Imperial College
OF SCIENCE, TECHNOLOGY AND MEDICINE

INTERNATIONAL ENERGY AGENCY (IEA) BIOENERGY TASK40 ON:

‘Sustainable International BioEnergy Trade:
Securing supply and demand’

Country Report for United Kingdom

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Executive Summary

This report provides an update to the UK Country Report 2006 [1] and concentrates on trade-related developments that have taken place in UK bioenergy in 2007. Much of the analysis is based on literature produced to assess the impacts of different renewable energy policies, many of which have been revised or re-examined during the year.

UK Energy Overview

The UK is reliant on imports to meet the country's primary energy demand. Imports of coal and gas were equivalent to 76% and 23% of demand respectively in 2006. Each of these fuels accounted for around 35% of electricity generation.

Renewable electricity generation has been growing in recent years and in 2006 accounted for 4.5% of electricity generation. Over 40% of this consisted of wind and hydro. The largest source of bioelectricity generation was landfill methane combustion followed by co-firing with coal. The energy policy target for the UK is to achieve a 60% reduction in CO_2 emissions by 2050. Several interim targets exist to support this, although it is unlikely that the immediate target of 10% renewable electricity supply by 2010 will be met.

Policies to Support Bioenergy

The two major policies supporting UK bioenergy are the Renewables Obligation (RO) and Renewable Transport Fuel Obligation (RTFO) operating in the electricity and transport fuel markets respectively. Both consist of cap-and-trade schemes intended to allow specific renewable energy targets to be met at least cost. Other fiscal incentives include limited funding for small-scale renewable energy projects, financial support for farmers growing energy crops and exemption of biomass from taxes on fossil fuel and energy use and CO_2 emissions.

Domestic Biomass Availability

Assuming current land-use, over 200 PJ of biomass could be made available for energy. Of this, the largest single resource is wood, including sawmill waste, arboricultural arisings and, most importantly, municipal wood waste. Up to 15,000 ha have been planted with woody energy crops (SRC and miscanthus) with studies identifying several 100,000 ha as suitable for planting. However, it appears unlikely that plantings will increase substantially in the short-term, primarily as a result of high prices in other agricultural markets. The UK also has a net annual wheat surplus of around 1 Mt which is targeted by many producers as the basis for a UK bioethanol production industry.

Biomass Consumption

Consumption of wood and wood waste for (heat) energy in 2006 was 8.5 PJ and 3.3 PJ respectively. This compares to 48.7 PJ of various biomass residues used for primarily for electricity generation, 20.8 PJ of which were imported. Co-firing generated 2.5 TWh of electricity in 2006, compared to 797 GWh from dedicated biomass plants. Several coal plant operators have signalled their intention to make further investments in co-firing, most notably Drax Power who have signed a contract to secure 300,000t of Miscanthus annually. The number of proposed dedicated bioelectricity plants is also increasing, with five new plants (combined 151 MW capacity) planned. Most of these have identified an intended domestic feedstock, although a single 350 MW plant intends to rely on shipments of imported woody biomass.

A number of biodiesel plants are already operating in the UK, with other biodiesel and bioethanol plants under construction. If all plants are constructed on the scale proposed, the feedstock requirement will be greater than the current non-food production of wheat and rapeseed, implying the need for imported feedstocks. However, the total intended capacity of these plants would be sufficient to meet projected UK biofuel demand in 2010.

Drivers and Barriers for UK Bioenergy Trade

In the absence of greater policy incentives, the main drivers of international bioenergy trade are the demand created by the RTFO and RO. Since biodiesel and bioethanol are likely to dominate the markets for renewable transport fuel, the market for imported biofuels and feedstocks created by the RTFO is likely to be the more stable. In the electricity market, proposed reforms to the RO include the introduction of ‘banding’. Under this reform, less restrictions would be placed on co-firing of biomass but less support would be offered per MWh of co-fired electricity generated. Other forms of biomass conversion would be treated more favourably with dedicated energy crop combustion receiving 8 times more support than co-firing per MWh. The net effect of these changes on international bioenergy trade is uncertain and sensitive to developments outside the biomass sector. The introduction of new dedicated bioelectricity plants provides an additional market for imported biomass. Even though most of these plants are designed to make use of local resources, they are more likely to accept a wider variety of materials compared to co-firing.

Conclusions

The use of imported biomass for energy has increased greatly since 2002, largely due to the co-firing of biomass with coal. More dedicated biomass facilities for production of electricity and transport fuels are currently being installed. These should provide a permanent basis for the use of bioenergy in the UK, including the creation of new markets for imported biomass. The main driver for this expansion is the RO and RTFO. Since both frameworks allow participants to buy-out of their renewable energy obligations, there is a risk that the bioenergy market will not develop to the extent suggested by nominal

policy targets.

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1. General Introduction

The population of the UK stood at 60.6 million inhabitants in mid- 2006, giving average GDP per capita in the financial year 2006-07[1] of €32,013 (£21,824[2]) [2] [3]. The total land area of the UK is 24.2 million hectares (Mha), of which total agricultural land use accounted for 18.7 Mha (77%) and arable land for 5.6 Mha (23%). Total forest area accounted for 2.8 Mha in 2005, around 30% higher than the 1980 level [4].

1.1 Main Industries

The UK economy is dominated by the service sector which accounts for 74.4% of GDP, compared to 1% for agriculture, 6% for construction and 18.6% for other productive industries. In terms of gross value added, no particular industry dominate the 'other productive' sector. The largest of these industries are food and beverages; pulp, paper, publishing and printing; and chemicals, each accounting respectively for around 2% of GDP in 2003. In 2006, agriculture, forestry, hunting and fishing employed 434,000 people (1.4% of the labour force) [5]. The largest arable crops by area are wheat, barley and oilseed rape, accounting for 42%, 20% and 12% of the agricultural land area respectively [6].

1.2 CO_2 Reduction Requirements

In 2004, UK emissions of greenhouse gases (GHG) were 656 megatonnes (Mt) of CO_2 equivalent ($MtCO_2eq$), 15% lower than the Kyoto baseline. Emissions since 1990 have fallen in all sectors except residential and transport, although emissions from the energy sector have risen by 5.5% since 2000. Under the Kyoto Protocol, the UK is committed to reducing GHG emissions by 12.5% compared to 1990 levels by 2010. An actual reduction of 19.4% is expected by that time [7]. However, it is less likely that the UK will meet subsequent GHG emissions and renewable energy targets (see Section 2).

1.3 Domestic Energy Production and Consumption[3]

In 2006, total UK consumption of primary energy was 9.7 EJ (232.3 Mtoe), compared to indigenous production of 8.2 EJ. Natural gas was the largest single source, accounting for 38.4%. Hydroelectricity, renewables and waste accounted for 2.1%, twice the level recorded in 1997. The UK was a net importer of primary energy in 2006. Most notably, the equivalent of 76% of primary demand for coal and 23% for gas were imported. Though the UK is a net importer of primary oils, there is also substantial domestic production and export as well as a net export of processed petroleum products (by energy content), as illustrated in Figure 1.

[1] 01 May 2006 – 31 April 2007
[2] All currency conversions assume £1 = €1.46689. The (non-weighted) average exchange rate for 2006 as per http://fx.sauder.ubc.ca/cgi/fxdata
[3] All references in this section are from the Digest of UK Energy Statistics [8] unless otherwise stated.

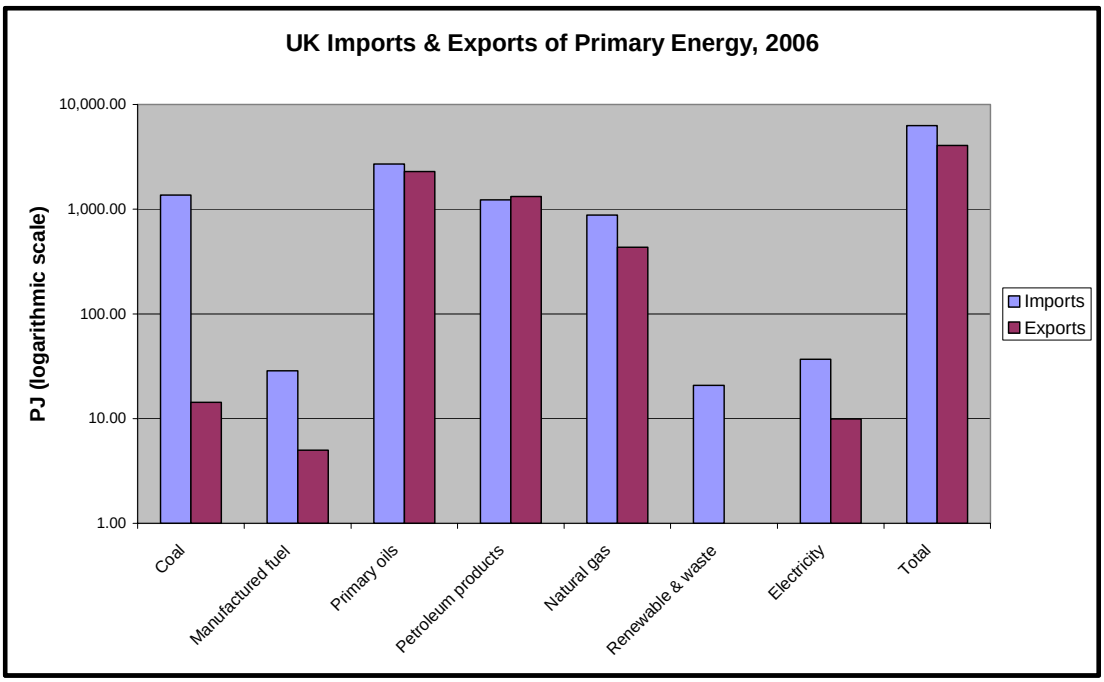

Figure 1: UK Imports & Exports of Primary Energy, 2006
NB: Primary Energy (in PJ) is shown on logarithmic scale

1.4 Domestic Electricity Production

Total electricity supplied in the UK was 380 TWh (1.4 EJ), a breakdown by source is shown in Figure 2.

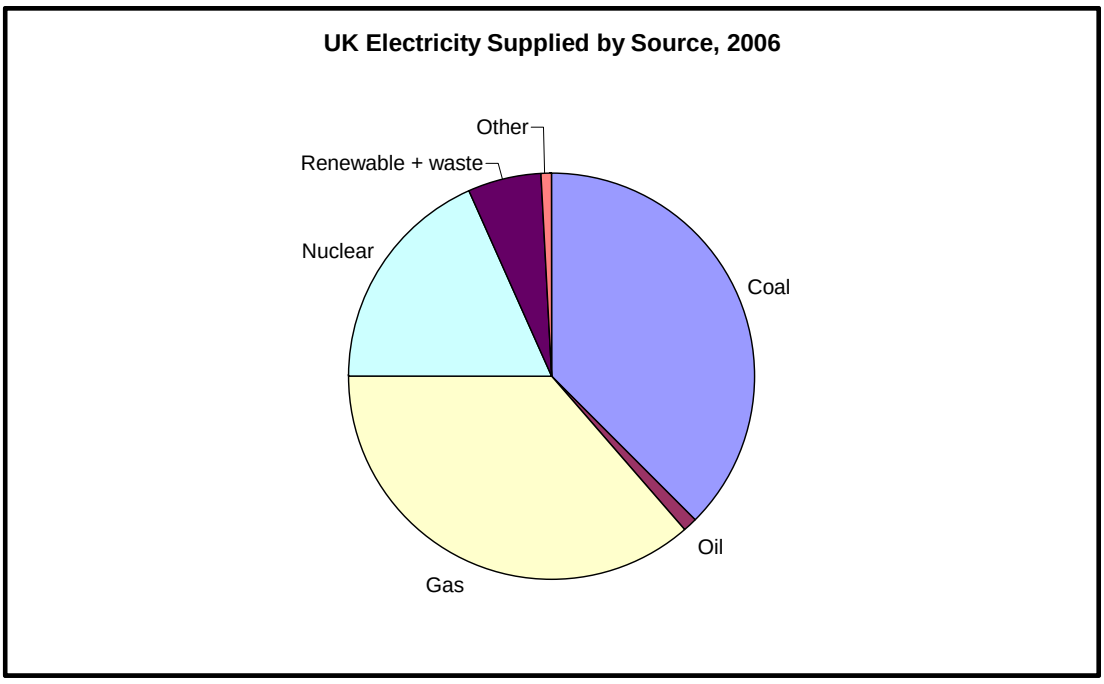

Figure 2: UK electricity supplied by source
NB – renewables + waste category includes some non-biodegradable waste

Electricity generated from renewable sources in 2006 was 18 TWh, compared to 10 TWh in 2000. In absolute terms, the greatest growth in generation has been from

landfill methane combustion, while the proportional growth in co-firing of biomass with fossil fuels has also been rapid.

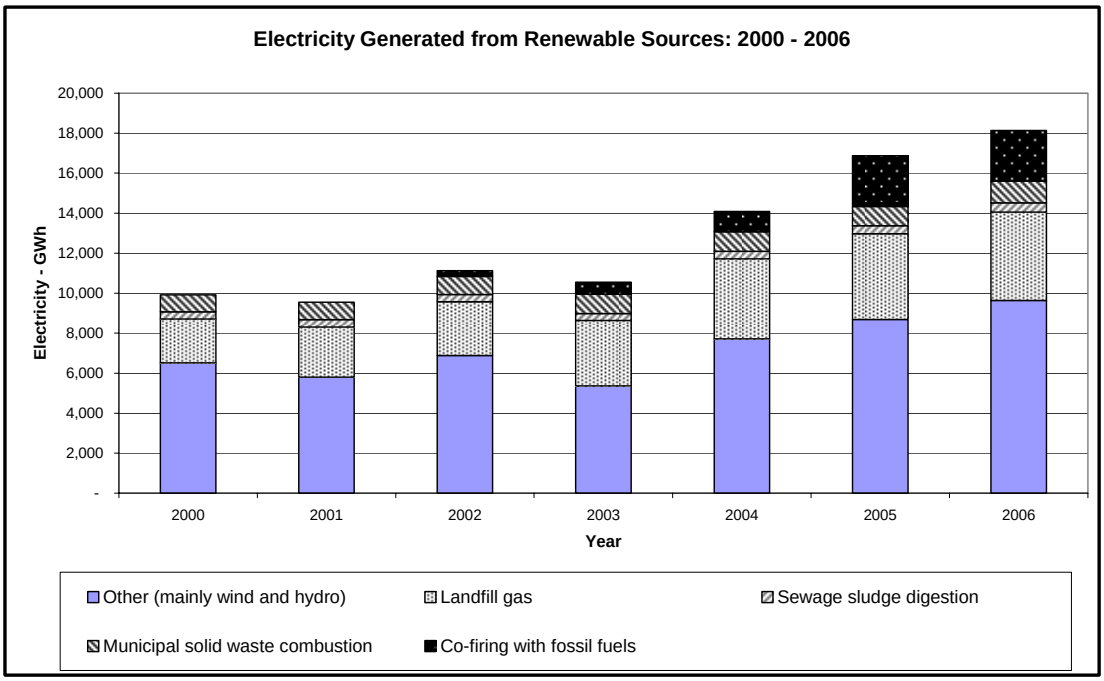

Figure 3: Electricity generation from renewable sources, 2000 - 2006
NB – Municipal solid waste combustion refers to biodegradable element only

In 2006, renewable sources accounted for 4.5% of electricity generation. In the heat market, 20.6 PJ of renewable primary fuel was used, of which 15 PJ consisted of wood and straw combustion. In total, the UK heat market is estimated to account for over a third of UK primary energy consumption [9], a total demand of over 3.2 EJ.

2. Policy Objectives

2.1 GHG Emissions Targets

The overall aim of UK Energy Policy is to achieve by 2050 a 60% reduction in CO_2 emissions compared to 1990. Caveats to this goal include maintaining reliability of energy supplies, economic competitiveness and productivity and ensuring adequate, affordable heating for households [10]. A draft law, the Climate Change Bill, has been introduced in 2007 which, in its current form, would see the 60% reduction become a legally-binding target, with the 'emissions budget' set in 5-year tranches and monitored by an independent committee with the goal of reaching the 60% target by 2050 [11]. The UK also has a domestic commitment to achieve a 20% reduction in CO_2 emissions by 2010. According to current projections, this target is unlikely to be achieved.

2.3 Renewable Energy Targets

Aside from the emissions reduction targets mentioned above, the UK has a domestic target to achieve a 10% share of electricity supply from renewable sources by 2010, increasing to 20% by 2020 [7]. Recent analysis shows that the 2010 target is unlikely to be met. There are several other energy and emissions targets active in the UK that are specifically linked to the cap-and-trade schemes designed to enforce them. These are discussed in Section 3.

The UK currently has no target to increase the share of renewables in energy consumption overall. It is possible that such a requirement will appear as part of the burden-sharing agreement under the 2007 Spring Council commitments to an EU-wide reduction in GHG emissions, improvement in energy efficiency and minimum penetration of renewables in overall energy supply (all by 20%) [12].

2.4 UK Biomass Strategy

In recent years, the UK has had no overall strategy for the role of biomass and bioenergy, although biomass is explicitly included or indirectly affected by various energy and waste policy measures. In 2007, the first UK Biomass Strategy document was published as part of the Energy White Paper [13]. Although this document does not contain specific new targets or policies for UK bioenergy, it does provide a strategic overview of the potential role for biomass in existing policy commitments.

3. Mandatory Targets, Fiscal Incentives and Other Policy Measures

This section of the report is divided into 3 parts. The first two parts examine the transport fuel and electricity markets respectively. These markets are the focus of the two main policy drivers for UK bioenergy - the Renewables Obligation (RO) in the electricity market and the Renewable Transport Fuels Obligation (RTFO) in the transport fuels market. Both policies impose a statutory duty on energy suppliers to supply a specified percentage of their product from renewable sources, supported by a system of tradable credits enabling the industry as a whole to meet the specified targets in the most cost-effective way. The third part of the section discusses other markets where support for biomass and bioenergy is offered but is less systematic.

3.1 Renewable Transport Fuels

The RTFO

The main policy measure to encourage renewable transport fuel is the RTFO. This is an obligation placed on transport fuel suppliers to supply renewable fuels equivalent to 2.5% of total road transport fuel sales in 2008/09, rising to 5% in 2010/11 and beyond [14]. The blends stipulated in the obligation are expressed on a volumetric basis and are therefore substantially below the reference value of 5.75% set out in the European Biofuels Directive [15] (5% biofuel by volume is equivalent to 3.4% and 4.4% by energy content for bioethanol and biodiesel respectively [16]). Although the RTFO is not specifically aimed at the promotion of biofuels, it is likely that bioethanol and biodiesel will form the overwhelming majority of renewable fuels initially consumed under the obligation. Biogas is also eligible while other fuels may qualify as they become available. In order to limit the cost of the RTFO to consumers, suppliers are permitted to trade RTFO certificates rather than produce a quantity of biofuel exactly equivalent to their obligation. In addition, the RTFO includes a buy-out mechanism whereby suppliers can pay the buy-out price, initially 15p (€0.22) per litre, instead of fulfilling their obligation to supply renewable transport fuel[4].

The RTFO does not offer differentiated levels of support to biofuels depending on their origin, social and environmental impacts or demonstrable GHG emissions savings. However, the RTFO system does include a reporting framework that obliges each fuel supplier to provide information concerning the carbon emissions and sustainability implications of their biofuel. Information concerning the environmental

[4] The buy-out fund is recycled to holders of RTFO certificates at the end of the year, providing an additional incentive to meet the obligation through supplying renewable fuel. The same principle applies to renewable electricity under the RO.

impact of each supplier's biofuel will then be published by the RTFO administrator. Although suppliers can provide as much or as little information as they like regarding the origin of their fuel, when no information is provided the carbon emissions and sustainability of the fuel will be calculated on a 'conservative' basis using default values that represent the worst common practice. The intention of the reporting mechanism is to encourage suppliers to supply the most sustainable biofuels and engage actively in the improvement of processes along the supply chain. After 2011, the eligibility of biofuels towards future RTFO-style targets may be directly linked to their environmental and social performance [17].

In addition to the RTFO, bioethanol and biodiesel benefit from reduced levels of fuel excise duty compared to petrol and diesel. For both fuels, duty of 27.10p (€0.40) per litre is charged compared to 47.10p (€0.69) for the least polluting fossil fuel equivalent. The combined effect of the duty incentive and the buy-out fund is to offer a fiscal incentive of 35p (€0.51) per litre of biofuel, up to the level required for RTFO compliance. Production cost comparisons for petrol, diesel and their biofuel equivalents indicate that the duty incentive should be sufficient to encourage suppliers to participate in the RTFO rather than pay the buy-out price [18] [19]. Biofuels also benefit indirectly from the Enhanced Capital Allowance Scheme that allows 100% of the capital cost of low carbon vehicles and refuelling infrastructure to be deducted from businesses' taxable profits.

3.2 Renewable Electricity

The RO

The RO was introduced in 2002 as a means of meeting the domestic target to supply 10% of electricity from renewable sources by 2010. The RO operates in a similar fashion to the RTFO, with mandatory caps set annually and the ability for suppliers to trade RO certificates (ROCs) or pay into a buy-out fund if they are unable to meet their obligation through ROCs generated in-house[5]. Although the level of the RO will be 10.4% in 2010/11, it is projected that only 8.1% of electricity supply will come from RO-eligible renewables in 2010 [20]. The contributions of renewable electricity and buy-out payments to the overall obligation are shown in Table 1.

Table 1: Contribution of renewable electricity supply and buy-out fund payments to the Renewables Obligation in England, Wales, Scotland and Northern Ireland

	2002-03	2003-04	2004-05	2005-06	2006-07
Total Obligation (MWh)	9,261,568	13,627,412	15,761,067	18,032,904	21,629,676
Total Number of ROCs Presented	5,451,449	7,610,144	10,855,848	13,699,317	14,612,654
% Obligation met by ROCs	58.9	55.8	68.9	76.0	67.6

Source: [21] [22]

The RO is guaranteed to remain in place until 2027, with level of obligation set at 15.4% of electricity supplied from 2015/16 onwards. However, recent changes have been proposed to both the level of the obligation and the nature of the RO (see Biomass & the Future of the RO section below).

[5] Electricity suppliers (the obligated party under the RO) do not necessarily generate their own electricity. The ability to trade ROCs is therefore an essential part of the RO.

Other Support Policies for Electricity from Biomass

Several other policy measures are available to support the use of biomass for electricity, though most are not exclusively aimed at biomass or electricity production. Some of these measures are listed below:

- **Climate Change Levy (CCL)** This is a tax on energy use other than in the domestic sector. Users must pay 0.43p (€0.63) per KWh of electricity consumed, 0.15p (€0.22) per KWh for gas, 0.96p (€1.41) per kg of liquid petroleum gas and 1.17p (€1.72) per kg for solid fuels and fuel commodities. Electricity supplied from renewable sources, including biomass is exempt from the levy, as long as a Levy Exemption Certificate (LEC) is supplied to the consumer together with the electricity [23].

- **European Emissions Trading Scheme (EU-ETS)** Biomass is considered to be carbon-neutral under EU-ETS, allowing installations to replace fossil fuels with biomass in order to meet their compliance obligations or generate revenue from the sale of credits. Total annual allowances of 246 $MtCO_2$ have been created under the UK allocation plan for the current phase (2008-2012). Slightly more than half of these allowances (54%) have been awarded to electricity and CHP producers [24].

- **Energy Crop Schemes** Since before the introduction of the RO, government policy has explicitly favoured the cultivation of dedicated energy crops for bioenergy use over the use of residues and other biomass. Energy crops are supported more generously under the RO than other biomass. In addition, farmers can claim an establishment grant of £1,000 (€1,467) per hectare for planting SRC willow or £920 (€1,350) for miscanthus. Farmers can also claim up to £2,000 (€2,934) to cover the cost of setting up an SRC producer group and purchasing capital equipment. Both schemes operate on a stop-start basis and accept applications in a series of rounds rather than providing systematic support to biomass growers [25].

Biomass and the Future of the RO

As Figure 4 demonstrates, the RO has been successful in encouraging the co-firing of biomass with coal in UK power stations while the contribution of non-co-fired biomass (the yellow band) has increased little since the scheme's inception.

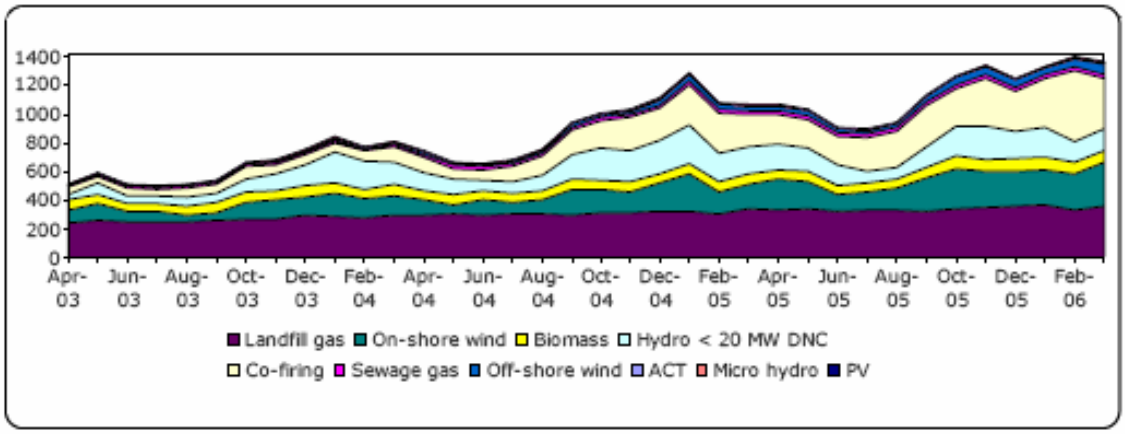

Figure 4: Renewable Electricity Supplied under the RO, by technology
Source: OFGEM, Annual Report 2005-06 [21]

The dominance of wind, landfill gas and co-firing within the RO is a result of the scheme's technologically-neutral design that awards 1 ROC per MWh of electricity supplied across all eligible technologies. This means that technologies with low unit costs and capital investment requirements are automatically favoured. The growth in co-firing of biomass may have been more rapid were it not for a cap imposed on the percentage of ROC claims permitted to come from co-firing. In 2005/06, suppliers were allowed to claim only 25% of ROCs from co-firing, a limit that was reduced to 10% in 2006/07.

Given that a technologically-neutral framework is likely to provide more support than necessary to some technologies while preventing others from developing, the Government has proposed that the ROC system be changed to a 'banding' mechanism where some technologies receive more ROCs per MWh than others [26]. As Figure 5 shows, the proposed bands award only 0.25 ROCs/MWh for co-firing but place electricity generation in dedicated biomass plants in a higher support bracket than wind, hydro and waste. Combustion of energy crops in dedicated biomass plants is given the highest support of level of all, equal to that awarded to wave power and advanced biomass conversion technologies and 8 times greater than that awarded to co-fired biomass.

Band	Technologies	Level of support ROCs/MWh
Established	Sewage gas; landfill gas; co-firing of non-energy crop (regular) biomass	0.25
Reference	Onshore wind; hydro-electric; co-firing of energy crops; EfW with combined heat and power; other not specified	1.0
Post-demonstration	Offshore wind; dedicated regular biomass	1.5
Emerging technologies	Wave; tidal stream; advanced conversion technologies (anaerobic digestion, gasification and pyrolysis); dedicated biomass burning energy crops (with or without CHP), dedicated regular biomass with CHP; solar photovoltaics; geothermal	2.0

Figure 5: Proposed banding levels for the RO post-2009
Source: [20]

In addition to banding, the proposal for reform of the RO includes the introduction of 'headroom' mechanism to maintain the price of ROCs as the level of supply reaches the obligation level. Under the current system, uncertainty over the future value of ROCs[6] means that an incentive to under-achieve is inherently built in to the RO system [27]. Under the headroom proposal, the Government will estimate the level of renewable generation likely to take place in the following year. If this estimate is significantly below the level of the obligation[7], then the obligation will be raised, thereby reducing the risk of a fall in the ROC price due to oversupply of renewable electricity.

3.3 Other Biomass Support Measures

In addition to the policies mentioned above, there are 3 main grant programmes that contribute towards the cost of installing small-scale renewable energy systems. These are the Low Carbon Buildings Programme phase 1[8] and 2[9] and the Bioenergy

[6] which depends crucially on the size of the buy-out fund and hence on how much of the obligation is being met by renewable generation in the industry at large
[7] If the projected generation level * 1.06 is still below the obligation [28]
[8] www.lowcarbonbuildings.org.uk

Capital Grants Scheme. Each of these schemes is stop-start in nature since a limited amount of funding is available to the scheme overall, applications are accepted in a series rounds and the precise nature of each scheme remains uncertain from one round to the next. The latest funding available under each scheme is briefly described below.

- ***Low Carbon Buildings Programme (Phase 1)*** – From 2006-2009, a total of £18m (€26.4m) has been made available to households to contribute to installation costs of small-scale heat and electricity applications. Various technologies are eligible including a contribution of 20%[10] and 30%[11] towards the cost of pellet stoves and wood-fuelled boilers respectively.
- ***Low Carbon Buildings Programme (Phase 2)*** – Phase 2 of the programme provides up to 35%[12] of the project cost for installation of pellet stoves and wood-fuelled boilers (and non-biomass technologies) for public sector and non-profit organisations.
- ***Bio-energy Capital Grants Scheme*** – The latest (3rd) round of this scheme offered support to the development of biomass heating systems in the industrial, commercial and non-profit sectors. Grants of up to 40%[12] of the difference between the proposed scheme and the fossil fuel alternative were available.

4. Biomass Resources

Table 2 shows an estimate of the total UK Biomass Resource availability, compared with potential resources that could be made available, given current land-use. The table is primarily based on the updated Biomass Task Force Assessment [13] which should be viewed as a measure of techno-economic potential since alternative uses for biomass (for example, leaving straw in-field or using waste as materials) are deducted from the total.

As Table 2 shows, planting grants for energy crops (SRC and miscanthus) have been awarded to an area of 15,546 ha. These grants are likely to cover the overwhelming majority of such plantations in the UK. Since this figure includes recently approved grants where plantation has not yet taken place, it is uncertain whether the entire area will be planted given historically high wheat prices.

The UK's potential to supply energy from crops has been estimated at 122-151 PJ by the Carbon Trust [29]. This assumes that woody energy crops are grown on 680,000 ha., an area roughly equivalent to the area under setaside land at the time of the study (the 2006 setaside area was 438,000 ha [6]). The European Environment Agency [30] estimated that in 2010, 142 PJ could be made available from 824,000 ha assuming a mixture of energy crops are cultivated and some land is released from cultivation as a result of CAP reform. Research is ongoing into the suitability of large areas of UK land for energy crop cultivation. In England and Scotland, 39% of agricultural land (7.3 Mha) is classed as Grade 3. This is considered average quality agricultural land suitable for extensive arable farming. Andersen et al. [31] use their own classification system to determine that around 2 Mha of land in Scotland are suitable for cultivation of SRC, sufficient to provide 3.3 GW of power.

Additional biomass for energy markets may be available from arable crops such as wheat and oilseed rape. Wheat production in 2006 was 14.7 Mt of which 2.2 Mt was exported (*net* exports were 1 Mt). This surplus production has been identified as a

[9] www.lowcarbonbuildingsphase2.org.uk
[10] Capped at £600 (€880)
[11] Capped at £1,500 (€2,200)
[12] Capped at £1 million (€1,466,890)

feedstock for UK bioethanol production (see Section 5). In addition, 0.51 Mt of oilseed rape were grown either on setaside land or with funding under the European Energy Crops Aid Scheme in 2005 (compared to total production of 1.9 Mt).

Table 2: Assessment of current and potential availability of biomass for energy in the UK

Resource	Current Availability (1)		Potential Availability from Existing Land Use	
	Odt	PJ	Odt	PJ
Sawmill Residue, Arboricultural Arisings and Municipal Waste Wood	813 278 (2)	13.79 – 14.26	6 875 000	116.6 – 120.6
Energy Crops	155,463 – 222,787 (3)	2.8 – 4.0	155,463 – 222,787	2.8 – 4.0
Paper & Card and Garden/Plant Waste	2 673 407 (4)	11.2 – 19.9	6 561 000	27.4 – 48.9
Straw	200 000 (5)	2.7 – 3.3	3 000 000	40.5 – 49.5
Sewage Sludge (dry solids)	340 000 (6)	5.1 - 6.8	340 000	5.1 – 6.8
Food Waste	1 628 978 (4)	3.7 - 6.5	10 040 000	9 - 16
Animal Waste	N/A	N/A	3 998 400	32.3 – 36.31
Total	5 811 126 – 5 878 450	39.3 - 54.8	30 969 863 - 31 037 187	233.7 – 282.1

Source: [13] unless otherwise specified

Notes:

(1) Available quantities taken from various sources, see below. Calorific values assumed identical to [13] and adjusted proportionately.

(2) Sawmill Residues, arboricultural arisings and clean waste not sold to wood processing industry from [32].

(3) Assumes 15,546 ha, the area of woody energy crops in receipt of public grants.

(4) Potential assumes recovery rate can be increased to 27%, as per [13]. Current level assumes 11% recovery.

(5) 200,000t is the amount of surplus straw that is currently burned for energy, as per [13].

(6) Includes all sewage sludge not applied to farmland or used in land reclamation.

5. Consumption of Biomass for Energy

5.1 Biomass consumption in 2006

A breakdown of UK biomass use for energy, as presented in the UK energy statistics [8], is provided in Table 3. The use of this information is limited by the highly aggregated nature of the *Poultry litter etc.* category. Nevertheless, the table demonstrates that the overwhelming majority of UK biomass use is for electricity

generation (most of which is co-firing) and that over half of this material is imported. The final consumption in the sectors identified consists entirely of biomass used for heat generation.

Table 3: Commodity Balance for Biomass, 2006

Biomass input (TJ) (Gross Calorific Value)	Wood Waste	Wood	Poultry litter, meat and bone, biomass, straw, farm waste and SRC	Sewage Gas	Landfill Gas
Production	3,391	8,541	27,968	8,374	61,337
Import	-	-	20,808	-	-
Total Supply	3,387	8,541	48,776	8,374	61,337
Electricity Generation	-	-	45,762	6,364	60,750
Final Consumption	-	-	-	-	-
Industry	3,391	-	-	-	586
Domestic	-	8,541	-	-	-
Public Administration	-	-	-	2,010	-
Agriculture	-	-	3,014	-	-

Source: [8]

In addition to the biomass use identified in Table 3, 192,000 t of biodiesel were produced in the UK in 2006 [33].

5.2 Major Consumers of Biomass

Co-firing

In 2006, 2.5 TWh of electricity were generated through co-firing of biomass with coal. This is slightly lower than the amount co-fired in 2005. The reduction is most likely due to the reduction in maximum level of co-firing under the RO, from 25% to 10%, from April 2006[13]. Before the proposed move to a banded RO, the future of co-firing was uncertain as the previous RO required its progressive elimination and a requirement to use increasing proportions of energy crops as a feedstock. With the introduction of banding, these restrictions would be removed, offering co-firing a permanent role within the RO, albeit at a lower level of support per MWh. Since 2002, almost all large coal-fired power stations have co-fired biomass, at least on a trial basis. It is not yet known how banding will affect the scale of co-firing, the composition of the biomass used (especially energy crop vs. other biomass) or the basis on which the option to use co-firing, as one of several renewable technologies, is treated by the electricity generating companies.

Table 4 shows some variety in the actions and publicly stated positions of the participating companies towards co-firing. This is not surprising since for some companies (like Drax Power) co-firing is crucial to the company's ability to generate ROCs while for others the role of co-firing is less important and support for co-firing could affect the viability of other renewable investments. In addition, although some companies have agreed contracts with suppliers of energy crops, these crops have

[13] This reduction, coupled with an increase in the overall RO from 5.5% to 6.7% amounts to a halving of the ROC-eligible level of co-firing.

not all been planted. The Drax contract alone represents more biomass than the upper limit for biomass from current plantations (see Table 2). Even if met in its entirety, this contract would represent less than 20% of the material required for the station to provide 10% of electricity from biomass[14]. If large-scale co-firing is to continue under a reformed ROC regime it will therefore rely on imported biomass and/or increased exploitation of domestic material such as forestry residues and wood waste.

Table 4: Recent developments in UK coal plant operators' position on co-firing

Company	Generating Capacity (MW, number of plants)	Comments	Sources
AES	520 (1 plant)	Co-firing not thought to be attractive under capped RO or banding.	[34]
British Energy	1,960 (1 plant)	Company opposed to removal of cap on co-firing and encouragement of energy crops	[35]
Drax Power Ltd	3,870 (1 plant)	Company has target for generating 10% of electricity from renewable sources and has a contract with a supplier for 300,000t of miscanthus.	[36] [37]
EDF Energy	3,980 (2 plants)	Company has acquired specialist biomass trading company RFSL (now part of EDF Trading Ltd.)	[38]
E.ON-UK plc	4,910 (4 plants)	Company has recently invested in dedicated bioelectricity plants (see Dedicated Biomass section)	
RWE npower	4,451 (3 plants)	Considering incorporating capacity for 10% co-firing (by heat input) at the planning stage for two new supercritical coal plants. One contract signed to supply 30,000t of SRC willow per year from 2009.	[39]
Scottish Power	3,456 (2 plants)	Seeking to secure 250,000t of energy crops for co-firing. Also developing new plant fired by sewage and wood waste	[40] [41]
Scottish & Southern Energy	3,916 (2 plants)	In 2006, company invested in direct injection biomass burners capable of supplying 10% of input energy.	[42]

[14] Assumes electrical generation of 26.97 TWh in 2006, same calorific value as assumed in Table 2 and 40% plant efficiency

Dedicated Biomass Plant

Interest in dedicated biomass plants has increased noticeably in recent years, with two new plants coming on-stream in 2007 and others in development. Table 5 gives details of these facilities.

Table 5: Current and proposed dedicated bioelectricity plants over 5 MW capacity (excluding sewage).

Plant Name	Generating Capacity (MW)	Proposed Feedstocks	Operating Company
Active, consuming energy crops and woody biomass			
Stevens Croft, Lockerbie	42	Sawmill and forestry residues, energy crops	E.ON UK plc www.eon-ukplc.com
Wilton 10, Teesside	10	SRC, Forestry residue	SembCorp Utilities (UK) Ltd. www.sembutilities.co.uk
Proposed, consuming energy crops and woody biomass			
Blackburn Meadows, Sheffield	25	Recycled wood waste, potentially energy crops	E.ON UK plc www.eon-ukplc.com
Nevis Power, Newport	49	Wood (domestic and imported)	Welsh Power Ltd. www.welshpower.com
Port Talbot Biomass Power Station, Port Talbot	14	Forest biomass, sawmill residue	Eco2 Ltd. www.eco2.uk.com
Port Talbot Renewable Energy Plant	350	Imported wood chip	Prenergy Power Ltd. www.prenergypower.com
Sleaford Renewable Energy Plant	40	Cereal straw	Eco2 Ltd. www.eco2.uk.com
WINBEG, Winkleigh	23	Miscanthus, wood waste	Peninsula Power www.peninsulapower.co.uk
Active, consuming waste and residues			
Ely Power Station	38	Cereal straw	EPR Ltd. http://www.eprl.co.uk
Eye Power Station	12.7	Poultry litter. Charges a gate fee to burn feathers and other agricultural waste. Plant also produces fertiliser	EPR Ltd. http://www.eprl.co.uk
Glanford Power Station	13.5	Originally designed to burn poultry waste. Now charges gate fee to burn meat and bone marrow.	EPR Ltd. http://www.eprl.co.uk
Goosey Lodge Power Plant	16	Incineration of various waste materials	Wykes Engineering Ltd. http://www.wykesengineering.co.uk
PDM Widnes	9.5	Food residues	PDM Group http://www.pdm-group.co.uk
Thetford Power Station	38.5	Poultry litter. Fertiliser produced as a by-product	EPR Ltd. http://www.eprl.co.uk
UPM Shotton Paper Mill	19.7	Waste from paper recycling process and other biomass	UPM Kymmene (UK) Ltd. http://w3.upm-kymmene.com/
Westfield Biomass Plant	9.8	Poultry litter. Fertiliser produced as a by-product	EPR Ltd. http://www.eprl.co.uk

As Figure 4 shows, electricity generation from biomass in dedicated plants has traditionally played a minor role, with 797 GWh generated from biomass other than landfill gas and sewage sludge in 2006 [8]. Table 5 shows that most existing biomass plants are fed by local agricultural residues, in particular animal waste. Most new plants are designed to use woody biomass such as forestry residues wood waste and energy crops. If completed, the Sleaford Renewable Energy Plant will require 240,000 tonnes of baled straw per year [43]. Assuming a similar amount is consumed by Ely Power Station (which currently claims to be the world's largest straw-fired power station), the stations' combined consumption would amount to 16% of the surplus straw availability estimated in Table 2. Most of the proposed plants have a capacity under 50 MW and have identified a specific local biomass resource to form a large fraction of the feedstock supply. However, both the Wilton 10 and Stevens Croft plants are equipped with bubbling fluidised-bed boilers capable of accepting a wider variety of fuels, raising the possibility that a variety of domestic and imported feedstocks will be used. A notable exception to the tendency to identify a local fuel source is the Port Talbot Renewable Energy Plant which, if constructed, will have a capacity 7 times larger than that of the next largest biomass plant. This plant will be situated at a vacant site near to a deep-water harbour. The proposed feedstock for the plant is imported wood chip, with an estimated annual import requirement of 2.5-3 Mt per year [44].

Biofuels for Transport

The UK produced 192,000 tonnes of biodiesel in 2006. The two main producers are Biofuels Corporation[15], who produced 101,140t of biodiesel from domestic and imported vegetable oils in the year 2006/07, and Argent Energy, who produce biodiesel from tallow and waste cooking oil in a 45,000t capacity plant. Several more biodiesel and bioethanol plants have been proposed, (see Table 6). It is not certain how much of this capacity will be realised given the difficulties that biofuel producers have faced due to high feedstock prices and competition from subsidised imports of biodiesel from the USA. These factors are cited as contributing to the de-listing of Biofuels Corporation from the Alternative Investment Market and the scaling-back of D1 Oils' expansion plans [45] [46].

All of the bioethanol plants listed in Table 6 intend to use wheat as a feedstock, with the exception of the British Sugar plant. If all succeed in producing ethanol to capacity, 1.25 Mt of ethanol would be produced, requiring 4.34 Mt of fresh wheat as feedstock[16]. This is substantially more than the current UK wheat surplus (1Mt net surplus in 2006), implying that grain would need to be imported or compete with current non-energy uses. The total capacity of the biodiesel plants listed in Table 6 amounts to 1.28 Mt – 1.87 Mt, the equivalent of 3.3 – 4.9 Mt of rapeseed[16]. The combined production of biodiesel and bioethanol from the plants identified is also sufficient to meet the projected demand for UK transport biofuels in 2010 (see Trend Analysis Section below).

International wheat prices in November 2007 were over 50% higher than in November 2006 [48] while prices for soybean oil and palm oil increased by over 35% year-on-year [49]. It is not yet known whether prices will fall in 2008 in response to anticipated extra planting. Nevertheless, some of the investments listed in Table 6, where large amounts of invested capital are dependent on a volatile commodity market, may not go ahead to the extent listed.

[15] www.biofuelscorp.com
[16] Assumes 362 l ethanol / t wheat (fresh) and 422 l biodiesel / t rapeseed (fresh) as per [47]

Table 6: Major UK biofuel proposed plants

	Planned Capacity	Comments
Biodiesel		
Argent Energy	195,000t	Feedstocks are used cooking oil and tallow. Current plant has 45,000t capacity. Additional 150,000t plant planned.
Biofuels Corporation	250,000t – 650,000t	Produced 101,140t in 2006. Existing plant has nominal 250,000t capacity. Two additional units planned.
D1 Oils	142,000t – 320,000t by end of 2008	Long-term business plan is based around development of jatropha. Company refines conventional vegetable oils at present.
Greenergy	200,000t by end of 2008	
Ineos	500,000t by mid-2008	
Bioethanol		
Ensus	400 Ml. (318,750t)	Intended feedstock is imported wheat.
BP	420 Ml. (334,688t)	Intended feedstock is wheat. Facility includes biobutanol demonstration plant.
British Sugar	55,000t	Intended feedstock is sugar beet
Green Spirit Fuels	300,000t	Company is an offshoot of Wessex Grain. First plant (100,000t capacity) due to open in 2008.
Vireol	150,000t	Intended feedstock is local wheat and grain.
Losonoco	150,000t	Intended feedstock is local wheat

Source: Websites of companies listed

Trend Analysis of Domestic Production / Consumption

Modelling was undertaken, as part of the 2007 Energy White Paper, into the likely effect that banding of the RO would have on the volume and composition of renewable electricity generated in the UK [50]. Figure 6 shows the volume and composition of renewable electricity generated under the modelling scenario that matches the proposed banding regime (see Figure 5). This analysis predicts that co-firing will generate 2.9 TWh of electricity in 2010/11, rising to 5 TWh by 2014/15, all

of this taking place in existing coal-fired power stations. Dedicated biomass combustion is estimated to generate 1.6 TWh by 2010/11 and 3 TWh by 2020/21. From 2012/13, biomass CHP and combustion of energy crops in dedicated biomass plants are expected each to generate 0.3 TWh.

The projected level of biomass co-fired in this analysis is extremely sensitive to changes in model parameters that are not directly related to biomass, a finding that does not appear unreasonable given the multi-technology nature of the RO. For example, when limits are place on the build rate of wind energy projects, in order to simulate delays in the planning system, the rate of co-firing from 2010/11 onwards rises to 7.4TWh. This supports the notion that co-firing can be used as a marginal producer of ROCs due to its low capital investment requirements. If the level of co-firing is inherently volatile, it appears unlikely that co-firing will be able to provide the stable market necessary to encourage farmers to grow energy crops, which would in turn mean that UK co-firing would continue to rely on imported biomass.

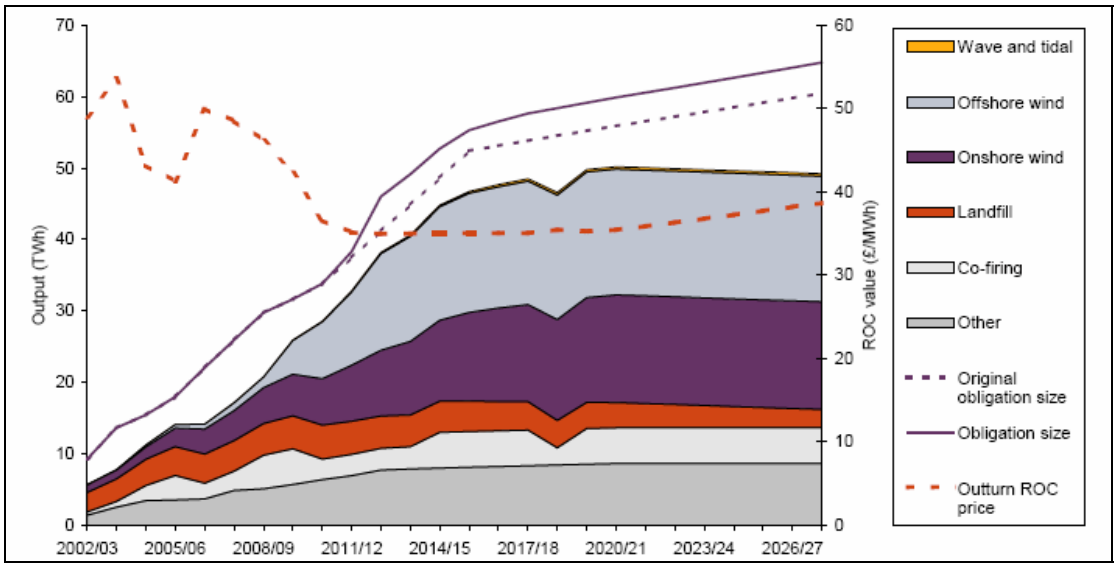

Figure 6: Projected renewable electricity generation and ROC price under banding
Source: [50]

For dedicated bioelectricity plants, the prediction made by the modelling may be pessimistic. The estimated generation of 1.6 TWh is equivalent to the plants listed in Table 5 running at a load factor of 25% (or 51% if the 350 MW Port Talbot plant is not built).

The Government Biomass Strategy [13] predicts that demand for biofuels under the RTFO will amount to 1.06 Mt of bioethanol and 1.28 Mt of biodiesel in 2010. If a linear regression model is applied to UK transport demand for petrol and diesel, the predicted demand is smaller at 819,000 t of bioethanol and 1.06 Mt of biodiesel.

6. Biomass Prices

Publicy available statistics on the prices of different biomass and fossil fuels are listed in Table 7.

Table 7: Prices of Fuels in the UK

Woody Biomass	€ / GJ	Source
Chip - Forest Woodfuel	2.93 - 4.40	[19]
Logs - Forest Woodfuel	1.47 - 2.93	
Arboricultural Arisings	2.93 - 4.40	
Waste – Clean	2.93 - 4.40	
Waste – Contaminated	0.73 - 2.20	
Pellets - Forest Woodfuel	5.87 - 7.33	
Pellets – SRC	7.33 - 8.80	
Pellets – Miscanthus	6.60 - 8.07	
Pellets – Domestic, delivered	8.80 - 11.74	
Energy Crops		
SRC	4.4 – 5.87	[19]
Miscanthus	3.67 - 5.13	
SRC (delivered)	8.58	[51]
Miscanthus (delivered)	7.26	
Imports		
Palm Kernels	7.63 - 8.65	[51]
Olive Residues	6.45 - 7.63	
Other Biomass		
Straw	2.20 – 3.67	[19]
'Typical' Imports	5.13 - 8.07	[19]
Fossil Fuel – industrial consumers *		
Coal	2.31	[52]
Heavy Fuel Oil	8.92	
Gas Oil	12.66	
Electricity	22.44	
Natural Gas	7.35	
Fossil Fuel – at power plants *		
Coal	2.13	
Oil	9.71	
Natural Gas	5.24	
Premium Unleaded (/l)	1.34	
ULS Diesel (/l)	1.4	

Notes: * Fossil fuel prices are 2006 averages, excluding VAT and Climate Change Levy

7. Biomass Import – Export, 2006

Little detailed data concerning imports and exports of bioenergy is available. This is due to the lack of precision of trade statistics, the commercial sensitivity of data and the fact that several common types of biomass can serve both energy and non-energy uses. Table 8 shows the 2006 imports and exports of types of biomass that have important energy uses. However, it should be noted that many of these products have important non-energy uses in the food, animal feed or material sectors.

CN Code	Description	Import Volume (t)	Import Value (€)	Export Volume (t)	Export Value (€)
Wood					
44012100, 44012200	Wood chips	148,337	9,173,584	58,263	5,239,843
44010000	Fuel wood	3,168	1,176,715	105,190	3,459,640
44013010	Sawdust	50,752	5,916,281	17,566	2,018,453
44013090	Wood waste and scrap	61,986	11,131,271	7,353	2,650,376
Tall Oil					
38030010, 38030090, 38070090	Tall Oil	58,616	21,532,881	1,046	2,083,192
Ethanol					
22071000	Undenatured	336,733	207,360,548	188,517	102,674,881
22072000	Denatured	92,247	51,126,127	5,629	5,829,367
29091900	ETBE	5,019	395,716,464	12,802	13,077,966
Vegetable Oil Residues					
23069011	Olive (<3% oil content)	36,664	3,365,480	-	-
23066000	Palm	909,872	69,613,403	3,761	427,375
23063000	Sunflower	392,453	41,749,454	12,504	1,322,492
Biofuels for Transport		Consumption (2005)		Production (2006)	
Biodiesel (t)		29,930		192,000	
Bioethanol (t)		67,734		-	

Table 8: Imports and Exports of Common Bioenergy Products in 2006

Source: [53] [54], classification of products taken from [55]

It is thought that imported biomass counts for the overwhelming majority of biomass co-fired. Figure 7 shows that vegetable oil co-products (palm, olive, shea and sunflower) accounted for over half of co-firing feedstocks in 2005. Tall oil and the majority of the wood pellet used in co-firing are also likely to be imported. It is unlikely that significant quantities of biomass were imported in 2006 for combustion in dedicated bioelectricity plants since the active plants listed in Table 5 are designed to use specific local resources. This may change when newer dedicated plants come onstream. Consumption of wood pellet fuel, particularly in municipal buildings such as schools, has developed in recent years as a result of the support measures mentioned in section 3.3. However, this sector is still small and does not register in official statistics.

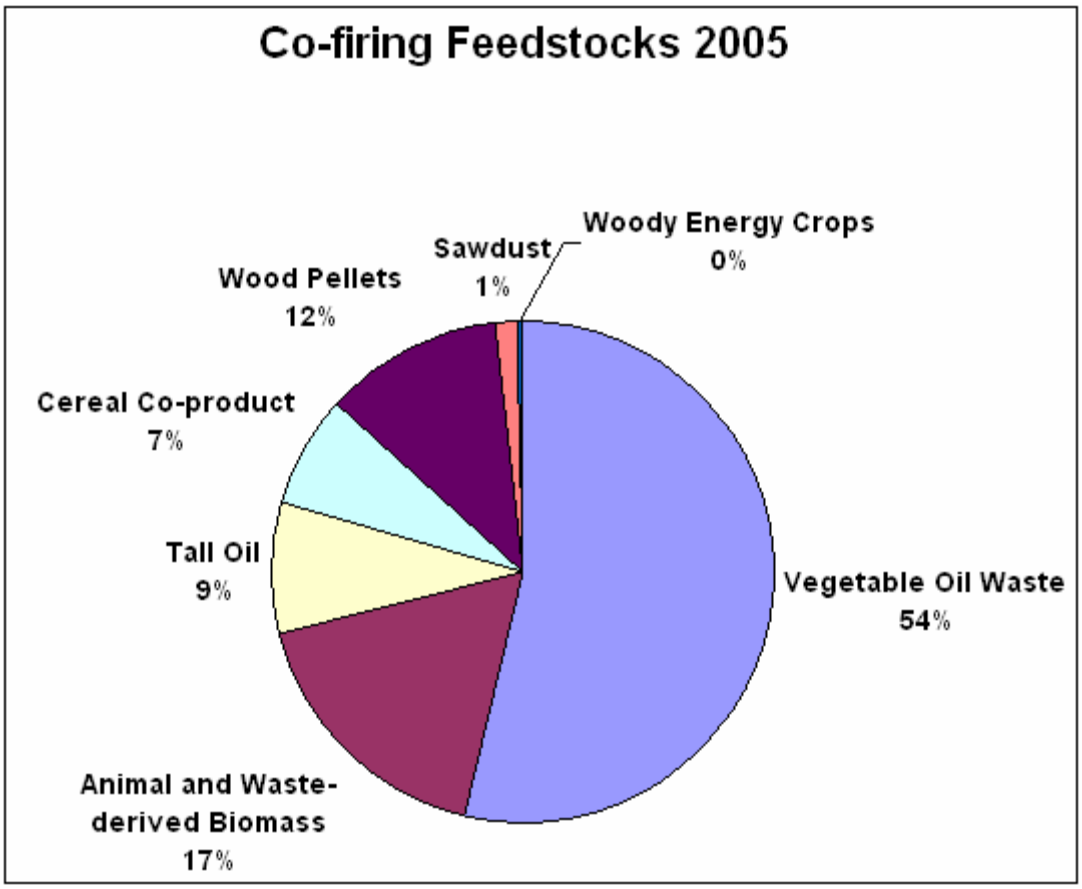

Figure 7: UK Co-firing Feedstocks, 2005
Source: [56]

8. Barriers and Opportunities for International Bioenergy Trade

In volumetric terms, the RTFO and reform of the RO appear to offer increased opportunities for UK bioenergy trade. The RTFO provides a guaranteed market for low blend biofuels. The planned ethanol production facilities listed in Table 6 would, if constructed and operating at full capacity, be able to supply almost all of the UK's projected 2010 ethanol demand. However, given that some of these plants may not be completed and that production costs for wheat ethanol can be more than twice those of Brazilian sugar cane ethanol [18], opportunities exist for large quantities of bioethanol to be imported. Opportunities for import of biodiesel, especially in the form of feedstocks such as vegetable oils or oilseeds, are probably greater than for bioethanol since the UK produces smaller quantities of oil crops and petrol demand has been falling year-on-year while diesel demand is growing [8].

The banded RO, if implemented, will provide greater opportunities for bioenergy trade than the previous RO regime. This is because the removal of quantitative caps on co-firing will allow operators to co-fire biomass whenever it is economically viable to do so. However, the viability of co-firing will be harmed by the reduction in the ROC-value awarded per MWh. The removal of the cap on the ROC-eligibility of co-firing and introduction of a headroom mechanism also reduce the 'game' element of the RO. This is because under the previous RO framework, co-firers who did not need to produce co-fired ROCs for their own needs faced the risk that no other supplier would be willing to buy them. Under banding, the risks associated with generating co-fired ROCs will be the same as those associated with generating ROCs from any other technology.

Despite the market created by the RO and RTFO, several factors could limit the extent to which bioenergy is encouraged under these frameworks. The potential demand for biomass is jeopardised by the existence of a buy-out price and the inclusion of biomass and other renewable technologies under the same incentive scheme. In addition, the banding of RO may encourage other renewable technologies over biomass. Also, if the RO is successful in encouraging the development of dedicated bioelectricity plants at the expense of co-firing, then less biomass will be consumed per ROC produced, reducing the size of the biomass market compared to a market dominated by co-firing. As discussed in section 5.2, the size of the bioelectricity market is also sensitive to several factors that are not directly related to biomass. This situation, coupled with the 'banding down' of co-firing under the RO, could enhance the role of co-firing, using imported biomass, as the most liquid and therefore marginal generator of ROCs, producing a varied amount from year to year depending on biomass availability and conditions elsewhere in the renewable electricity market.

Outside of the transport and electricity markets, incentives such as EU-ETS, the Climate Change Levy and the Low Carbon Buildings Programme provide opportunities for development of small-scale projects in the heat and electricity markets. However, the amount of this support is limited and only available on a case-by-case basis. Aside from the financial barriers to renewable heat, a stakeholder consultation [57] identified key barriers to renewable heat development as planning (difficulty in obtaining permission for new builds and retrofitting of existing premises), fuel supply (difficulty in obtaining long-term supply contracts, leading to uncertainty for investors) and uncertainties associated with a new market (concerns over product quality and availability of after-sales service).

9. Conclusions

The main conclusions from this report are the following:

- The use of biomass in the electricity and transport markets is growing in the UK. This growth is likely to continue as obligations in these markets demand progressively greater shares of renewable energy.

- Interest in the generation of electricity in dedicated biomass plants is particularly strong with the construction of 500 MW of generating capacity under consideration.

- High feedstock costs appear to have slowed the development of a UK biofuel production industry. This appears to have had a proportionally greater impact on biodiesel producers. This is perhaps because biodiesel producers are more reliant on international commodity markets for feedstocks.

- High costs could slow the development of a biomass market in both the electricity and transport sectors since both sectors are dependent on policies that contain the ability to buy-out instead of supplying renewable fuel. In addition, the design of the RO means that several different renewable electricity technologies are interdependent, increasing the uncertainty regarding the long-term role of biomass.

- Anecdotally, the use of renewable heat is growing in the UK, particularly in the municipal and institutional sectors. However, this growth is too small to register in national energy statistics. The development of the renewable heat sector is not supported by systematic policy incentives such as a feed-in tariff or obligation. Therefore the sector is still dependent on grant funding and isolated local initiatives.

- Apart from cultivation of woody crops, cereals and oilseeds as energy crops, the UK has over 200 PJ of domestic biomass resources that could be made available for energy use. Some of these resources have been identified as feedstocks for new dedicated bioelectricity plants.

- The UK will have to import significant quantities of biomass, in particular vegetable oils or oilseeds, in order to meet targets for the penetration of renewable transport fuels, in particular biodiesel.

- There is also greater potential for import of feedstocks for bioelectricity thanks to the construction of dedicated plants capable of accepting a variety of feedstocks and the likely liberalisation of co-firing support mechanism under the RO. However, international trade in both these markets is likely to remain volatile since the viability of bioelectricity is fundamentally linked to developments elsewhere in the renewable electricity market and most UK bioelectricity infrastructure uses imported biomass to supplement an alternative feedstock (either coal or local biomass).

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