy principles are respected.

3.3. Land use change and carbon stocks

Land Use Change (LUC) results from a wide range of drivers that are difficult to identify and it is even more difficult (if not impossible) to quantify the share of causality between the drivers. For bioenergy, LUC results from the expansion or conversion of land to provide feedstocks. Where competition for land or the resulting products occur, indirect impacts will also result as the wider agriculture or forestry markets adjust to compensate for displaced feedstocks or land.

Changes in land use can have a significant impact on GHG emissions, carbon stocks, biodiversity, water quality and availability. The clearing of above ground carbon and the oxidation of soil organic material, as the result of land tillage, will result in a flux of emissions. The conversion of different types of high carbon stock lands e.g. permanent grassland, forestland and peatland, for the production of crops for biofuel/bioenergy production can result in such substantial and rapid releases of GHGs that any savings arising from the end use of the bioenergy e.g. through fossil fuel substitution, are completely overwhelmed. Where dedicated biomass crops replace a previous land use, the carbon debt (carbon 'pay-back' time) or carbon credit (carbon sequestration potential) should be considered. The potential carbon debt or credit effects from LUC resulting from planting and extraction of biomass for energy, provides particular problems in terms of adequately representing the real variance and uncertainty that exists in estimating land-based carbon stocks. Such assessments are sensitive to the methodology used, and models and their input parameters e.g. the type of crop, geographical location and physical characteristics of land (soil), crop yields, land availability, and agricultural and energy market dynamics among other factors. However, certifications schemes (e.g. FSC) and public policies focused on the sustainable production of bioenergy (e.g. agro-ecological zoning (AEZ) of land and sustainable financing) can reduce the risks of these potential effects. It is also important to recognise the potential benefits of increasing carbon stocks through LUC where, for example, degraded lands are regenerated through planting with robust perennial crops. The use of biomass residues and crops with high energy performances, particularly the more photosynthetically efficient plants (e.g. C4-pathway plants such as sugarcane and miscanthus) can also significantly reduce carbon impacts.

Another significant issue around LUC is the loss of habitats supporting a range of plant and animal species and the detrimental effects on biodiversity. Whilst by no means a desirable outcome, the advancement of agricultural frontiers continues as human demands for materials increase, but it is increasingly recognised and essential to consider the value of ecosystems services provided by areas of land which support biodiversity. Opportunities exist to incorporate management practices to preserve biodiversity, including using land as biodiversity pockets or corridors on large scale areas or leaving field margins to support biodiversity on the smaller scale – practices which already exist in the UK and EU through Environmental Stewardship Schemes.

The drivers for LUC are multifaceted and complex although it is necessary to recognise that, possibly because of the scale of implementation across the agricultural industry, feedstocks for bioenergy have sustainability standards applied where other supply chains for food and materials do not. Such a differentiation is not logical except as a short term expedient. By a similar logic, the concept of Indirect Land Use Change (ILUC) needs questioning in the absence of similar standards for agriculture and forestry.

Emissions from ILUC are not currently included in GHG balances for biofuels, although there is recognition of their potential impact. At the time of writing, the ILUC issue has received considerable attention but a suitable methodology for dealing with ILUC for liquid biofuel supply chains has not yet been decided at the EU level. Methodologies put forward include: economic modelling methodologies to define an ILUC factor (JRC, 2010); a causal-descriptive methodology to define an ILUC factor (E4Tech, 2010) and better land use definitions which avoid ILUC, by encouraging the expansion of croplands onto Responsible Cultivation Areas (RSA) (Ecofys, 2011). However, when attempting to extrapolate the issues derived from bioliquid production to the use of biomass, it is important to note that the biomass industry is very different to that generating bioliquids in that it uses a great deal of residues from agriculture and forestry, rather than primary products. Hence there is little direct land use change in the biomass industry and hence a lower potential for 'carbon debt,' since the biomass source is material which otherwise has no commercial value. Even though the industry uses residues from sawmills (such as offcuts, thinnings and sawdust), it is necessary to ensure that the management of the forest from which the material is extracted is sustainable. The essence of this is that the supplier re-plants and re-grows the forest or plantation at a rate equal or greater than the rate of extraction. Only in this way can the carbon neutrality of the forest management/ biomass production process be assured.

There are situations where the biomass industry may cause direct LUC, but planting forests on previously underustilsed, badly managed or degraded land <u>increases</u> carbon stock rather than decreasing it (positive benefit). This is clearly the case with several energy crop programmes where (mainly poor quality) land is used to produce a biomass-generation area.

Since the introduction of legislation to promote the use of biomass for biofuels and bioenergy, the understanding of what can be practically reported down a supply chain, has been constantly improving. Uncertainty will also decrease as supply chains and standards address specific land areas and research explores the relevant area-specific issues, such as carbon stocks on land (above and below ground), biodiversity and water availability. Understanding these complex environmental interactions, in light of developments in management practices for existing crops and/or the introduction of 'new' crops is an on-going challenge and understanding sustainability is an evolutionary process.

Within this context, assuring the sustainability of feedstock supply must co-evolve with the coalescence of the range of initiatives which have been developing in the last few years in the biofuels and food and forestry sectors. The Sustainability Policy which Drax employs for its supply chains has been developed to manage security and the wider sustainability of supply within this dynamic and evolutionary market.

3.4. Lifecycle carbon footprinting

The main purpose of using biomass to generate electricity is to reduce overall emissions of GHGs (principally CO_2). The principal policy mechanism for achieving these reductions across the EU is the ETS, which caps the amount of CO_2 emitted from large emitters such as power plants. Flue gas (exhaust) emissions from biomass are omitted from the ETS since it is assumed that the absorption of CO_2 during biomass growth is balanced by its emission during combustion. Lifecycle emissions (i.e. those related to production and transport) are not addressed in the ETS for any fuel, although it is essential that these are considered to improve the understanding of impacts, as well as to ensure that wider environmental policies are appropriately developed.

Previous work in this area by Woods et al. (2006) for DTI/BERR examined the sustainability and CO_2 benefits of biomass for co-firing and concluded, *inter alia*, that "*the net carbon balance for the production, transport and use of biomass for co-firing is positive in almost all circumstances, including for both imported and domestic materials*". Additionally its authors state that "*importing waste/co-product biomass is unlikely to have significant negative environmental impacts. GHG emissions associated with bulk transport by sea are low in relation to the GHG benefits from avoided fossil fuel combustion*".

The actual atmospheric GHG implications of burning biomass for energy are complex and require an understanding of the technologies used in electricity generation, the fossil fuel that is being replaced, the biophysical environment in which the biomass is cultivated and harvested and the crop/forest management techniques used.

Establishing a lifecycle emissions standard for biomass is a transparent way of demonstrating the carbon savings of electricity generated from biomass. Indeed, lifecycle carbon assessment of biomass, from field to furnace, is now well developed in the UK where a mandatory lifecycle standard for biomass of 79 gCO_2/MJ (by 2013) leads the EU. However, the choices made in defining the lifecycle, methodology and boundary setting, as well as the use of default values and the interpretation of the results needs to be clearly and logically set out, well understood and subject to public review. Inconsistencies in allocation methodologies, choices made in conversion efficiencies and the use of default values which may be unrepresentative or too broad, can lead to unfair comparisons between supply chains and can be commercially damaging, both to the reputation of the industry and to individual suppliers.

With a conducive policy environment, lifecycle biomass GHG emissions are likely to decrease over time, through higher energy crop yields and better overall crop management, including improvements in the use of nitrogenous fertiliser (Skenhall, 2011), lower transport emissions using biofuels or electric/hydrogen vehicles, improvements in pelleting processes and higher conversion efficiencies. The use of lifecycle methodology can inform and drive this process by enabling competition between bioenergy producers.

The most efficient and convenient means of bulk transportation, storage and handling of biomass involves removing excess moisture and compressing the material into a densified pellet as near to the point of biomass origin as possible. The additional costs and CO_2 emissions associated with the pellet making process are taken into account in the overall lifecycle assessments but can be offset by reduced transportation and handling costs. Electricity usage in the pelleting process is plant and fuel specific and can vary considerably and potentially contribute a significant fraction of the overall GHG emissions. However, pellet plants will often use a portion of the low grade biomass feedstock (such as wood bark) as fuel to offset the energy requirements of the mill to dry the biomass, thereby reducing the amount of electricity needed for pellet production.

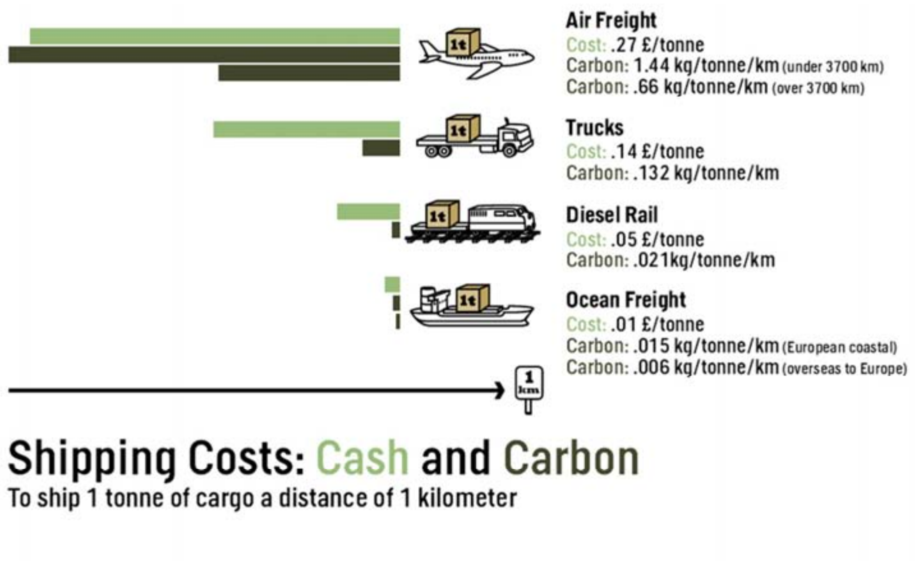


Figure 2: emissions and economics of transporting biomass

When it comes to transporting large volumes of material the distance of travel is less important than the mode of transportation as shown in Figure 2. Bulk marine transportation is the most economical and least carbon-intensive mode of transportation available. This is because of the substantial volume of material that can be transported by each ocean-going vessel. A similar analysis underpins the investment Drax is making in specially designed biomass rail wagons to increase volume stowage and further reduce the environmental impact of domestic logistics

Furthermore, when assessing the GHG emissions of transporting biomass (by truck, rail or ship) it is essential to recognise the benefits of higher density and lower moisture content associated with pelletised biomass. Whereas woodchip supply chains may have lower overall processing impacts compared to pellet fuels, these can be partially offset by increased emissions from transport, particularly if the fuel is sourced internationally. Such benefits are also manifested in a more stable product which can be stored for longer, is less prone to decomposition and can be handled with less dust or odour nuisance. In light of these analyses, it is likely that the pelleting of biomass will grow as an industry potentially leading to the commoditisation of biomass for bioenergy use.

3.5. Chapter conclusions

The use of biomass as feedstock for the production of bioenergy can present real opportunities, not only for the electricity generation industry but also in improving efficiency of feedstock production and land management.

The potential of biomass to reduce GHG emissions depends on the source of the biomass (including location and management techniques) and its net land-use effects. Utilising residues from crop management practices for bioenergy creates a new market opportunity and may alleviate disposal problems and/or prevent GHG emissions from uncontrolled decomposition. However, understanding the appropriate levels of residue extraction versus residues returned to soil is also an important consideration, which will vary according to crop, climate and particular land (soil) conditions. Furthermore, the planting of perennial biomass crops provide opportunities for improved land management, such as additional carbon storage over time and wider consequences for ecosystems services. These are poorly understood for many regions and the impact of managed habitats/plantations on e.g. water cycles, will come under increasing scrutiny if anticipated climate change outcomes and increasing desertification become widespread.

Sustainably sourcing large volumes of biomass is not without its challenges and the potential benefits of using biomass for bioenergy cannot be taken for granted. The effort needed to ensure such benefits is likely to be substantial and entail long-term commitments to suppliers and originating communities. Understanding management practices to grow the feedstock, the potential for negative land use change (plantation replaces high biodiversity areas or food crops), pollution from growing activities, over-harvesting of residues and degradation of soil quality, as well as the potential for the displacement of vulnerable communities are all elements of sustainability which should be taken into account. Diligence, systematic scrutiny and verification are needed to ensure biomass delivers on its promises but does not impact negatively on the wider reaching environment.

There continues to be a risk of negative reputational damage because of differing levels of understanding and interpretation of the sustainability of biomass. The development of the biomass sector should occur with the support of the public and through the implementation of transparent and publicly acceptable standards (including environmental and social criteria) to give credibility of the sector.

Chapter 4. Biomass availability

4.1. Estimating global biomass availability

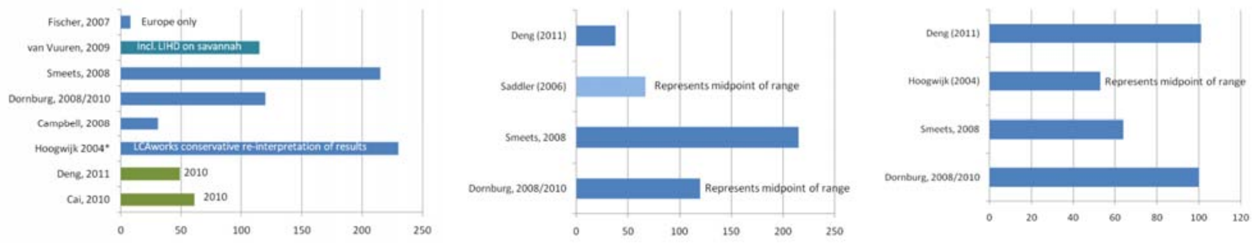
There are now numerous studies assessing the global potential to supply biomass for energy. Most of these start by evaluating the underlying capacity of the biosphere to produce biomass in sufficient quantities to meet the multiple and rapidly increasing demands it is exposed to, and then extrapolate in varying degrees of complexity, future demands for biomass to supply its multiple markets. All these assessments remain highly uncertain and vulnerable to both technological and political innovation and change.

A recent meta-study by Akhurst et al. (2011b), of over 30 of these global assessments concluded that despite the wide variation in projected potentials reported, a technical potential of up to 350 EJ of primary biomass energy might be available per year, by 2050. Similar conclusions were reached by Chum et al. (2011), in a major report for the Intergovernmental Panel on Climate Change (IPCC) (current (2010) global primary energy consumption is about 520 EJ).

Out of this 350EJ, about 100 to 150 EJ was assessed to be economically viable. At the upper end, this scale of demand is equivalent to consuming over 10 billion tonnes of oven dry biomass or about 9% of the total net photosynthetic capacity of the biosphere, representing over one-third of current primary energy consumption. By comparison, global cereal production reached 2.5 billion tonnes in 2008 or about 5 billion tonnes when residues such as straw are included. Clearly, therefore, bioenergy will represent a major new off-take for global photosynthesis although it is notable that traditional biomass use currently consumes nearly 0.9 billion tonnes and modern bioenergy another 0.6 billion tonnes of biomass.

The meta-study also highlighted the diverse range of biomass resources and wide geographic distribution of those resources which fall under three broad categories (as shown in Figure 3):

a) crops that can be grown on abandoned agricultural land (substantial areas of which are emerging in the industrialised economies in particular);
b) surplus forest products (difference between projected forest productivity and industrial demand for forest products); and
c) wastes and residues (arising from farming, forestry and municipal activities).



a) b) c)

Figure 3; a) Abandoned Land Potential (EJ). b) surplus forest products (EJ). c) residues and wastes (EJ). Akhurst et al., 2011.

Within this global context, the projected demands for biomass for energy in the UK (power, heat and transport) are very small. In this report we estimate a total biomass demand for energy in 2020 of between 40 to 50 million tonnes with just under half dedicated to electricity production (c. 20 million tonnes, see Table 1). Beyond 2020, its use could continue to increase rapidly as it becomes coupled to carbon capture and storage (CCS) and possibly beyond that, carbon capture and re-use, offering the potential for a significant supply of negative emissions electricity. It is also worth noting that the feedstocks for electricity production are currently predominantly based on wastes and residues and indeed many of these residues may arise from the clearing and renewal of managed agricultural land and plantations that are currently under-represented in the resource estimates provided in Figure 3.

4.2. The UK situation: biomass availability for renewable energy generation

Demand estimates for biomass for renewable energy provision for the UK in 2020, 2030 out to 2050, tend to be based on final or, sometimes primary, energy provision forecasts (AEA, 2011; DECC 2011). Reconciling these demand-side energy-based estimates of the UK biomass resource base with actual biomass demand is difficult because of the range of conversion efficiencies seen in the current technology mix and possible changes in those efficiencies in future technologies deployed for the provision of bioenergy, and in the provision of biofuels (in particular, the co-production of non-energy products such as distiller's grains and solubles (DGS) and feed meals from oil bearing crops).

In their comprehensive review of published UK biomass potential estimates for the UK's Energy Research Centre (UKERC), Slade et al. (2011), find that the total contribution of bioenergy to UK primary energy in 2030 ranges from 400 to 1100 PJ per year (equivalent to 4–11% of UK 2008 primary energy), with the upper end of the range only possible if biomass production for energy is completely unconstrained. This range of primary energy provision is equivalent to 22 to 61 million tonnes of biomass, with consumption in 2008 estimated at around 9.5 million tonnes. The biomass resource arises from combinations of wastes, residues (agriculture and forestry), and dedicated annual and perennial energy crops.

Whittaker and Murphy (2008), carried out an evaluation of the UK biomass resource based on mimicking the much quoted US '1 Billion Ton' report's methodology. They estimated the indigenous UK biomass resource to range from 25 million tonnes in 2008 to between 49 to 69 million tonnes annually by 2030 (Table 3). By comparison, total cereal grain production in the UK has ranged from 19 million to 24 million tonnes per year between 2000 and 2009.

Table 3: Estimates of the UK biomass resource to 2030 (Mt). Whittaker and Murphy, 2008.

	Current (2008)	**2030**
Forest resources and waste wood (including commercial, MSW, C&D waste wood, etc.)	12 to 15	26
Agriculture derived biomass (including energy crops e.g. SRC, energy grasses, etc)	13.5	23 to 43
Total	25.5 to 28.5	49 to 69

RSPB (2011), recently estimated the future demand for biomass for electricity production indicating a '*substantial shift from primarily domestic supply (74%) to a bioenergy industry based largely on imports (81%).*' RSPB estimates that around 36 million oven dried tonnes (odt) of wood would be needed in 2020 compared to 15 million odt in 2010, implying that domestic supplies would decrease from 11 million tonnes in 2010 to 7 million tonnes in 2020 and imports increase from 4.4 to 29 million odt over the same period.

With many studies indicating that biomass could be an important component of the future energy mix for both power and heat, and as outlined above, surveys of the availability of biomass in and to the UK highlighting the large scale of the potential biomass resource, a more optimistic view on the use of biomass for energy has emerged. In 2010, a report for DECC (AEA 2011), indicated that the total biomass supply available to the UK could be around 450-750PJ in 2020 and 500-780PJ in 2030. AEA assumed that 10% of the biomass potentially available in the international market would be available to the UK. This figure is somewhat subjective as is the expectation that much of the increase in supply will originate from ex-agricultural land planted with energy crops and conventional biofuel feedstocks. However, even given these caveats, the report indicated that, provided that energy crops can be developed globally, there will be adequate biomass resource available to the UK up to 2030 at least. Table 4 provides the range in AEA estimates of biomass energy (for power generation and heat) available to the UK over the next two decades.

From a basic supply perspective, it therefore might be possible to supply roughly half to all the UK 2020 bioenergy demand from indigenous resources. However, in practice, biomass consumers will be driven by balancing costs with perceived risk against sustainability criteria and supply disruption.

Table 4: Estimates of potential biomass energy available to the UK (TWhe per year). AEA, 2011.

	Scenario	2010	2015	2020	2025	2030
UK solid biomass	Low	20.6	13.7	17.4	21.0	32.2
	Medium	44.0	23.7	26.9	32.7	59.6
	High	58.0	31.1	34.6	50.1	86.6
Imported solid biomass	Low	23.3	17.6	40.9	106.8	254.1
	Medium	23.3	44.0	109.9	254.6	593.8
	High	23.3	59.9	169.7	422.5	1000.2

There will possibly be tight limits on land available for growth of biomass feedstocks given the need to feed a significantly growing and increasingly wealthy global population over the coming decades. The implication is that there will be limits on the level of biomass that is available for energy. Therefore, complementarities of food-energy synergy need to be explored in full. Modernisation and transformation of the agricultural sector needs to be addressed. Land use planning (such as AEZ) could be a basic tool for promoting the symbiotic, rather than competitive, production of both food and fuel.

The International Energy Agency estimates that, by 2050, sustainable biomass could supply up to 20% of the world's primary energy requirements (IEA, 2008). A potential competition for this raw material may be the demand for second generation biofuels, in which celluloses and hemicelluloses would be used to produce sugar and then ethanol through distillation processes. However, even with this technology being available and competitive in the medium term it is likely that just part of the total modern biomass production worldwide would be converted into liquid fuels using this technology. In addition, even in the second generation biofuels plants the lignin arising from the refining of lignocellulose could be burned in CHP systems to produce heat and electricity. This case may happen in the sugarcane-based ethanol plants for example, in which the sugarcane bagasse and in-field residues could be collected and used as feedstocks in the coupled lignocellulosic and conventional fermentation conversion systems (Strapasson, 2008).

Commitment to a secure supply chain, whether through long term contracts or direct investment, is critical to unlocking the potential of the biomass market. Access to the multitude of different biomass resources is growing, yet both the domestic and international markets are still immature. Our assessment is that there are ample and diverse sources of sustainable biomass available globally to meet the UK's requirements although significant investment will be required in UK port and rail infrastructure to handle this, with generators having to enter into long term commitments to support these developments if they are to have secure access to the biomass. Because there is not yet a buoyant spot market for biomass, large volumes of biomass can currently only be secured through long term commitments. Although contracts are currently bespoke, the market will develop to a point where pricing will be more transparent, with indexation mechanisms linked more closely to energy, and infrastructure costs in the supply chain will have been capitalised, leading to a move away from the requirement for bespoke medium/long term bilateral contracts to a more merchant contract/spot based market.

Many commentators argue that biomass is most advantageously used close to the point of production, however many of the countries that provide overseas sources of biomass are already maximising their use of such fuel or have plans to do so. In this case, surplus material from verifiably sustainable sources is available for marketing as an energy source creating additional revenue upon which these countries can further develop (albeit concomitantly increasing their own need for more energy and thereby over the long term increasing local demand for energy).

In the case of certain large scale producers, e.g. Canada, Russia, USA, and Brazil, output from new and re-planting will likely always outstrip indigenous demand, and their long term supply capacity is projected to meet or slightly exceed global demand. Additionally, the routine use of biomass from longer-rotation planting is expected to have the positive effect in maintaining or increasing global forestation levels and carbon stocks. Risks do arise in the short to medium term, where a rapid increase in demand cannot be met through re-stocking and care needs to be taken when accessing biomass feedstocks that robust re-stocking plans are put in place at point of source.

4.3. Feedstock for pellets (international bioenergy trade)

Estimating the potential of bioenergy is difficult for various reasons. Firstly, it is quite difficult to come up with reasonably acceptable estimates, given the huge range and widely different estimates. Secondly, how to estimate the proportion of the feedstock that could be used for pellets given the competing end-uses and poor statistical base. Thirdly, it is even more difficult to estimate the sustainable potential against combined economic, social and environmental parameters.

One of the factors which raises the most uncertainty are the forecasts of potentially available land for energy crops, particularly on agricultural land. According to Bruinsma (2011),

'...it is estimated that about 30 percent of the world's land surface, or 4.2 billion ha is suitable to some extent for rainfed agriculture based on the Global Agro-Ecological Zone (GAEZ) published in 2002 (Fischer et al., 2002). Of this area some 1.6 billion ha are already under cultivation. The developing countries have some 2.8 billion ha of land of varying qualities which have potential for growing rainfed crops at yields above an "acceptable" minimum level, of which nearly 970 million ha are already under cultivation. The gross land balance of 2.6 billion ha (4.2 – 1.6 billion; 1.8 billion ha for the developing countries) would therefore seem to provide significant scope for further expansion of agriculture.'

Despite the scale of estimates of potentially available land and doubts about whether more land will be needed in practice to meet future food demands due to raised yields and cropping intensity, Bruinsma raises a number of caveats, and it remains clear that the production of biomass for energy and for food will remain closely coupled and at times competitive. The availability of arable land is therefore one of the most sensitive factors influencing projections for the growth in supplies of feedstocks for bioenergy. A key global challenge will be to produce bioenergy in such a way that does not adversely affect food production.

In Europe there is a significant potential for further development of bioenergy without necessarily competing with food production. Here, 19% (833 PJ) of electricity, 78% (3.621 PJ) of heat and 90% (1.243 PJ) of energy for transportation is expected to derive from biomass sources by 2020(IEA, 2010). The expected import volume of biodiesel is 235 PJ and 74 PJ of bioethanol/bioethyl tertiary butyl ether (bioETBE) in 2020, is equivalent to about 25 % of the projected biofuel consumption (Beurskens and Hekkenberg, 2011). The share of biomass and waste in the total primary energy demand of OECD Europe is expected to double from 5.9 to 13% by 2035 with an average annual growth rate of 3%, whereas the global share is expected to increase from 10% to 12% (IEA, 2010).

Pellets, and more importantly wood pellets, are usually produced as a by-product of sawmilling or other wood transformation activities and agro-forestry residues. In past few years round wood and wood chips have also been used as feedstock. Wood pellets can be used on various scales, ranging from combustion in stoves for heating of households (e.g. in Austria, Italy, Germany and the USA) to co-firing in large scale in coal power plants in for example, the UK, Netherlands and Belgium.

Production, consumption and trade have grown strongly worldwide, but primarily in Europe and North America. In 2008, as a rough estimate, about 8Mt of pellets were produced in 30 European countries, compared to 1.8Mt in the US and 1.4Mt in Canada. European consumption in 2009 was thought to total about 8.5Mt. The largest EU consumers are Sweden (1.8Mt), Denmark, the Netherlands, Belgium, Germany and Italy (all roughly one million tonnes). Also, the USA is a major consumer of wood pellets (see Junginger et al 2011).

The first intercontinental wood pellet trade was reported in 1998, a shipment from British Columbia (Canada) to Sweden. Since then, Canada has been a major exporter to Europe (especially Sweden, the Netherlands and Belgium) and more recently to the US and Japan. In 2008, the USA also started to export wood pellets to Europe. Estimated globally, traded wood pellets totalled about 5.5Mt in 2009 of which 3.9Mt were exported to the EU (Junginger et al. 2011).

According to Sekkema et al. (2011), the wood pellet market is booming in Europe with about 650 pellet plants producing more than 10Mt in 2009. Total European consumption that year was about 9.8Mt, of which some 9.2Mt was traded within the EU-27. Industrial pellet markets are relatively mature, compared to non-industrial ones, because of their advanced storage facilities and long-term price setting. However, industrial pellet markets are unstable, depending mainly on the establishment or the abolishment of public support schemes.

Sekkema et al. (2011a) have estimated additional demand for 2020 for woody biomass ranging from 105Mt/yr (based on market forecasts for pellets in the energy sector and a reference growth of the forest sector) to 305Mt/yr (based on maximum demand in energy and transport sectors and a rapid growth of the forest sector). Additional supply of woody biomass may vary from 45Mt/yr from increased harvest levels to 400Mt/yr after the recovery of slash via altered forest management, the recovery of waste wood via recycling, and the establishment of woody energy plantations in the future, are included.

4.4. UK energy crop potential

Assessing the potential for the supply of energy crops in the UK remains controversial primarily because the UK is not self-sufficient in food supplies and therefore it has often been assumed that any energy cropping will result in competition for food. Despite this, a number of studies have been carried out which seek to minimise the impacts on food security and identify land that could be used for energy crops. For example, Lovett et al (2009) used spatially explicit GIS modelling to exclude high grade land and unsuitable areas for the growth of miscanthus to develop a policy-related scenario for increased planting and identified 350,000 ha, 4 to 28% (depending on the region) of lower grade land, that would not necessarily greatly impact on UK food security. About 4Mdt of biomass would be produced on this land if planted with miscanthus. They also note that if biomass production were to be increased to the circa 1 to 2Mha which may be required in the UK to meet current renewable energy targets for renewable liquid transport fuels, there would be increased pressure on land and implicitly on food production.

Whittaker and Murphy (2008), estimate the total current availability of biomass from agricultural land in the UK to be approximately 13.4Mdt/yr, of which 6.1Mt is straw. In accounting for possible future yield increases in conventional crops they estimate that the availability of biomass from agricultural land could increase to 18 and 23.2Mt in the years 2020 and 2030 respectively. This is due to wheat yield increases of 16% and 20% respectively, conversion of our excess wheat to biofuels, the Landfill Directive's restrictions on landfilling biodegradable waste, including greater infrastructure for collection of other agricultural residues such as manure and poultry litter. When including perennial woody crop expansion the agricultural resource increases to 21Modt in their 'moderate case' scenario, and 37Modt in the 'high case.'

Drax is committed to the development of biomass supplies in the UK and has a twin approach of utilising agricultural and forestry residues as well as encouraging the use of energy crops. This strategy helps mitigate geographical risk and promotes use of indigenous biomass, which has a positive effect on sustainability and lifeycle GHG results compared to the fossil fuels. As part of this strategy, Drax has built a 100,000 t/yr pellet plant at Goole in Yorkshire to access local straw and energy crop miscanthus.

Energy crops have been given a distinctive incentive in the UK RO to facilitate their development and to allow energy companies to contract at a price and term needed to incentivise the creation of this new market. Long term certainty of offtake is a critical aspect to this new market development. Drax has taken on this task and now procures a substantial proportion of the energy crops produced in the UK. However, although Drax is one of the largest buyers, the volumes are still very small compared to the demand for biomass and potential volumes that could still be developed. There are several reasons for this, although the main one is the absence of consistency and continuity in approach to regulation and Government strategy which can be reflected in long term contracts and investment decisions. Drax is working hard to increase these numbers through positive marketing, contracting and working very closely with the whole supply chain. In particular, it has become apparent that there is a knowledge gap for farmers, landowners (large and small), politicians and students in the UK about energy crops and Drax has now engaged with Masstock Arable (UK) Ltd, one of the leading agronomy companies in the UK, to develop and run an Energy Crop Demonstration Farm (Smart Farm) on Drax owned land.

4.5. International trade

Biomass for energy has until relatively recently, only been traded locally. However, the rapidly increasing demand in industrial countries, primarily in the forms of solids (wood pellets and wood chips) and liquid (biodiesel and bioethanol) is transforming this market. Up to now the trade flows have been between industrial countries and from South to North. This will change if countries such as China start to import biomass for energy in large quantities. Since this market is still immature, supply imbalances can be expected, though technological developments may play an important role in balancing supply. A study by IEA Task 40 on "Prospects for international trade of wood chips" is still on-going and should be completed before the end of this year. An important component to realising a strong and globally significant international trade in biomass for energy is the development of regional and global quality standards such as described below.

The European Committee for Standardisation (CEN), under technical committee TC335, has published 27 technical specifications (pre-standards) for solid biofuels during 2003 – 2006 (Alakangas, 2010). The following step is to upgrade these technical specifications to full EU standards. When EU standards are in force, the national standards have to be adapted to these standards. Wood chips can be specified according to standard EN 14961-1 for general use. Demolition wood is not included in the scope of the EN 14961-1, but in the scope of EN 14588 (used wood arising from demolition of buildings or civil engineering installations). The EN 14961-1 includes also wood waste, if they do not contain halogenated organic compounds or heavy metals as a result of treatment with wood preservatives or coatings. The following characteristics are described for specification of wood chips, in the frame of EU 14961-1: origin (forest, plantation and other virgin wood; by-products and residues from wood processing industry; used wood; blends and mixtures), dimensions, moisture, ash content, nitrogen, chlorine, net calorific value, bulk density, ash melting behaviour.

For wood pellets, for the EU, the CEN/TC 335 working group developed biomass standards to describe all forms of solid biofuels within the EU, including wood chips, wood pellets and briquettes, logs, sawdust and straw bales (Junginger et al., 2011).

A number of logistical barriers also exist to the development of an international market in biomass that is capable of supplying scales of biomass demand for energy outlined above. One of the main logistical barriers is a general lack of technically mature pre-treatment technologies in compacting biomass at low cost to facilitate transportation. While densification technology has recently improved significantly (for example for wood pellets) this technology is only suitable for certain biomass types.

Transport and lack of infrastructure are also major barriers. Various studies have shown that long-distance international transport by ship is feasible in terms of energy use and transportation costs (e.g. Sikkema et al., 2010) but the availability of suitable vessels and meteorological conditions (e.g. winter time in Scandinavia and Russia) needs be considered. The lack of significant volumes of biomass can also hamper logistics since, in order to achieve low costs, large volumes need to be shipped on a more regular basis. Only if this can be assured, will there be investment forthcoming on the supply side in, for example, new biomass pellet factories, which will reduce costs per tonne significantly through economies of scale.

Local transportation by truck or train (both for biomass exporting and importing countries) may be also a high cost factor, which can influence the overall energy balance and total biomass costs. For example, due to increasing export demand for bioethanol, Brazil is encouraging major investment in dedicated long-distance bioethanol pipelines and terminals. For wood pellets, further growth of transport from the hinterland of British Columbia to the Ports of Vancouver and Prince Rupert by train may be seriously hampered by limited logistical infrastructure (single rail tracks).

For wood pellets no sanitary and phytosanitary measures are currently required although significant import controls exist for untreated round wood and chips from outside Europe. Similarly, agricultural residues which could be used either as fodder or for production of heat and electricity may currently be denied entry if they do not meet certain fodder requirements. These kinds of practices may be avoided when adequate technical and sustainability standards are in place.

As bioenergy is increasingly traded at much larger scale, new health and safety requirements are coming to light. However, there is little reliable information and for this reason, the IEA Bioenergy Committee agreed to a study to investigate and assess the health and safety aspects of biomass handling, transportation and storage. It will be important to put in place relevant risk assessment and appropriate mitigation measures to ensure that the development does not lead to significant (direct or indirect) costs in the form of damage from fires, explosions, as well as health impacts due to dust, fungi and odour.

4.6. Supply chain

Establishing resilient, sustainable and cost effective supply chains is the key foundation for an increased international trade in biomass for energy. Despite the high biomass potential of many countries, especially in the tropics and sub-tropics, logistics and infrastructure for biomass transport remains a limitation, especially for many developing countries. These factors could significantly increase costs with potential new suppliers remaining unviable even where the country has significant biomass availability, for example, due to poor road conditions, lack of suitable ports and storage facilities or potential conflict over the resource. Political instability may also constrain foreign investment.

Another challenge in the supply chain is in the production of the biomass, possibly the most fragile part of the biomass chain. The risks of supply interruptions usually increase when large numbers of small-holder farmers are involved who are more vulnerable to economic crises and climatic impacts than large scale industrial producers. These risks could be reduced by stimulating farming cooperatives and other farmer organization models but requires comprehensive, careful and transparent stakeholder involvement.

Therefore, the private sector must identify the suppliers and transport companies that could guarantee the biomass supply mainly through the development of long term contracts in order to manage the risk to disruption of supply. The organisation of the biomass market worldwide for energy purposes will demand new investments in logistics, infrastructure, monitoring and traceability. Hence, support from international funding institutions e.g. the International Monetary Fund (IMF), World Band (WB) and the African Development Bank (AfDB), private sector groups, and both domestic and international public policies are necessary for those exporting countries, especially in many African countries.

4.7. Future trends

The work of IEA Task 40 over the years reinforces the view of the international biomass energy market as a complex and multi-layer subject. Bioenergy trade needs to evolve from bilateral to spot markets. Uniquely, much more site-specific supply chain data is needed on demand and supply factors so as to have a better idea of potential for future development and to provide confidence that sustainable markets can be developed. Some major points are:

- Current policy in many countries favour the development of international bioenergy trade;
- Sustainability is at the core of bioenergy trade;
- International trade has proven to be an important enabling factor for both suppliers and users;
- Strong policy efforts e.g. strategies, certification, are being put in place, be it a slow pace; and
- Many impacts (food supplies, land use, social) and interactions (development, markets) are still poorly understood.

4.8. Chapter conclusions

Domestic supplies of biomass feedstocks for renewable energy generation are considerable but are unlikely to fulfil more than 50% of 2020 demand, with a declining share beyond that date.

Estimating the global supply and demand balance is more complicated although UK demand is likely to be very small in scale relative to the global supply. It is difficult to predict the future development of international bioenergy trade as it is still an immature market and depends largely on energy policy support mechanisms such as measures to promote domestically produced biofuels over imports, import and export tariffs and sustainability issues.

The public debate on potential unsustainable consequences of bioenergy has become a key and determinant factor on future developments and therefore a key global challenge will be to produce bioenergy in ways that does not adversely affect food production. The immaturity of this market will probably result in supply imbalances, though technological developments, particularly for biofuels, can play an important role in balancing supply.

Sustainability issues are at the core of supplying biomass for energy. But there are many diverse views on what constitutes sustainability which if not properly addressed and implemented, will seriously impede rather than promote bioenergy trade. Task 40 studies show that import tariffs and the implementation of sustainability certification systems are perceived potentially as major barriers for the trade of bioethanol and biodiesel, though less so in the case of woody biomass for heat and power.

Historically, biomass for energy has, until recently, been traded locally. However, demand in industrial countries, primarily in the forms of solid biomass (wood, pellets) and liquid (biodiesel and bioethanol) is rapidly changing this market. Up to now the trade flows have been between industrial countries and from South to North. This could change if countries such as China were to import biomass for energy in large quantities

Overall, the market for pellets looks very promising, unless there is a major shift in policy in many countries. Also, much will depend on the development of the co-firing sector, the biomass logistics and infrastructure, and the potential future commoditisation of the pellets market.

Chapter 5. Conclusions and policy recommendations

This report has re-evaluated the role of large-scale biomass power production in the light of the recent confluence of several key factors, namely new work on the long term availability of biomass, an increasing confidence that such biomass can be extracted sustainably in specified locations around the world, and the growing legal and societal pressures on reducing carbon emissions as well as the potential to rapidly (and relatively cheaply) transform existing coal (and potentially industrial heat) plant to burn large quantities of biomass. This combination of factors opens up the potential for industry to invest in the supply chains necessary to deliver consistent quantities of sustainable biomass over the next few decades and in substantially larger volumes than hitherto seen.

The use of large volumes of biomass has attracted criticism from certain stakeholders based on the perception that some biomass use is environmentally negative and that the global biomass resource is already constrained and in many cases over-exploited. These risks and perceptions will only be effectively mitigated by demonstrating compliance with strict sustainability standards which are comprehensive, legally binding and well implemented at large scales and across supply chains. This report confirms the need for credible sustainability standards to be applied by all major biomass users (for heat, power or transport) and integrated into their biomass fuel procurement activities with clear criteria and methodologies that operationally define sustainability and calculate life cycle environmental benefits.

The use of biomass provides a significant contribution to short-to-medium term national environmental requirements as well as enabling the construction of extensive supply chains which will be available for the UK to deploy in the future low carbon world. Whilst biomass will inevitably be extensively used for many decades, there is still a considerable technological uncertainty about its optimum long term use. Much will depend on the developments in technologies such as biomass CCS, the conversion of coal plant to biomass, second generation bioliquids as well as improvements in the understanding the long term availability of global, sustainable biomass. Certainty in the outcomes of these developments will only be learnt in the late 2020s or early 2030s and this report therefore advocates a ‘no-regrets’ policy, encouraging for example, the use of the conversion of existing coal plant to biomass as a transitional, but low-carbon, power generation technique that determines to what extent, the supply base will be inherently constrained.

We conclude that there is a significant biomass potential for electricity generation worldwide. However, some key issues must be addressed to push this market forward, such as to:

- Improve infrastructure and logistics for biomass transport: this remains a key limiting factor for many potential suppliers, especially in tropical developing countries with high biomass yields;
- Establish an international legal framework for bioenergy linked to CCS. This technology will demand additional investments and therefore will also require clear legislation to stimulate it;
- Develop market regulation: tax systems must be appropriate and trade barriers should be reduced or eliminated for bioenergy. The opportunity cost between “coal, natural gas, oil” and “biomass” must prefer renewable energy to fossil fuels. In general the transaction and establishment costs are higher for renewables than for the incumbent fuels; and
- Promote the commoditisation of bioenergy for solid biomass for power generation. It is necessary to have more countries trading biomass in significant amounts in order to ensure its international supply. However, demonstrating effective sustainability certification and quality standardisation schemes is seen as an essential component of this, not just for gaining public and political support, but also in terms of enabling the development of a global biomass market.

The large scale markets for bioenergy are building and the novel systems to ensure sustainable provision, will take time. Several transitional activities are required, such as the development of long-term contracts between biomass suppliers and end-consumers as well as using independent certified schemes for standardisation and sustainable criteria. In order to increase the availability of biomass for electricity generation, demand must also be stimulated to give a clear signal for producers and new investors about this potential market and its benefits and to overcome early-stage market barriers and establishment costs. There is a learning process that must be overcome towards a significant biomass trade worldwide, and therefore time-limited additional public policies are necessary to overcome these challenges.

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