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Bioenergy Review

Resource efficiency science programme
Science report: SC070001/SR1

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Steve Killeen

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Head of Science

Executive summary

This report was undertaken by AEA Energy and Environment for the Environment Agency to review the requirements for and impacts of greater bioenergy production in the UK, as determined by the Renewable Transport Fuels Obligation (RTFO) and Renewable Obligation Certificate (ROC) schemes, in order to inform its regulatory and policy activities. The project examined the full range of bioenergy options for transport, heat and electricity, including liquid biofuels, biogas, energy crops and waste.

The potential make up of bioenergy in 2010 was examined under five scenarios based on potential policy options:

- Continuing as at present (‘business as usual’).
- Continuing as at present but with support to address the barriers to bioenergy (‘progress with barriers’).
- Increased support for all bioenergy (‘support for all’).
- Increased support focussed on heat and power with no increased support for biofuels (‘focus on electricity and heat’).
- Increased support focussed on transport biofuels with no increased support for heat and power (‘focus on transport biofuels’).

These scenarios were developed by AEA in consultation with the Environment Agency steering group and were based on policy options currently being considered, potential responses to proposed legislation (such as the Renewable Energy Directive and the Fuel Quality Directive) and an understanding of Government strategies (such as the Biomass Strategy and the proposed Renewable Energy Strategy, currently in consultation). In addition, key issues that influence the bioenergy sector were also considered (such as availability of feedstocks, costs, R&D and local issues).

The results provide information on tonnes of feedstock required, greenhouse gas (GHG) emissions and land take in the UK (for energy and biofuels crops). The scenario analysis indicates that supporting all bioenergy technologies or focusing policy on heat and power will result in the greatest energy potential from biomass; policies that focus on biofuels alone are likely to limit investment in combustion technologies. In other words, one of the greatest influences on bioenergy will be the enabling policies introduced at national level. This will be particularly important for combustion technologies for heat as there is little support at present, which means that renewable heat (including biomass) is not well-established in the UK at present. The greatest GHG emissions benefits come from policies that support combustion (for heat and power) either with or without support for biofuels – although these benefits were assessed without taking direct and indirect land use change into account. Land take for bioenergy crops in the UK is currently highest for biofuels, mainly because of the use of conventional crops for biofuels and because energy crops for combustion have not been planted at great scale in the UK to date. As it takes some time to establish energy crops, it is thought that the area planted in 2010 will remain low. Tables 1 to 3 show results for 2006 and the ‘business as usual’ and ‘support for all’ scenarios.

Table 1. Biomass use in 2006

Sector	Installed capacity 2006 (MW)	Generation 2006 (GWh/y)	Thousand odt[3] feedstock 2006	Land take in UK in 2006 (ha)	GHG reduction 2006 (kt CO_2 equivalent)
Co-firing power	19,496[1]	1,534	877	487	1,650
Stand alone biomass power and CHP					
a) Combustion	118	611	643	179	149
b) Gasification	0	0	0	0	0
Large-scale CHP	80	297 GWh_e 1,187 GWh_{th}	340	0	484
Biomass heat					
Large-scale heat	168	1,680 GWh_{th}	443	0	1,064
Small-scale heat	32	200 GWh_{th}	51	0	96
Domestic heat	132	376 GWh_{th}	95	0	128
Anaerobic Digestion (AD) – power	6	12	291	0	11
AD – heat	0	0	0	0	0
TOTAL (heat and power)	**20,005[2]**	**2,453 GW_e** **3,443 GW_{th}**	**2,740**	**666**	**3,581**
Transport biofuels					
Transport biofuels	1,688	296Ml	340,000 t	43,241	626

[1] Co-firing capacity assumed to be eight per cent of total power generation capacity
[2] Uses assumed value for co-firing indicated above.
[3] Odt: Oven dried tonnes, that is, with no moisture content. This is a method of expressing biomass feedstock in a comparable manner. In reality biomass feedstocks contain variable amounts of moisture (the moisture content of wood, for example, can be 30-60 per cent), which means that it is difficult to compare data on a per tonne basis.

Table 2. Results for 2010: 'business as usual' scenario

Sector	Installed capacity 2010 (MW)	Generation 2010 (GWh/y)	Thousand odt[3] feedstock 2010	Land take in UK in 2010 (ha)	GHG reduction 2010 (kt CO_2)
Co-firing power	20,492[1]	3,123	1,829	3,321	3,318
Stand alone biomass power and CHP					
a) Combustion	187	944	881	7,100	466
b) Gasification	0	0	0	0	0
Large-scale CHP	193	511 GWh_e 2043 GWh_{th}	674	2754	953
Biomass heat					
Large-scale heat	225	2,105 GWh_{th}	565	0	1,249

Small-scale heat	42	267 GWh_{th}	69	827	118
Domestic heat	156	408 GWh_{th}	102	0	138
Anaerobic Digestion (AD) – power	6	15	379	0	14
AD – heat	0	0	0	0	0
TOTAL (heat and power)	**21,301[2]**	**4,593 GWh_e 4,823 GW_{th}**	**4,500**	**13,997**	**6,255**
Transport biofuels					
Transport biofuels	4,375 Ml	1,693 Ml	3,852,000 tonnes	340,400	1,799

[1] Co-firing capacity assumed to represent 10% of power generation capacity
[2] Uses assumed value for co-firing indicated above.
[3] Odt: Oven dried tonnes, that is, with no moisture content. This is a method of expressing biomass feedstock in a comparable manner. In reality biomass feedstocks contain variable amounts of moisture (the moisture content of wood, for example, can be 30-60 per cent), which means that it is difficult to compare data on a per tonne basis.

Table 3. Results for 2010: 'support for all' scenario.

Sector	Installed capacity 2010 (MW)	Generation 2010 (GWh/y)	Thousand odt[3] feedstock 2010	Land take in UK in 2010 (ha)	GHG reduction 2010 (kt CO_2)
Co-firing power	20,492[1]	3,788	2,257	44,294	3,984
Stand alone biomass power and CHP					
a) Combustion	577	2,324	2,007	18,421	1,547
b) Gasification	0	0	0	0	0
Large-scale CHP	193	511 GWh_e 2,043 GWh_{th}	669	22,754	1,002
Biomass heat					
Large-scale heat	300	2,370 GWh_{th}	635	0	1,438
Small-scale heat	92	600 GWh_{th}	157	5,800	219
Domestic heat	146	504 GWh_{th}	124	0	167
Anaerobic Digestion (AD) – power	6	15	379	0	14
AD – heat	0	0	0	0	0
TOTAL (heat and power)	**22,110[2]**	**6,639 GWh_e 5,517 GWh_{th}**	**6,227**	**71,268**	**8,372**
Transport biofuels					
Transport biofuels	4,919 Ml	2,623Ml	5,252,000 tonnes	484,000	2,655

[1] Co-firing capacity assumed to represent 10% of power generation capacity.
[2] Uses assumed value for co-firing indicated above.
[3] Odt: Oven dried tonnes, that is, with no moisture content. This is a method of expressing biomass feedstock in a comparable manner. In reality biomass feedstocks contain variable amounts of moisture (the moisture content of wood, for example, can be 30-60 per cent), which means that it is difficult to compare data on a per tonne basis.

The four figures below show the results for all of the scenario analyses. The first graph shows results for 2006 on the left, followed by the projections for 2010 under the five different scenarios.

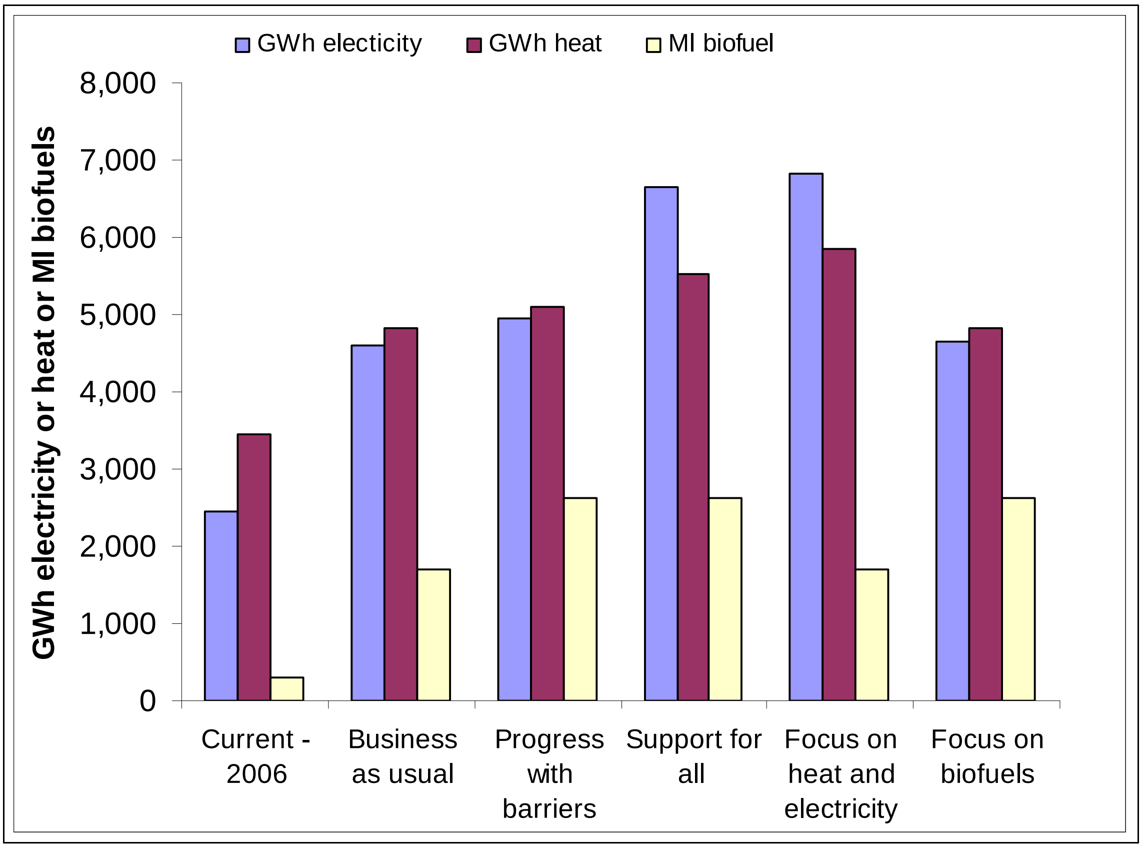

Figure 1. Bioenergy generation in 2010 for the different scenarios

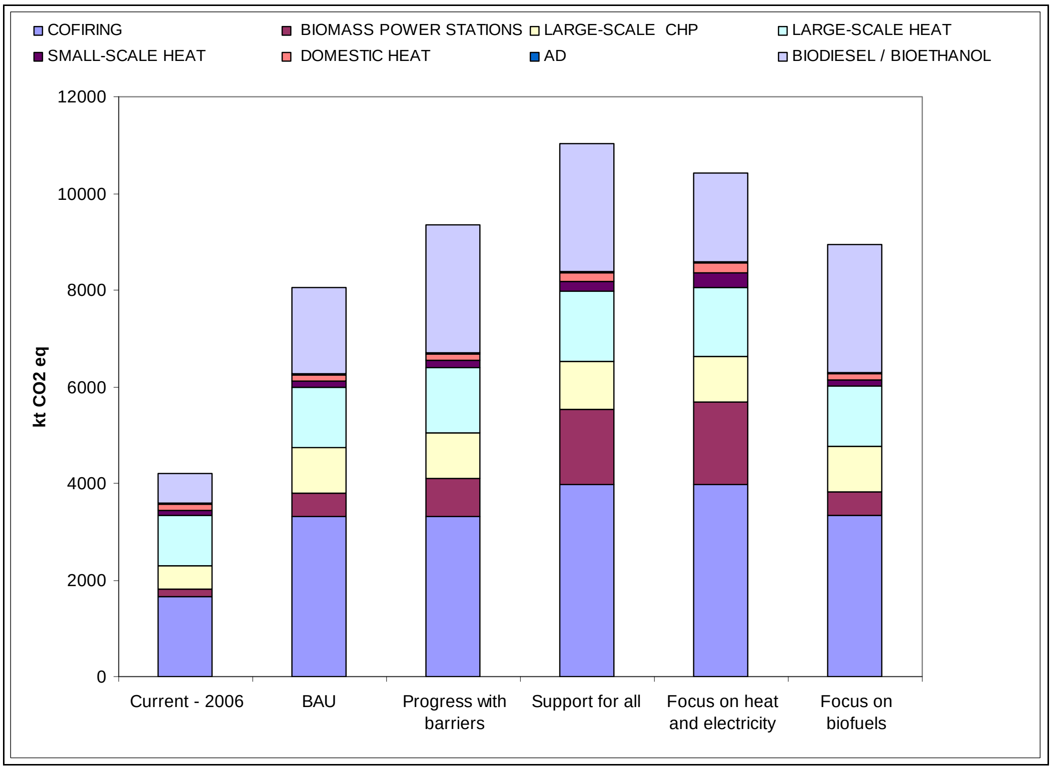

Figure 2. Breakdown of GHG emissions savings in 2010 for all scenarios by technology (ktCO_2 eq)

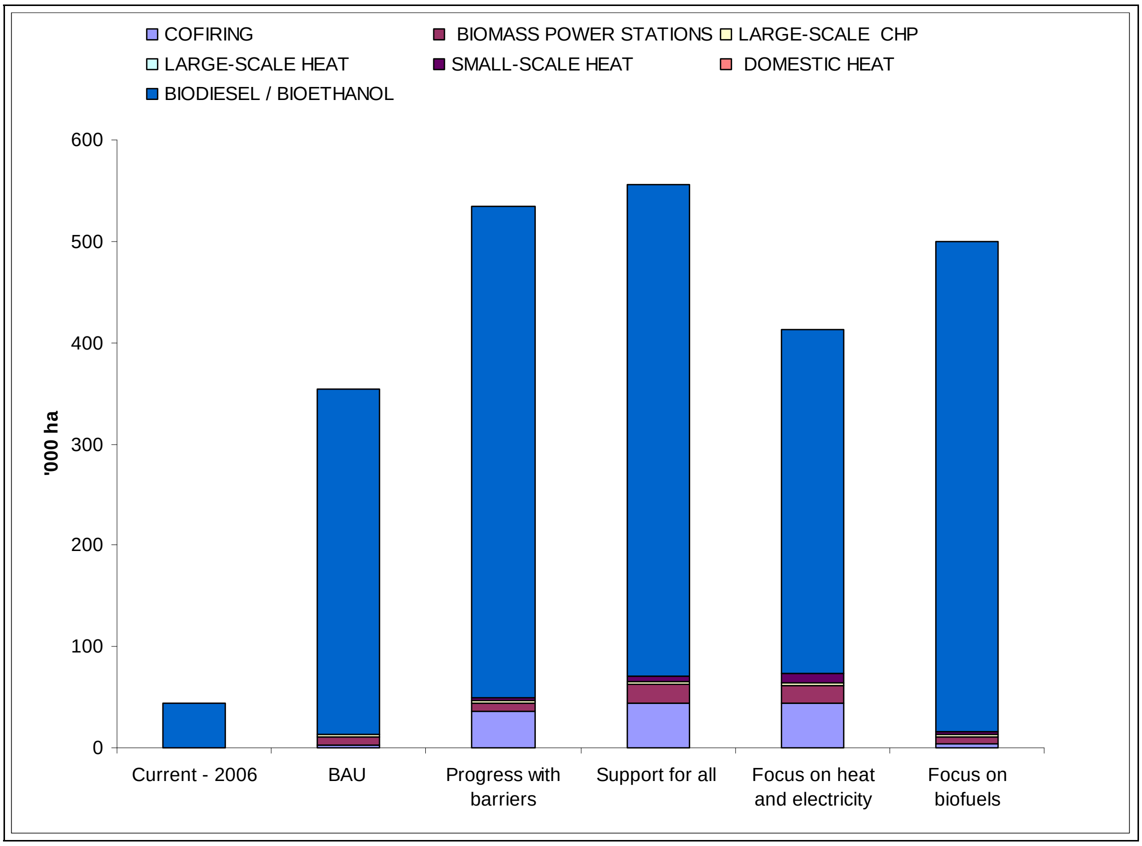

Figure 3. Breakdown of UK land take in 2010 for all scenarios by technology ('000ha)

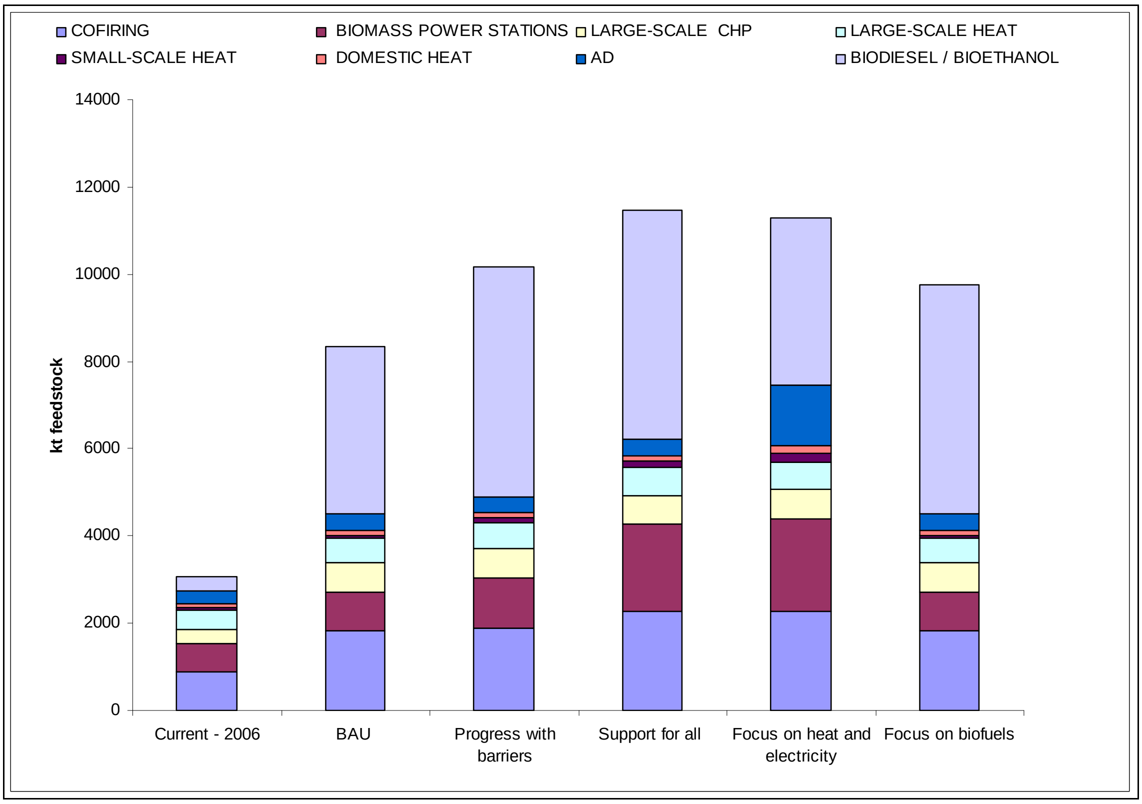

Figure 4. Breakdown of feedstock use in 2010 by technology (kt)

These results indicate that bioenergy will increase by 2010. As a large proportion of the biomass feedstock for power generation (particularly co-firing, but also increasingly stand-alone biomass plants) is sourced overseas, the impact on UK land take is lower for these technologies than for biofuels. The scenario analysis indicate that land take for biofuels could increase to 340,000 - 484,000ha from the current 43,200ha. 82-97 per cent of the land take in the UK is due to biofuels. The tonnage of feedstock required increases from 2,740 kt for heat and power and 340kt for biofuels in 2006, to 6,227 kt for heat and power and 5,252kt for biofuels in the 'support for all' scenario in 2010. Feedstock is dominated by co-firing (18.4-22 per cent), large-scale biomass power (9-19 per cent) and biofuels (34-54 per cent), which results from the economics of bioenergy and the current policy emphasis. If all of the proposed stand alone biomass power plants are built, this will also represent a significant biomass requirement, but not before 2010. GHG savings could rise from the current 4,207 kt carbon dioxide equivalent to 8,000-11,000 kt carbon dioxide equivalent depending on the scenario ('support for all' representing highest savings). These savings are dominated by co-firing and large-scale biomass heat, with biofuels showing lower savings (biofuels represent 17-30 per cent of savings depending on scenario, compared to 35-41 per cent of savings coming from co-firing). Even in support for biofuels, co-firing still provides a significantly higher percentage of GHG emissions savings (37.3 per cent) compared to biofuels (29.7 per cent). The lower cumulative savings from the other technologies are due to the lack of opportunity or support for these technologies to date. In 'focus on heat and electricity', biomass power and heat represent 16 and 14 per cent of GHG savings compared to the proportion of savings from biofuels (17.5 per cent).

These figures show that co-firing, biomass power and biofuels will continue to dominate bioenergy in 2010. Biomass heat is currently dominated by the use of tallow in the rendering industry and waste wood in the panel board manufacturing industry. These are both classified as waste fuels and their use is compromised by the application of the Waste Incineration Directive (which impacts on the economics of their use). It is likely that the best opportunities for large-scale biomass heat will continue to be industrial use of residues.

Biomass CHP (combined heat and power) is not thought to make a large contribution on the time scale examined in this report. However, if there is support for heat under the 2020 targets this, combined with incentives for CHP in the Renewables Obligation (RO), should mean that the significance of CHP will grow. Currently large manufacturers (particularly in food processing) are considering switching to biomass when boilers need to be replaced/ refurbished. Changes in policy may encourage this trend and bring decisions forward.

The key barriers to bioenergy uptake are:

- Lack of data on the use of bioenergy, including potential environmental impact and abatement of emissions. This means that there is little data available with which to answer concerns about biomass at the planning stage.
- Uncertainty in biomass supply, resulting in a volatile market and fluctuating prices.
- Little information on the cumulative air emissions impacts of small schemes, leading to issues in planning.
- Complex and changing policy and legislation, particularly for waste biomass, leading to confusion in terms of supply and hesitancy in investment.
- Public perception, particularly with regard to impact on local environment, health and transport.

- Uncertainty regarding sustainability, which has yet to be legally defined, causing uncertainty for suppliers and developers.
- Competition for land – including conflicts with other biomass commodities such as timber, food and other biomass-based raw materials.
- The cost of complying with the Waste Incineration Directive, which is applied to all biomass waste streams including relatively clean fractions, because of the potential for contamination. This may prove to be significant for biomass heat where the most promising opportunities are in the use of residues in manufacturing and food processing.

The report presents recommendations to address these barriers. These include:

- An improved information database on the operation of plants, including good quality data on environmental emissions and the cost/benefit of emissions abatement.
- Support for development of appropriate skills.
- Consideration of the cumulative impact of small schemes.
- Continued provision of guidance on legislation, particularly on emissions controls and provision of biomass protocols where necessary.
- Resolution of the lack of data on the sustainability of bioenergy
- Examination of conflicts in land use and the alternative use of residues and waste biomass.
- Resolution of the issues with the use of clean biomass wastes.

We have evaluated the carbon benefits of energy recovery from waste with other recycling options for representative waste streams (kitchen and garden waste, clean wood waste, cereal milling residue and sludge from dairy waste water treatment). This preliminary analysis shows that energy recovery options offer a net decrease in GHG emissions, due to displacement of fossil fuels. This reduction was substantially higher than reductions resulting from recycling options, except for anaerobic digestion (which includes an energy recovery element). These findings need to be examined in more detail, with respect to other potential environmental impacts or benefits, rather than just carbon benefits.

In conclusion, the analysis in the report shows a significant increase in bioenergy in England and Wales to 2010, with the nature of this increase dependent on Government policy. The key factors in this will be the proposed changes to the Renewable Transport Fuels Obligation, the potential introduction of support for renewable heat and the implementation of the Renewable Energy Strategy, together with recognition of barriers and initiatives to address them. Other factors that influence the uptake of bioenergy include the price of agricultural and forestry commodities (food, feed and panel board) and competition for feedstock between biofuels and combustion markets. Our analysis has shown that the most significant GHG benefits come from the use of combustion technologies (heat and power). Although we have not included the impact of land use change, the recent Gallagher Review has demonstrated that this could have a significant impact on the GHG emissions reduction from some biofuels options and that this is an area where further work is needed.

We believe there are some key issues that are of relevance to the Environment Agency, particularly in light of the large expansion of bioenergy indicated in the Renewable Energy Strategy (Department for Business, Enterprise and Regulatory Reform (BERR), 2008b). These include:

- The permitting of plants operating on mixed feedstocks; that is, there is likely to be a significant increase in plants burning a range of biomass feedstocks (such as a range of wood fractions in the same plant or combinations of biomass waste fractions).
- The growing demand for waste wood for fuel and the need to improve recovery of this feedstock. There is a need to develop techniques to measure contamination in mixed waste wood streams.
- The potential cumulative impact of small-scale biomass combustion plants on air quality, particularly in urban areas. The potential cumulative impacts of small-scale biofuels (biodiesel) production, which is currently not monitored (with the result that there is no estimate of how many plants there are, where they are or what the standard of operational practice is).
- The rationale behind promoting the use of some fractions of waste for energy recovery rather than recycling options further up the waste hierarchy.
- The significant increase in the need for biomass storage prior to energy recovery.
- The legal definition of sustainability and methodology for assessing, auditing and accreditation of sustainability, particularly for imported biomass.

Contents

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1 Introduction

This report was prepared for the UK Environment Agency in response to its need to understand the way in which biomass energy will develop in the immediate future (specifically to 2010).

Biomass is a flexible resource; it can be used for production of heat, electricity or transport biofuels. It is a particularly useful renewable resource because it can be stored and provides a continuous production potential. As a result it is one of the key renewable technologies proposed in the Renewable Energy Strategy currently under consultation (Department for Business, Enterprise and Regulatory Reform (BERR), 2008b).

There are many sources of biomass - energy crops, forestry, residues, biomass wastes and so on. The matrix of potential biomass fuel feedstock and energy technology that can be applied is therefore large, offering potential for generation of heat, power or transport fuels from almost all the different biomass feedstocks. The challenge is to make the best use of all the biomass resources, both in the UK and throughout the world. This involves using the biomass efficiently to maximise the energy output and potentially reduce greenhouse gas emissions. At the same time it is important to ensure that emissions at all stages of production and utilisation are minimised, and to take into account any negative impacts of the biomass production and utilisation. Current concerns with the production of biomass crops include: whether or not they conflict with food production; the potential for land use impacts; the competition for water resource and the potential impacts on biodiversity. There are also concerns over the potential for air emissions from boilers, particularly nitrogen oxides and particulates from biomass combustion.

Generation of electricity, heat and transport fuels from biomass is usually not competitive with fossil energy sources on a simple cost basis. A range of Government incentives have therefore been introduced to help establish bioenergy. It is important to continually review the legislation to ensure it works to encourage the best overall utilisation of biomass. It is also important to review how other legislation, for example the Waste Incineration Directive (WID), influences the use of biomass for energy production.

Currently relatively small amounts of biomass are used for energy in the UK (a combination of UK energy crops, conventional crops, wood residues and wastes). Large power stations import biomass residues, such as palm kernel expeller and olive stones, for co-firing and oils are imported for biofuels production. To meet the 2010 and later targets for bioenergy, the quantities of all currently utilised biomass sources will need to increase substantially, and new sources may be required both from the UK and from abroad.

In this study we have examined the current situation in the UK for production and utilisation of biomass, and how this situation is likely to develop under the influence of current incentives such as the Renewables Obligation (RO), the Renewable Transport Fuels Obligation (RTFO), The Climate Change Bill (2007), the Waste Strategy for England 2007 and other possible upcoming incentives for renewable heat. This has been undertaken with a view to assessing the environmental implications in the UK of greater biomass production and utilisation.

This report takes a critical look at the total biomass resources that will be required to meet the 2010 targets, ways in which these resources may be secured and the environmental implications of utilisation of this quantity of biomass. This has been done on a bottom up approach:

- Chapter 2 examines current and planned biomass use, together with a critique of the sources of data.
- Chapter 3 examines the barriers to biomass development, including in particular those that are relevant to the Environment Agency and those that it may be able to influence (or at least should be aware of).
- Chapter 4 provides an analysis of how biomass may be used in 2010, under a number of scenarios. These are influenced predominantly by government policy, because legislative and regulatory drivers as well as support mechanisms are some of the most important drivers for biomass at present.
- Chapter 5 compares the GHG emissions of energy generation from representative examples of waste biomass to the GHG emissions from alternative waste treatment processes.

The study was specifically intended to only examine the 2010 time horizon, bearing in mind the need for planning plants well in advance. As a result, plants that are proposed and policies that could have an impact by 2015 were taken into account in the work, even if these plants are not built in 2010 or the policies not implemented by then. Examples of this are the proposals for large-scale biofuels production in the North East of England (currently in planning but which may not be built by 2010) or the Government's current consideration of the need for a heat support mechanism for all renewable heat (currently under review).

Biomass – what biomass is included in this report

The term bioenergy describes heat, electricity and transport fuels derived from biomass feedstocks. For this project we have used the definition of biomass included in the Renewable Energy Directive:

> "'Biomass' shall mean the biodegradable fraction of products, waste and residues from agriculture (including vegetable and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste."

We have not included landfill gas and sewage gas in the analysis in the report.

Tools used in this report

For the analysis of biomass energy in this report we have used two software tools. The first of these is the Biomass Environmental Assessment Tool (version 2) ($BEAT_2$), developed for Defra (Department for Environment, Food and Rural Affairs) and the Environment Agency to examine the environmental impact of biomass energy. $BEAT_2$ is a life cycle assessment software tool developed by AEA and North Energy Associates that allows assessment greenhouse gas emissions and other environmental impacts from the use of biomass to produce heat, power and transport fuels. $BEAT_2$ has been used in this report to support estimations of the biomass resource and to provide an indication of greenhouse gas (GHG) emissions in Chapter 5.

In Chapter 5 the GHG emissions from alternatives to recovery of energy from biomass wastes are also examined using WRATE (Waste and Resources Assessment Tool for the Environment). This is the Environment Agency's life cycle assessment (LCA) software tool for comparing different management systems treating Municipal Solid Waste (MSW).

2 Biomass resource and current use in England and Wales

2.1 Introduction

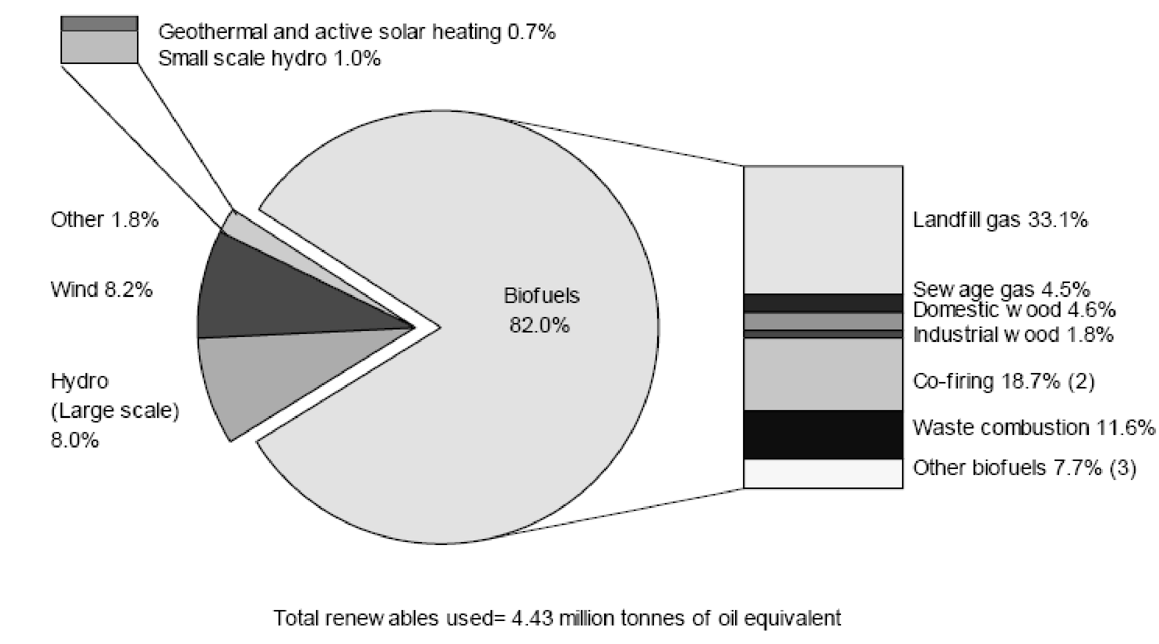
This chapter examines the amount of biomass energy used in the UK and the biomass resource available. Data have been drawn from official statistics, such as BERR's Renewable Energy Statistics database (RESTATS) and Ofgem's Renewable Obligation Certificate (ROC) database; from other official sources of information such as data available from the Bioenergy Capital Grants Scheme; from published literature and the Internet; and from AEA's own database of information. For future schemes and schemes in planning we have relied on developers' own information, on information available through Platts (Power UK) and on our own internal information. Some of these data sources are highly reliable; some are extrapolations of small surveys and therefore associated with higher errors. For example, nobody really knows exactly how much domestic heat is provided by biomass fuel in the UK. The estimates used here are based on surveys and assumptions about the proportion of households in non-Clean Air zones that may be using biomass heat. On the other hand, Ofgem's data on power generation is based on real information from the generators and is much more reliable. In general it is the small-scale information that is less certain. One recent (and improving) source of such data is the Regional Development Agencies. These are beginning to compile statistics on renewable energy in their regions. For biomass two regions stood out: the South West Region and Yorkshire and Humber. These have both monitored the installation of small-scale biomass heat (and power) and have compiled good databases of information.

As a result of these factors we have to remain realistic about the uncertainty of data on biomass use, particularly at small scale.

The utilisation of renewable energy in the UK in 2006 is shown in the chart below. The total biofuels utilisation in the UK in 2006 was 3.63 million tonnes of oil equivalent, or 42.2TWh. The chart shows that bio-energy is the dominant contributor, at 82 per cent. However, within this, landfill gas, sewage gas and waste combustion make a high contribution, almost 50 per cent, while the 'other biofuels' category (which contains stand alone bio-energy power generation) is currently only 7.7 per cent.

In this chapter we examine the use of biomass for: heat, power (including co-firing), heat and power (CHP), and transport. The technologies considered are thermal conversion[1], anaerobic digestion, and transesterification and fermentation. Biomass feedstocks are farm slurries and manures, agro-industrial processing residues, wood fuels, industrial residues, agricultural crops and residues, fuels recovered from waste ('solid recovered fuels' (SRF)), and imported fuels (wood, agricultural residues, animal feeds and energy crops). We have not included the use of sewage or landfill gas.

[1] Thermal conversion includes all conversion systems that can be used for biomass: conventional boilers, grates and advanced systems such as gasification and pyrolysis.



(1) Excludes all passive use of solar energy and all non-biodegradable wastes. In this Chart renewables are measured in primary input terms – see paragraph 7.13.
(2) Biomass co-fired with fossil fuels in power stations.
(3) 'Other biofuels' include farm waste, poultry litter, meat and bone, and short rotation coppice.

Figure 2.1. **Renewable energy utilisation 2006 (Digest of UK Energy Statistics, (DUKES), 2007)**

(Figures above represent the energy content of the fuel used, not the energy output, for biofuels)

The table below shows current estimated biomass use in each sector.

Table 2.1. Biomass use in each sector in the UK

Sector	Thousand oven dried tonnes (odt) biomass used in 2006
Existing large fossil power stations – co-firing	870
Biomass power stations electricity only	
a. Combustion	646
b. Gasification	0
Large-scale industrial CHP	338
Large-scale industrial heat only	438
Small-scale CHP	0
Small-scale heat only	49
Domestic heat only	550
AD - electricity only	300 wet tonnes
AD - heat only	0 wet tonnes
Transport biofuels	293 tonnes

The fuels used for each of these sectors are considered separately below, and the origin of the data is discussed.

2.2 Electricity generation from biomass

2.2.1 Power generation plants

Power generation from biomass in the UK is presented in Table 2.2 to Table 2.5. The best data available for biomass power generation come from the ROC database, compiled by Ofgem (Ofgem, 2008b). This site does not give information on feedstocks, so we have used information from AEA knowledge, company websites and papers published on co-firing in the UK (Woods *et al.*, 2006; IPA, 2006).

There are currently no operating plants generating power using gasification or pyrolysis in this category. Table 2.6 presents information on proposed plants, taken from Platts and from contact with developers.

Table 2.2. Electricity production from stand alone conventional biomass combustion (Ofgem, 2008a,b)

Plant name	Installed capacity, kW	Generation in 2006, MWh	Feedstock
Genny	8	0	Vegetable oil
Bioflame	600	0	Waste wood
Chestnut Bio Power Ltd (formally: Ecoenergy ltd)	980	0	Waste vegetable oil
Eccleshall Biomass	2,645	0	Wood chip and miscanthus
Elean Business Park	36,850	216,112	Cereal straw, miscanthus
Eye Power Station (Fibropower)	14,316	82,999	Chicken litter
Fawley Waste to Energy Plant	8,600	32,926	Meat and bone meal
Glanford Power Station (Fibrogen)	16,700	78,788	Meat and bone meal
Knypersley Renewable Generator	7,200	0	
Longma Thorn	400	119	Vegetable oil
LPL - Hockwold	400	0	Vegetable oil
Mossborough Hall Farm	300	0	Wood chip
Thetford Power Station	41,500	199,763	Chicken litter
Wilton 10 Biomass Gen station	35,220	0	Waste wood, SRC
Total	**165,719**	**610,707**	

Table 2.3. Electricity production from biomass and waste using anaerobic digestion (Ofgem, 2008a,b)

Plant name	Installed capacity, kW	Generation in 2006, MWh	Feedstock
Bedfordia Biogas Ltd (Twinwoods)	786	584	Vegetable/ farm waste
Biogas Engine, Mauri Products Ltd	850	728	Vegetable/animal waste
Holsworthy Biogas Company Project	2,696	9,453	Farm/abattoir waste
Little Woolden Hall Farm	85	19	Farm waste
South Shropshire Biowaste Digester	200	24	Waste/ putrescibles
Twyford Power Station	250	0	Animal slurry
Wanlip AD Plant	1,434	1,224	Food waste
Total	**6,301**	**12,032**	

Table 2.4. Electricity generation from co-firing biomass with fossil fuel (Ofgem, 2008a,b)[2]

Plant name	Installed capacity kW[a]	Generation in 2006 MWh	Feedstock
Aberthaw B Power Station, near Cardiff	1,552,500	78,494	Wood chips, palm oil, sawdust tallow
Alcan Lynmouth Power Station	420,000	2,026	Wood chips
Cottam Power Station[a]	2,000,000	97,765	Energy crops, wood pellets, olive cake
Didcot 'A' Power Station	2,100,000	114,896	Sawdust, PKE
Drakelow Power Station	333,000	0	
Drax Power Station*	4,065,000	63,582	Miscanthus, SRC, PKE, timber, olive cake, wood pellets, sunflower seeds
Eggborough Power Limited	1,062,000	161,953	SRC, PKE, olive pellets, shea pellets and meal
Ferrybridge C Power Station	200,000	343,048	Wood chip, PKE, olive stones
Fibrepower (Slough)[a]	12,000	40,628	Waste derived fuel, sawmill residues
Fiddler's Ferry Power Station	1,995,000	271,400	Olive residues, PKE, shea nuts, olive pellets, citrus pulp pellets, wood.
Glanford Brigg Power Station	272,000	0	biodiesel
Ironbridge Power Station	970,000	28,668	Wood chip, shea nut meal, PKE, miscanthus

[2] The maximum percentage of co-fired ROCs that a supplier can present against its obligation was reduced from 25 per cent in 2005-06 to 10 per cent in 2006-07. This leads to a reduction of almost a factor of two in the number of co-firing ROCs presented in 2006-07.

Plant name	Installed capacity kW[a]	Generation in 2006 MWh	Feedstock
Kingsnorth Power Station	2,034,000	221,811	Cereal co-product, wood chip, tall oil, PKE
Ratcliffe-On-Soar Power Station	2,034,000	0	Wood chip, tall oil, PKE
Tilbury Power Station	1,085,000	61,351	Wood sawdust, PKE
Uskmouth Power Plant	393,000	0	Wood chips, shea pellets
West Burton Power Station	2,000,000	48,338	Energy crops, wood pellets, olive cake, shea
Rugeley B, Staffs	50,000	0	
Total	**19,496,000**	**1,533,960**	

[a] Capacities are for the whole power station, not just the part that co-fires biomass.

Table 2.5. **Electricity from Industrial CHP (Ofgem, 2008a, b)**

Plant name	Installed capacity kW	Generation in 2006 MWh	Feedstock
Goosey Lodge Power Plant	16,000	82,092	Bonemeal and tallow
Old Manor House	100	4	Miscanthus
PDM Group Widnes	9,500	34,048	Meat and bone meal
UPM Shotton Paper Boiler 7	19,655	14,407	Sludge from paper recycling
Slough Electricity Contracts Ltd	35,000	166,148	Wood and non-recyclable paper
Weston Industrial Estate	500	0	
Buckland down, Somerset	7000	0	Forest residues and waste wood
Total	**87,755**	**296,699**	

Table 2.6. **Proposed electricity plants (Power UK, 2007)**

This information is based on the September 2007 edition of Platts Power UK and has been updated and modified by AEA staff in consultation with project developers.

Plant name	Proposed capacity kW	Due date for commissioning	MWhe 2010	MWhe 2015	Proposed feedstock
Hereford	10,000	2010	58,692	58,692	Wood
Castle Cary, Somerset	11,200	2016	0	0	SRC/ forest residues
Port Talbot	13,800	Apr-08	80,995	80,995	Forest biomass, sawmill residue.
Tinsley (also known as Blackburn Meadows), Sheffield	25,000	2011	0	146,730	Recycled wood/ grass
Express Park,	40,000	2010	0	234,768	

Plant name	Proposed capacity kW	Due date for commissioning	MWhe 2010	MWhe 2015	Proposed feedstock
Bridgewater Stallingborough	65,000	2012	0	381,498	Residues from Biodiesel production.
Teeside	65,000	2012	0	381,498	Residues from Biodiesel production.
Port Talbot	350,000	2011	0	2,054,220	Imported wood chips
Port Talbot	40,000	2012	0	234,768	Wood chips
Daganham SRF	Unknown		0	0	
Brigg straw fired plant (next to Glanford Brigg power station), Sleaford.	40,000	2012	0	200,000	Straw
Total	**700,000**		**139,687**	**3,773,169**	

Box 2.1. Summary of biomass power in England and Wales

Biomass power generation in England and Wales is currently dominated by co-firing, although large stand-alone biomass power plants make a significant contribution. This is likely to increase in the near future if current proposals are realised. Anaerobic digestion from farm and food processing residues do not represent a large power resource at present and will not grow significantly without financial support.

2.2.2 Estimates of the quantities of biomass used for power generation plants

The section above provides an indication of the type of biomass used; in this section we look at estimates of how much biomass fuel is being used by sector.

Co-firing

Figure 2.2 shows the breakdown of biomass fuels co-fired in the UK in 2005. Co-firing power stations remain flexible users and are able to switch fuels (providing they have the right handling and preparation equipment at their disposal), so this figure represents a snapshot in time. Recent changes in the availability of some fuels and the cost of others will probably have changed the proportions of biomass fuels co-fired. The majority of the biomass used for co-firing in 2005 was imported. This is not likely to have changed since then. In particular, large quantities of wood fuel were imported. Most of the imported biomass fuels do not come under WID; they are either untreated wood residues, agricultural or food processing residues.

There was also a significant contribution from liquid biomass, bio-oils such as palm oil, tall oil and tallow. Coal and oil stations have used bio-oils to replace heavy fuel oil with considerable success, and this use could expand.

Gas stations have investigated using bio-oil and bio-diesel to replace gas oil.

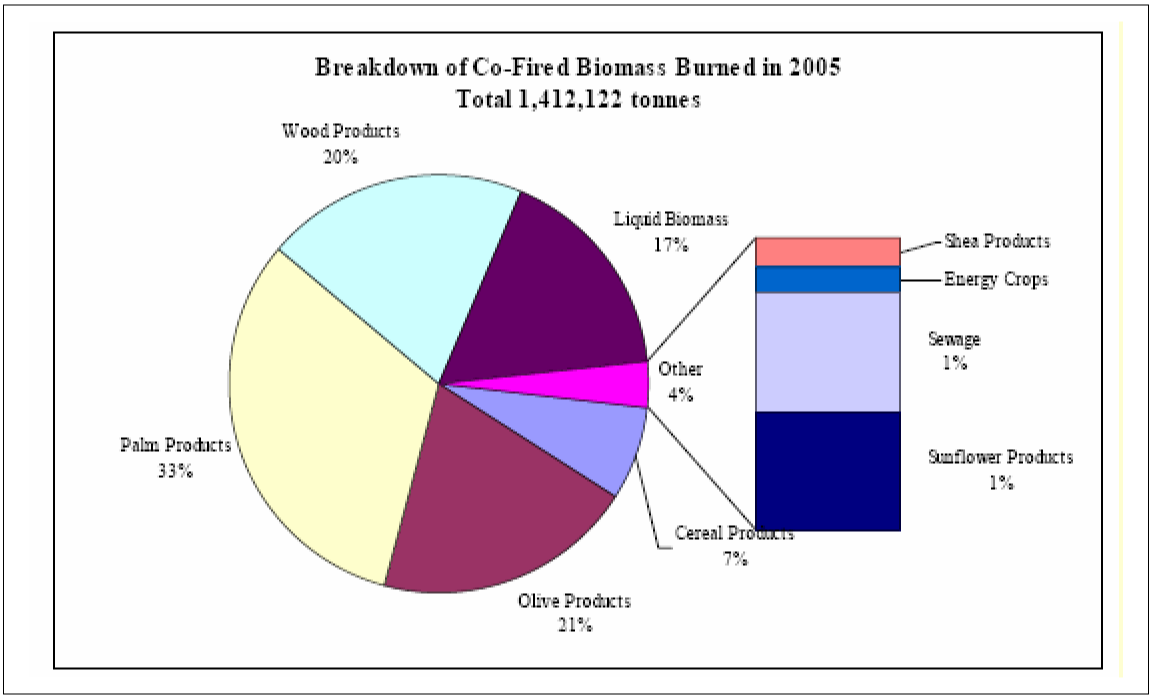


Figure 2.2. Breakdown of co-fired biomass burned in 2005 (IPA, 2006)

The chart also demonstrates the current low contribution from energy crops. This use is projected to increase, giving opportunities to UK producers. In addition there is potential to import energy crops. Although there is currently a limited resource of energy crops for import, there are indications that power generators will be interested in importing these crops, stimulating increased planting abroad. The higher yields and lower production costs of imported energy crops may threaten the development of the UK industry. Which energy crops are used will depend on the interpretation of the definition of energy crops in the RO. Loosely defined this could be taken to include the residue from crops used to produce liquid biofuels. If this interpretation is used it will expand the amount of currently produced energy crops considerably. For example, straw from wheat grown specifically for bioethanol production could be classed as energy crop in this wide definition, as could the residue from palm oil used for biodiesel production; and there are many other residues that could be encompassed by such a wide interpretation. Whether this interpretation will be accepted by Ofgem (the regulator) is still unknown.

Table 2.7 shows the amounts of feedstocks AEA estimates were used in co-firing in 2006. These figures are based on the limited data available on the proportions of feedstock each power station is using. They are approximates and subject to some uncertainty.

Table 2.7. AEA estimates for feedstock use in co-firing in 2006

Feedstock	Thousand odt biomass used in 2006
Wood chips/pellets	112
Waste wood chips/pellets	128
Palm products/ olive/shea	504
Cereal residues	48
Other	78
Total	**870**

Stand alone biomass, CHP and advanced processes

Table 2.8 shows that the biomass combustion stations operating in 2006 used biomass residues, mainly straw, chicken litter and meat and bone meal.

Table 2.8. Feedstock used in stand alone biomass combustion

Feedstock	Thousand odt biomass used in 2006
Chicken litter	318
Straw	240
Meat and bone meal	82.6
Balance (miscanthus, OSR residues, vegetable oil)	5.4
Total	**646**

Table 2.9 shows that large-scale CHP also used a range of biomass residues, including some available at industrial sites.

Table 2.9 Biomass feedstock used in CHP plant in the UK

Feedstock	Thousand odt biomass used in 2006
Meat and bone meal	42
Bone meal and tallow	126
Sludge from paper recycling	22
Non-recyclable paper	125
Imported wood pellets	21
Miscanthus	2
Total	**338**

There was no generation of electricity from gasification or district heating CHP in 2006.

Box 2.2 Summary of biomass feedstock used for power in England and Wales

Biomass use for power generation in the UK is dominated by residues from food production and processing, and from the forestry and timber processing sector. Relatively low amounts of energy crops have been planted for biomass power, although this situation could change if farmers can be persuaded to grow crops for power generation.

2.3 Biomass heating

Biomass heating installations include heat only installations and combined heat and power (CHP) and can be categorised as follows (Brown, 2005):

Table 2.10. Categorisation of biomass heat and CHP plants (Brown, 2005)

Description	Size range	Utilisation %	Typical size
Large scale Industrial CHP	2.5-50 MWe	70	2.5 MWe/ 10MWth
Small scale CHP/ district heating	0.1-2.5 MWe	20/60[1]	0.25 MWe
Large scale Industrial heat	1.5 – 15 MWth	70	10 MWth
Small scale heat	0.10 – 1.5 MWth	20/60[1]	0.12 MWth
Domestic Heat	0.01-0.1 MWth	14	0.01 MWth

[1]The FES report (Brown, 2005) distinguishes two types of small-scale heat - those with intermittent loads such as offices and schools (mainly seasonal space heating) and those with more continuous loads such as leisure centres and hospitals. Utilisation figures are typically 20 per cent and 60 per cent respectively.

2.3.1 Estimates of heat use in the UK

Table 2.11 shows AEA estimates of biomass use in the heat sector in 2006.

Table 2.11. Energy demand and biomass use in the heat sector for 2006.

Description	Current demand TWh/y	Competing fuel	Current biomass use TWh/y	Current number of biomass installations
Large scale industrial heat	271	Gas/heavy oil/coal	2.7[a] 1.6[b]	59
Small scale heat (service sector)	148		0.2	265
Domestic heat	487		2.4	40,000

[a] Total including landfill gas, sewage sludge and MSW.
[b] Wood and straw, farm waste and SRC.

Table 2.12 shows current heat demand and biomass use. The data was derived as follows:

- Energy demand was taken from DTI Energy trends June 2007 (Department of Trade and Industry (DTI), 2007).
- The use of biomass for heat was taken from RESTATS, 2006[3] and represents energy input into heating. It can be broken down as in Table 2.12.
- For domestic heat the figure for biomass use is an estimate of use in all wood-fired domestic appliances, including open fires, cookers and stoves. Survey data suggests that about 550,000 odt/y wood is used in this market. Using an average efficiency of 15 per cent for traditional wood burners gives an energy output of about 0.36TWh. We estimate that about 40,000 appliances are

[3] RESTATS is BERR's statistical database on renewable energy in the UK.

currently in use in the UK. An estimate of the number of installations of modern biomass appliances is not possible from this data.

- Industrial wood and straw, farm waste and SRC together had an input of 1.8TWh. The RESTATS data includes both small scale heat and industrial heat. The current number of boilers in the small scale sector has been estimated from a survey of boiler manufacturers for the Enhanced Capital Allowance (ECA) scheme for boilers less than 10MWth. 265 boilers were estimated to be installed by 2006. Most of these boilers were in the 0.05MW_{th} to 1MW_{th} range. Total installed capacity is estimated at 32MW_{th}. Assuming an optimistic utilisation of 60 per cent gives a current contribution of 0.2 TWh/y.

- The remaining 1.6TWh is ascribed to the industrial use of biomass. The number of industrial wood users has been estimated from the RESTATS gap analysis – a survey of wood-fired combustion plants in excess of 400kW in the UK (RESTATS, 2006). It was estimated that 59 sites were still in operation, using 285,000 tonnes of wood. Most of these plants utilise the heat for space or water heating. Only one site is generating electricity.

Table 2.12 Heat demand and biomass use

Fuel	Heat use for 2006 from RESTATS, ktoe	Heat use on TWH/y
(Landfill gas	13.6	0.2
Sewage sludge	48.3	0.6)
Wood (domestic)	104.2	2.4
Wood (industrial)	80.9	0.9
Straw, farm & SRC	73.9	0.9
MSW	33.7	0.4
Total	454.6	5.4

Note: ktoe is kilo tonnes of oil equivalent. 1t fuel wood (as delivered) is around 0.32 toe.

These figures for current biomass use are broadly in line with figures used in the renewable heat initial business case prepared by Ernst and Young for BERR's examination of renewable heat support mechanisms (Ernst and Young, 2007a).

2.3.2 Details of installed heat boilers

This section examines heat only boilers. CHP units can be traced through the ROC reporting system for the electricity they generate.

Domestic boilers

There is no published national information on individual installations of modern wood-fired boilers. Estimates on the number of biomass boilers installed nationally, fuel usage and areas where wood fuel boilers are most common might be obtained by investigating what information is available from the grant programmes available for domestic installations or by surveying domestic boiler manufacturers. However, it was not possible to undertake this work on the timescales and budgets for this project. One Regional Development Agency (RDA) has published information on domestic biomass installations - this information is detailed in Table 9.2 of Appendix 9 and summarised in section 2.3.3. If we assume similar levels of installation throughout England, then we estimate that 300 biomass boilers are currently installed, with an installed capacity of about 12MW_{th}. We estimate these would supply about 16,000MWh_{th}/y.

Small scale heat

Small scale heat covers the commercial and service sectors. Estimates of the number of units and size range were obtained from the survey for the biomass ECA described above. However, this gave no information on individual installations.

The biomass capital grants scheme includes a list of compliant projects. Biomass capital grants have been made available for non-domestic, non-Waste Incineration Directive (WID) boilers and CHP. The total number of heat only boilers installed to date is 266 and the total installed capacity is 32MW_{th}.[1]

Industrial heat

Using the figures quoted for RESTATS (2006) above, there are an estimated 59 sites utilising waste wood in operation, using 285,000 tonnes of wood, most of which are used for space or water heating. The survey was based on sites previously known to have biomass boilers, and had a response rate of 55 per cent. Not all respondents knew the installed capacity of their plant, and fewer knew the thermal output. The installed capacity and thermal output of the sector therefore had to be estimated.

The UK Renderers Association also indicates utilisation of 83,000 t/y tallow for on-site process heat. Assuming a calorific value (CV) for tallow of 39GJ/t and a low efficiency of boilers of 40 per cent, this equates to energy output of about 330GWh/y.

According to RESTATS there is also about 17,000 odt/y straw burnt in small scale industrial boilers, giving an output of about 50GWh/y. The number and size of the boilers is not known.

2.3.3 Biomass heat data available regionally

The data presented above was collected by central Government. RDAs are also beginning to collect information on renewable energy installations in their regions in order to monitor progress towards regional and sub-regional targets, and to promote existing and prospective installations. This information will refer to many of the same installations as those detailed in the Bioenergy Capital Grant Scheme, but may include other installations supported by other routes.

To date, the South West Region is furthest ahead with its data collection, having produced a list of renewable energy installations. They have made available to us a list of the biomass installations and they have also published a map showing the location of these installations. The South East has launched SEE-STATS, an initiative to collect information in the region, but currently it is not published at individual scheme level. It is hoped that eventually SEE-STATS will be expanded to all the regions in the UK.

[1] There are more plants proposed under the Bioenergy Capital Grants scheme. We believe that most of these projects are likely to proceed. It is unlikely that non-grant projects will proceed at the current time (the conditions necessary to allow development of non-grant projects include confidence in fossil fuel prices remaining high and continuing to slowly increase). A summary of the ongoing grant projects is attached in Appendix 1. These figures are in good agreement with the estimates made above from the ECA survey.

To date, other regions have published a series of case studies rather than a complete list of installations. The gathering of regional statistics should be supported, as it will provide invaluable information on renewable developments in the future.

The list of projects from the South West region is given in Appendix 9.1. In summary, there are 64 thermal biomass installations in the South West. Twenty-five of these are domestic, ranging from $5kW_{th}$ to $100kW_{th}$, with the most common size being $25kW_{th}$. The total installed capacity is $973kW_{th}$, giving an average capacity of $39kW_{th}$. Thirty-nine of the installations are commercial. The majority are in the range $55kW_{th}$ to $500kW_{th}$, with one larger installation at $3MW_{th}$. The total capacity is $8,469kW_{th}$. The average capacity, excluding the 3MW installation, is $144kW_{th}$. Commercial installations include farms, shops and public buildings. The map shows that the commercial installations are spread over the whole region. Where the fuel is specified, the smaller capacity installations use wood pellets or logs and the larger scale installations use wood chip.

Information on commercial and industrial biomass plants in Yorkshire and the Humber has been published as part of the Vision for Biomass for Yorkshire and the Humber. The heat plants are listed in the Appendix 9.1. In summary, 29 thermal biomass plants were identified, with a total capacity of $10MW_{th}$ and a capacity range of $25kW_{th}$ to $1.4MW_{th}$. The average installed capacity was $390kW_{th}$, reflecting that several installations were for blocks of flats or large public buildings. This was possible as a conversion from previous coal heating. All the installations were wood-fuelled, with chips or pellets. Local wood was often specified as the fuel source. Some areas, such as Barnsley, have been particularly active in installing biomass heating systems.

2.3.4 Heat from biomass CHP

For large-scale industrial CHP, the heat load is assumed to follow the electricity, as the electricity is a premium product. A steam cycle is assumed with a full load ratio of four units of heat to one unit of electricity and an overall efficiency of 75 per cent. It is also assumed that the heat utilisation is 70 per cent. Using these assumptions, Table 2.13 gives an estimate of heat production from industrial CHP. Details of the electrical rating of the CHP units and the feedstocks are given in the electricity section.

Table 2.13 Industrial CHP in 2006

Plant	Heat produced in 2006 MWh_{th}
Goosey Lodge Power Plant	246,276
Old Manor House	12
PDM Group Widnes	102,144
UPM Shotton Paper Boiler 7	43,221
Slough Electricity Contracts Ltd	498,444
Weston Industrial Estate	0
Buckland down, Somerset	0
Total	**890,097**

We do not have information on any small-scale CHP schemes in England at this time.

2.3.5 Biomass fuels used in the heat sector

The use of biomass fuels for heat depends on the size of the plant and its location. We have examined this below for domestic, small-scale heat and large-scale heat.

Domestic heat

Most domestic biomass heat in the UK uses logs or pellets as fuels. Logs are normally obtained from a local supplier, and all traditional domestic biomass stoves are assumed to use logs. Modern biomass stoves and boilers are assumed to use pellets that are produced in the UK or imported.[2] It is generally thought that it is cheaper to produce wood pellets abroad than in the UK, and we assume that in 2006 80 per cent of pellets used were imported. However, as the demand for wood pellets increases in Europe, this situation may change. In addition, as pellet demand increases in the UK it is likely that more pellet plants will be developed here. The Balcas pellet plant in Northern Ireland is successful and there is a proposal to build another plant in Invergordon, Scotland. In addition other smaller pellet plants are being built in Scotland. The Biomass Energy Centre lists pellet manufacturers in the UK and there are some plants in England and Wales. There are also plans for more small-scale plants.

Wood pellets are an attractive fuel. They can be produced to standards (there are EU standards for wood pellet production) and they can be stored for long periods relative to other wood fuels. However, they are expensive and users have to be careful about the grade of fuel they burn.[3]

Small scale heat

Small-scale boilers typically use wood pellets or chips (Table 2.14). The larger plants tend to use wood chip and this is likely to be sourced in the UK, locally to the plant. The tables below are based on AEA estimates of the current balance between the different types of wood fuel used in the UK.

Table 2.14. Wood fuels for small-scale heat (AEA estimates)

Feedstock	Thousand odt biomass used in 2006
Wood residue chips (UK)	15
Wood residue pellets (UK)	9
Wood pellets (imported)	10
Wood waste chips	15
Total	**49**

Industrial heat

Industrial biomass heat plants tend to use their own biomass supply. On the whole these plants are situated in wood processing or paper and pulp mills.
Table 2.15 provides information about known biomass fuels used for heat in the UK. This covers the main sectors that use biomass heat. However, we know that some food processing industries use their own residues (for example, Kraft use coffee grounds in a purpose built boiler at their Banbury plant). These are not included in the table below as we do not have quantitative data. Table 2.16 provides information on the use of wood fuel for large-scale heat in the UK.

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[2] The production of pellets in the UK is currently quite low, while there is a successful and increasing production of pellets in Europe (for example Germany, Austria, Poland and Finland) and elsewhere (such as Russia and North America).
[3] The CEN standard for solid biofuels includes wood pellets, CEN/TC EN 335. For more information on wood pellets see: Information sheet 1: Wood pellets and briquettes, available from the Biomass Energy Centre, www.biomassenergycentre.org.uk/ or the logpile web site: www.nef.org.uk/logpile

Table 2.15. Biomass used in industrial plants in 2006 (AEA estimates)

Feedstock	Thousand odt biomass used in 2006
Waste wood /MDF offcuts	338
Tallow	83
Straw, farm waste and SRC	17
Total	**438**

2.3.6 Biomass heat fuels: key issues

There are a number of issues with biomass fuel supply for heat. These are summarised in Table 2.16. In addition to the use of wood fuels, straw and some food processing residues may be burnt, but this practice is not widespread and is not considered here.

The increase in wood pellet use and manufacture may result in some impacts. These will relate to noise, odour, dust, steam plumes and the type of fuel (grade of wood, including waste). In addition, the issue of sustainability of imported fuels is likely to be more important in the future (for example, factors related to the origin of the biomass resource, particularly the use of co-products from tropical wood processing).

Table 2.16. Types of wood fuels likely to be used for biomass heat and associated issues

Fuel	Scale of use	Issues
Wood pellets	Small-scale and domestic. Some use in co-firing due to good storage characteristics.	Pellets are used generally because they are produced to designated standards and transport and store well compared to other wood fuels. However, they are relatively expensive. Poor quality pellets have been reported. These crumble and do not store well. Quality control is important to ensure no contaminants are present. Sustainability will be an issue, particularly for wood pellets made from wood from non-sustainable sources.
Wood chips	Medium to large	Mainly sourced in UK[4].
Wood waste	Large	Some large-scale plants may be based on residues produced within the plant itself (for example plants at wood or board processing plants). The issue of whether or not the process needs to come under WID is significant. The large scale use of waste wood for heat has not been proposed outside the wood processing industry.[5]
	Small-scale	The use of waste wood in small-scale schemes does not come under Environment Agency

[4] Some power generators are importing large quantities from North America and the Baltic, but these are mainly used for power generation, not heat.
[5] There is increasing interest in using waste wood outside the wood processing industry, with a number of large-scale power generation plants in planning, but none of these will also generate heat (at present).

Fuel	Scale of use	Issues
		regulation. However, a large number of small-scale wood boilers may use waste wood, which may cause air quality issues.

Box 2.3 Summary of biomass heat in England and Wales

Currently biomass heat in England and Wales is dominated by domestic heat use of wood fuels and large-scale industrial heat. There are considerable uncertainties in the figures of biomass heat use and no current requirement to monitor or register renewable heat use. While forestry products (mainly logs and pellets) dominate the domestic and small-scale market, industrial biomass heat users are more likely to use their own residues, such as waste wood and food processing residues.

The uptake of biomass heat is currently low compared to its potential, which is due to the lack of incentives in the past (both the historically low cost of fossil fuels and the lack of Government support in this area).

2.4 Anaerobic digestion

This section examines anaerobic digestion (AD) of animal manures, food waste and other putrescible matter; landfill gas or sewage gas are not considered. There is only one Centralised Anaerobic Digester in the UK (at Holsworthy in Devon). This currently generates power only.

There are currently no heat-only centralised AD plants in the UK. However, there are a number of smaller-scale on-farm heat-only AD plants. A report for Defra summarised the situation regarding on-farm AD plants in the UK (AEA, 2005). This estimated that there are between 14 and 40 on-farm AD plants, of which up to 15 are operational. According to RESTATS, the farm AD sector generates around 22,100MWth. This represents less than one per cent of the total methane heat generation potential in the UK. The analysis in the AEA 2005 report indicated that there is considerable potential to increase the number of centralised AD plants in the UK (for example it showed that 20 large-scale CAD plants would be technically feasible). However the report also showed that these plants are not economically feasible without financial assistance and that (in 2005) on-farm systems were not economically feasible either.

2.5 Transport biofuels

In the UK in 2006 consumption of road transport fuels was:
- 24,000 million litres of diesel, of which 169 million litres was biodiesel.
- 25,000 million litres of petrol, with 95 million litres bioethanol.

Currently, biofuels production in the UK comprises:
- Biodiesel production by trans-esterification of vegetable oils and animal fats.
- Bioethanol production via fermentation of sugar beet and hydrolysis and fermentation of starch.

A survey of biodiesel and bioethanol producers in the UK was undertaken in February 2007 by AEAT for the BERR RESTATS programme. The tables below are based on the data from that survey.

2.5.1 Biodiesel

Biodiesel is produced from a range of fuels at a range of scales within the UK. Table 2.17 and Table 2.18 provide data for large- and medium-scale biodiesel production plants in the UK. For tax purposes, small-scale plants are defined as those producing less than 450,000 litres/y. Tax regulations have recently been amended so that plants producing less than 2,500litres/y do not need to register for tax purposes. There is therefore no longer any register of very small scale plant in the UK (HMRC, 2007). Recent correspondence with HMRC has revealed that there are currently 300 registered biodiesel producers in the UK. Many of these will be below 5,000 litres per year and so will not come under the Environment Agency permitting system. In addition HMRC estimates there could be up to 4,000 unregistered producers, producing less than 2500l/y.

The estimate of biodiesel production in the UK in 2006 was 291 million litres, as shown in the tables below and including an estimated amount for production from small-scale producers.

2.5.2 Bioethanol

There was no production of bioethanol in the UK in 2006. The 95 million litres consumed was all imported.

There is only one bioethanol plant operating in the UK at present. This is the British Sugar plant at Wissington. The Wissington plant is integrated with existing sugar production using local sugar beet. Other proposed bioethanol plants are based on the use of wheat as the feedstock. These plants are listed in Table 2.19. It can be seen from the table that many of the plants intend to use a mixture of UK wheat and imported feedstocks. Typically the plants propose to use 50 per cent UK wheat and the balance from imported feedstock. These plants will be situated near the centres of UK wheat production and near deep water ports to facilitate imports of feedstock and export of bioethanol. Although intending to use UK wheat, several of the plants emphasised that the source of the feedstock would be determined primarily by cost and availability.

Table 2.17. Large scale Biodiesel plant, > 50 million litres per year

Operator	Site	Capacity Million litres/y	Feedstock type	Opening date
V-Fuels	Bedlington	833	RVO[a] and imported oils	Apr-06
INEOS	Grangemouth	600		2008
Biofuels Corp	Seal Sands	300	UK OSR[b], Imported soya, palm	Mar 06
ESL (Ebony Solutions)		240		
Greenergy	Immingham (I)	114	UK OSR, Imported palm and soy oils	Apr-07

Operator	Site	Capacity Million litres/y	Feedstock type	Opening date
Greenergy	Immingham (II)	114	UK OSR, Imported palm and soy oils	2008
Brocklesby	Hull	60	UK RVO	Jul-06
Argent Energy	Motherwell	50	UK RVO and tallow	Mar-05
Argent Energy	Ellesmere Port	170	UK RVO and tallow	2009[c]
V-Fuels	Stewekely	62	RVO	
Total		**2,543**		

[a] RVO – Recycled vegetable oil
[b] OSR – Oil seed rape
[c] Estimated date of completion and commissioning for plant.

The total production in 2006 was estimated to be 250 million litres

Table 2.18. Medium scale plant, between 450,000 litres per year and 50 million litres per year

Operator	Site	Capacity Million litres/y	Feedstock type	Opening date
PDM Group	Silvertown	45		
D1 Oils	Middlesborough	50	Imported vegetable and inedible oils	2006
D1 oils	Bromborough	57	Imported vegetable and inedible oils	2008
BIP Ltd	Oldbury	22	UK RVO	2002
V-Fuels	Harlow	14	RVO	
Green Biodiesel Ltd	Walsall	6	UK RVO	2006
Centec	Middlewich	2	UK OSR/RVO. Imported soy.	2006
Viridine	Chailey	1	UK RVO	2006
JC Fuels	Colchester	1	UK RVO	2006
Bionic Fuels	Pevensey	0.6	UK/ imported RVO. Imported OSR	2007
Aeolus Partnership	Ashford	0.5	UK RVO	2001
D & B Biofuels	Bidford-on-Avon	0.5	RVO	2005
Total		**199.6**		

Total production in 2006 was 36 million litres

Table 2.19. Biothanol plants in England and Wales

Operator	Site	Capacity Million litres/y	Production 2006, million litres	Feedstock type	Opening date
Bioethanol Ltd	Immingham	130	0	UK and imported wheat	2008
Losonoco	Teeside	120	0	UK wheat	2009
Green Spirit Fuels	Henstridge	133	0	UK wheat	2008
Green Spirit Fuels (Humber biofuels)	Grimsby	250	0	Not known	Not known
Vireol plc	Grimsby	190	0	Not known	2010
Vireol plc	Teeside	190	0	Not known	2010
British Sugar	Wissington	70	0	UK sugar beet	2007
ENSUS	Wilton, Teeside	400	0	European wheat	2009
Roquette	Corby	120	0	UK wheat	2009
Abengoa	Immingham	500	0	Imported and UK wheat	2010
BP/ABF/ DuPont	Hull	420	0	Wheat	2009

The British Sugar plant at Wissington is the only bioethanol plant currently operating in the UK. The industry currently estimates that production by 2010 will be 1,700 million litres.

2.5.3 Biofuels feedstocks used in the UK

Biofuels feedstocks are shown in Table 2.20 and Table 2.21. Bioethanol will use home grown sugar beet for the Wissington plant. This plant was commissioned in 2007. A mixture of home grown wheat and imported wheat is proposed for other bio-ethanol plants, but none of these are in operation yet[6].

Table 2.20. Bioethanol feedstocks used in the UK in 2006

Feedstock	Thousand odt biomass used in 2006
Sugar beet	0
Wheat (UK produced)	0
Wheat (imported)	0
Total	**0**

[6] ENSUS claim that they will be the next plant to commence operation in 2009. This plant will use over a million tonnes of wheat a year from the North East of England. This will be low protein wheat normally used for animal feed, and the plant will also produce concentrated protein (DDGS) which can be used as animal feed. The operators claim this enables them to displace soy protein imported for animal feed and avoid indirect impacts from soy production. In addition they will also operate a CHP plant to ensure efficient use of co-product and efficient heat and power use. According to their calculations, this provides for very favourable GHG emissions reduction from the plant.

For biodiesel, a mixture of home grown OSR and imported vegetable oils is proposed for large scale biodiesel plant. Argent use animal fats for a medium scale plant. Recycled vegetable oils (RVO) are often used for smaller scale plant. These are usually sourced in the UK. Estimates of quantities used in 2006 are given below.

Table 2.21. Biodiesel feedstocks used in the UK in 2006

Feedstock	Thousand odt biomass used in 2006	Thousand ha used in UK in 2006
Oil seed rape oil (OSR) (UK)	46	43
Imported palm or soy oil	106	
RVO and tallow	140	
Total	**292**	

2.5.4 Second generation biofuels

Second generation biofuels involve the processing of lignocellulosic feedstocks to bioethanol. This requires a more complex plant configuration than first generation biofuels, but opens up opportunities to use more feedstocks and to manipulate the chemical processing. A logical extension of these plants is to use them as ‘refineries’ to produce transport biofuels and/or a range of high value chemicals. At the moment there are very few second generation plants in operation and all of the major plants are abroad. In the UK there has been some work on pyrolysis and gasification of wastes to produce fuels for heat and power. However, there are now proposals to build plants for biofuels and it is likely that a demonstration plant operating on a mixture of biomass residues and wastes could be in operation between 2010 and 2012 in the UK. These plants may address waste policy as well as biofuels policy.

The Environment Agency will be involved in permitting such plants and will need to appreciate the environmental implications of the plant operation. These plants could be based on steam or acid hydrolysis (or both) and may include pressurised vessels. They may also include biomass to liquid processing, including gasification and pyrolysis.

Box 2.4 Summary of biofuels in England and Wales

Current biofuels production in the UK is dominated by the use of used cooking oil, tallow, oil seed rape and imported oils for biodiesel and sugar beet for bioethanol production. Due to the high cost of seed and palm oils at present many of the biodiesel plants dependent on these feedstocks are operating at below capacity.

Future bioethanol plants are planned in the Teeside and Immingham areas, based predominantly on UK wheat and imported feedstocks. The ENSUS plant at Wilton will use wheat from the North of England and produce animal feed as a co-product. This is a model that many of the other plants will follow, allowing for substitution of other animal feeds.

Currently a number of plans have been shelved or put back until the price of feedstock decreases.

Little work has been undertaken on second or advanced generation plant, but there are signs that this situation is changing and there may be more interest in the near future.

2.6 Production of biomass fuels in the UK

2.6.1 Biomass grown in the UK for energy

A number of crops currently grown in the UK can be used as bioenergy feedstocks. Some of these crops are grown solely for bioenergy and some have well established markets in other sectors. In general, the energy crops grown solely for bioenergy are relatively novel to UK farmers, whereas the crops with established alternative markets are already well known. The crops currently used for bioenergy in the UK are shown in Table 2.22 and the amounts grown are shown in Table 2.23. (which also provides estimates for 2010, see below).

Table 2.22. Crops used for bioenergy grown in the UK

Crop	Markets	Total grown in the UK in 2007, thousand tonnes	Grown in UK for non-food uses in 2006, thousand tonnes.
SRC[a]	Electricity and heat	Not available	25.9[a]
Miscanthus[a]	Electricity and heat, animal bedding.	Not available	23.5[a]
Wheat	Food, animal feed, biofuels.	13,137	31.8
Sugar beet	Food, animal feed, biofuels	7,150	0
Oil seed rape seed	Food, animal feed , industrial processes, biofuels	2,108	866

[a]Assuming yields of 10 odt/ha. Quantities in odt.
Wheat and OSR grown in UK are taken from Defra, 2008.

Information is available on crop production at the regional level from: http://www.defra.gov.uk/esg/work_htm/publications/cs/farmstats_web/2_SURVEY_DATA_SEARCH/COMPLETE_DATASETS/PSM/RegCountUA_06.xls

Information on non-food crops production available from the National Non Food Crops Centre (NNFCC):
http://www.nnfcc.co.uk/metadot/index.pl?id=2179;isa=Category;op=show

There are currently no plants generating bio-ethanol from wheat in operation in the UK, so the wheat shown in Table 2.23 is for other non-food uses.

The only plant generating bio-ethanol from sugar beet is the Wissington plant, which started operation late in 2007. They estimate a use of 700,000 tonnes (10,000ha at 70t/ha) of locally sourced sugar beet per year from 2008.

The use of oil seed rape for biodiesel is difficult to estimate. Oil seed rape has a history of non-food uses over many years. The best estimate is probably to use the amount declared under the Energy Aid Payment Scheme, which amounts to 617,500 tonnes (190,000ha at 3.25t/ha). However, our estimates of use of UK-grown OSR in UK biodiesel production in 2006 are much lower, at about 100,000t. It is probable that the majority of the OSR for energy is currently exported into the European market. The attractiveness of this export market depends on continuing favourable conditions for biodiesel production in Europe, in particular the subsidies offered.

There is currently no set aside requirement in the UK, but if this were reinstated then annual crops grown for energy would be eligible to be grown on set aside land. Given high current prices for wheat and OSR it is likely that suitable ex-set aside land will be used for these crops. Assuming only some set aside is suitable and allowing for crop rotations, this could give an increased production of wheat estimated to be about 700,000 tonnes/annum and OSR of about 300,000 tonnes/annum. If we assume that the current wheat surplus of about 1,000,000 tonnes is all available for biofuels, and the current OSR grown for energy of 900,000 tonnes is all utilised for biofuels, then the estimated potential for 2010 is as shown in Table 2.23. . We assume that there is no increase in current yields of wheat and OSR in the UK, as these crops are already highly developed and there will be pressure to minimise agrochemical inputs to maximise GHG benefits of biofuels.

Table 2.23. Estimated production in 2006, and estimated potential to 2010

Crop	Estimate grown for biofuels in 2006, thousand tonnes	Estimate of potential for 2010, thousand tonnes	Estimate of land use in UK in 2010, thousand ha
SRC	25.9	300	30
Miscanthus	23.5	300	30
Wheat	0	1,600	200
Sugar beet	0	700	10
Oil seed rape	100	1,200	370

The quantities of SRC and miscanthus grown in the UK are still very low. IPA (2006) states that there are plans to increase the area from the current 5,000ha to 7,000ha in the next year or so, with indications that the area might rise to 60,000ha by 2010. These crops are likely to be sited on ex-set aside land not suitable for wheat or OSR. To give some idea of scale, a 2GW coal station requires 80,000ha energy crops (10 per cent of land in 50km radius) to provide 20 per cent thermal input.

Other possible energy crops include:

- Switch grass (favoured in the USA).
- Short Rotation Forestry (SRF). These crops are grown on eight- to 20-year cycle, and typically felled when they reach a diameter at breast height of between 10 and 20cm. A recent study (Hardcastle, 2006) estimates that wood produced under SRF could replace up to five per cent of coal in existing power stations.
- Reed canary grass (currently being used in Finland for power generation).

2.6.2 Other UK sources of biomass currently used for energy

There are other sources of biomass used for energy. These are listed in Table 2.24.

Table 2.24. Other UK sources of biomass currently used for energy

Resource	Current utilisation, thousand odt	Current arisings, thousand odt	Availability for bioenergy in 2010, thousand odt	Comments
Forest residues, under managed woodland and sawmill residues	280	3,000	1,800	Arisings include 1million odt from under-managed woodlands.
Cereal straw	240	9,000	3,000	Majority has other markets.
Waste wood-clean and contaminated	1,523	7,500	2,500	Arisings include 1.9mt clean wood.
Chicken litter	318	1,000	318	Suitable sources already exploited.
Meat and bone meal	116	600	116	Suitable sources already exploited.
Tallow	100ar	250ar	100ar	Suitable sources already exploited
Secondary recovered fuel (from MSW)	22	22	2,000	Waste strategy target for 2010 production is 2modt/y.
Paper recycling products	30	8,000	1500	Arisings include 0.5modt/y of sludge.
Recovered vegetable oil (RVO)	124[ar]	124[ar]	124[ar]	All suitable sources currently utilised.
MSW of which		29,000[ar]		UK arisings.
Garden/ plant	Unknown	6,000[ar]	4,000[ar]	Availability from waste strategy targets. Will depend on collection practices.
Kitchen		4,500[ar]	3,000[ar]	

Resource	Current utilisation, thousand odt	Current arisings, thousand odt	Availability for bioenergy in 2010, thousand odt	Comments
Animal manure or slurry	261	67,000[ar]	29,000[ar]	Availability includes collectable wastes, mainly slurry. 10%DM.
Food waste from industry	39	6,000[ar]	400[ar]	1.9mt currently landfilled. Availability from waste strategy targets of 20% for bioenergy.

ar: as received (that is, not oven dried tonnes)
Sources: Current utilisation estimated from AEA work. Potential availability in 2010 based on UK Biomass Strategy (Defra, 2007a), IEA Task 40 Country report for UK (Imperial College, 2007), Evaluating the sustainability of co-firing in the UK (Woods *et al.,* 2006) and Waste strategy for England (Defra, 2007b).

The estimate of wood residues available is provided in Table 2.25. The use of 2.4TWh of wood for domestic heating implies a current use of 550,000 odt wood in the UK. The available residues shown in the summary table assume only a proportion of the total residues are available for energy, but also include an additional 1 million odt of wood from under-managed woodlands.

Table 2.25. Estimated wood production (odt) (Forestry Commission, 2005)

Time Frame	Total wood biomass	Wood residues [a]
2003 to 2006	6,308,350	2,064,377
2007 to 2011	6,490,152	1,927,646
2012 to 2016	7,055,031	1,963,592
2017 to 2021	7,343,917	1,900,241

[a] Wood residues composed of stem wood with a diameter 7 to 14 cm, poor quality wood and brash.

Issues with UK-produced fuels

There is still a great deal of uncertainty about whether or not large quantities of energy crops will be planted in the UK. The following may be of concern:

- Production of increasing quantities of wheat and OSR will reduce crop diversity in the UK and could undermine recent advances in environmental benefits of set aside and farm environmental schemes.
- Farmers are still unsure about committing to unfamiliar perennial crops with a 20-year lifespan, particularly now with zero set aside and good prices for wheat and OSR.
- The logistics of supplying large-scale (>100MW) plant remain uncertain, leading to concerns about security of fuel supply.

2.6.3 Imported biofuels

Table 2.26. Estimated utilisation of imported biofuels in 2006

Resource	Current utilisation, thousand odt
Wood chips/ pellets	58
PKE	243
Olive residues	190
Shea nut meal	70
Cereal co-products	49
Tall oil	3
Soya oil	53
Palm oil	53
Jatropha oil	0
SRF/SRC	0
Perennial grasses	0

The graph in Figure 2.3 gives a summary of the total availability and current use of biomass fuels for co-firing:

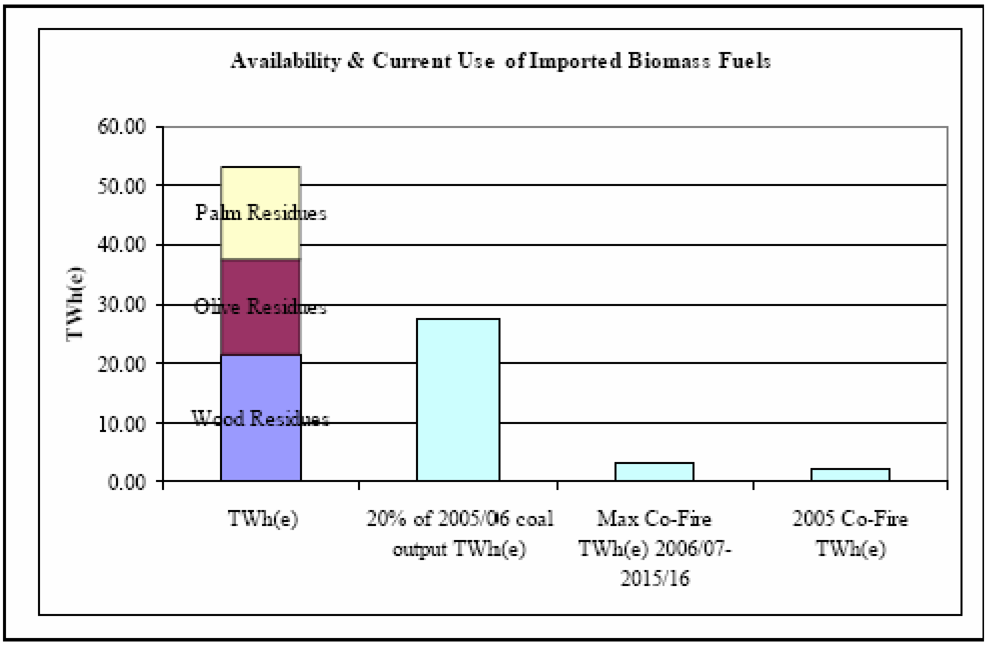

Figure 2.3. Availability and current use of co-firing fuels (IPA, 2006)

IPA (2006) concluded that there are sufficient volumes of fuel to satisfy any reasonable UK fuel requirement from co-firing. However, not all these potential fuel sources will be available to UK generation due to competing markets and to increasing demand from generation across the EU and internationally.

Recently the price of these commodities has risen markedly, making them less attractive as feedstocks for bio-energy production (Appendix 9.5 shows the prices of palm oil and other agricultural commodities).

An indication of prices of fuels in the UK is given in Figure 2.4.

Biomass	**EURO/GJ**
Chip- forest woodfuel Logs- forest woodfuel	2.93-4.40 1.47-2.03
Arboricultural arisings Waste-clean	2.93-4.40 2.93-4.40
Waste- contaminated	0.73-2.20
Pellets- forest woodfuel Pellets-SRC	5.87-7.33 7.33-8.80
Pellets- Miscanthus Pellets- domestic, delivered	6.60-8.07 8.8-11.74
Energy crops- SRC Energy crops- Miscanthus	4.4-5.87 3.67-5.13
SRC (delivered)	8.58
Miscanthus (delivered)	7.26
Imports -Palm kernels Olive residues 'Typical' imports	7.63-8.65 6.45-7.63 5.13-8.07
Fossil fuels- industrial customers Coal Heavy fuel oil Gas oil Electricity Natural gas	 2.31 8.02 12.66 22.44 7.35
Fossil fuel- at power plant Coal Oil Natural gas Premium unleaded euro/l ULS diesel euro/l	 2.13 9.71 5.24 1.34 1.4

(fossil fuel prices are 2006 average excluding VAT and CCL.)

Figure 2.4. Prices of fuels in the UK in 2007 (Imperial College, 2007)

Although imports are in some cases cheaper than home produced biomass feedstocks,
(fossil fuel prices are 2006 average excluding VAT and CCL.)

- **Figure 2.4** shows that this is not a decisive issue.
- The attraction of imports, particularly for large- scale users, is probably:
    - o Availability of suitable quantities and the reliability of supplies being tradable commodities.
    - o Secure logistics - the ability to use existing transport infrastructure such as ports and rail to convey large quantities of biomass to the plant.

In the future the issues with imported fuels are likely to be:

- Competition for resource.
- Rising prices - prices have been rising rapidly recently, particularly for products also sold into the food market. This applies to most of the biomass that has markets in either human or animal food.
- Sustainability - this has been a high profile issue for transport biofuels in particular, relating mainly to land use change and to the use of food products for fuel. Sustainability criteria and reporting are currently being introduced in both the UK and EU for transport biofuels and the EC is considering the issue as part of the Renewable Energy Directive. In addition sustainability reporting has been proposed for bioenergy from power generation under the RO.
- Indirect impacts of bioenergy - in addition to direct land use changes, which occur when crops are planted for bioenergy, there are also indirect impacts, which can be important. These result from the need to replace the crop that was previously grown on the land where bioenergy crops have been planted. It is possible that these crops can be displaced to regions outside the UK and that they may result in cultivation of previously uncultivated land. This is a controversial issue, because it is difficult to establish causality. In the face of uncertainties and gaps in the data the emissions that result from indirect land use change are not included in most current life cycle analyses of GHG emissions from bioenergy. This is an important issue for first generation biofuels crops that depend on food crops for feedstock. Indirect land use change is not so important for biomass heat and power, as much of the fuel to date has come from residues or waste materials, but the indirect impact on alternative markets for residues may be important.

Box 2.5 Summary of biomass fuel use

Biomass fuel use is dominated by the use of wood residues (forestry and wood processing residues), food processing residues and imported feedstocks.

The figures for 2006 presented in this report do not include a lot of biofuels, but these are set to grow in importance. The key biofuels feedstocks at present are: used cooking oil, tallow, oil seed rape and imported seed oils. It is likely that increasing quantities of wheat will be imported in the future.

Bioenergy is an immature market and bioenergy feedstocks are subject to typical issues seen in an immature market (such as fluctuating spot market prices). This means that many users currently contract directly to their supply chain.

Land use for bioenergy is dominated by potential biofuels production (at 150,000ha in 2006). Land use for lignocellulosic energy crops (energy grasses and coppiced wood) is much lower, reflecting farmers' doubts about entering this market and the high prices being paid for agricultural food and feed commodities at present.

2.7 Summary of current biomass use

- Current bioenergy use is dominated by co-firing and stand alone biomass power plants (land fill gas and sewage gas excepted). Supply for these plants is dominated by the use of residues, wood fuels and imported fuels.
- More recently biofuels production has stimulated the use of used cooking oil, tallow, sugar beet and oil seed rape. There are a lot of plans to expand biofuels production, principally based on the use of wheat to produce bioethanol. However, many of these plans have been put on hold while the price of feedstock remains high.
- Heat is dominated by the domestic use of wood and the industrial use of CHP at a few large plants. It is likely that small-scale heat use will increase as a result of the bioenergy capital grant scheme.
- Apart from land fill gas and sewage gas (which are not included in this analysis) anaerobic digestion (AD) does not represent a big resource at present. There is one centralised digester and a small number of on-farm digesters. There are also some industrial plants but no central database of information on these. It is likely that AD will increase in the future, but in response to a need to treat wastes rather than generate heat or power.

3 Barriers to Bioenergy

This section examines key barriers to biomass energy. Where appropriate it summarises guidance, protocols and other initiatives that have been produced to address these barriers.

3.1 Regulation of biomass plants

The regulation of biomass energy under Integrated Pollution, Prevention and Control (IPPC) regulations is provided in Appendix 9.2. This shows where the Environment Agency is responsible for regulation (and guidance) and where this is the responsibility of local authorities (in which case Defra provides guidance). Essentially the Environment Agency is responsible for:

- Combustion plants of > 50 MW thermal input burning any fuel.
- Combustion plants of 3-50 MW thermal input burning fuels containing or derived from waste.

However, if the whole activity on site is under IPPC, particularly if total heat or power generation on site is within the limits described above, the Environment Agency could be referred to if there is a request to change the fuel used on site.

In addition there are rules for IPPC as applied to biofuels plants. In this case the Environment Agency licenses plants that produce over 5,000l/year or 100l in any one week.

3.2 Barriers to biomass energy

The Government has funded a number of initiatives to support biomass energy, but its uptake has been slow. One of the main reasons for this has been the cheap cost (and convenience) of alternative fossil fuels, but there are other issues that have to be considered as well. Apart from the cost (and size) of capital equipment needed compared to fossil fuel equipment, the main barriers to biomass energy lie in the uncertainties associated with the development of a new technology for the UK, including the need to provide information on its use, the skills required for its development and the immaturity of the fuel supply chain. Regulation and legislation can be complex and costly. The relevance of these to the Environment Agency is discussed below and summarised in Table 3.1.

Table 3.1. Summary of the barriers to bioenergy that are relevant to the Environment Agency

Barrier	Comment	Relevance to the Environment Agency	Specific issues	Recommendations
Innovative use of biomass in the UK – lack of database of information.	In the absence of experience in the UK it is often difficult for plant developers to obtain good quality advice and information on: • Storage and collection of fuels. • Emissions from conversion processes. • Best Available Technologies (BAT) and disposal of residues etc. This can be an important barrier to bioenergy development.	The Environment Agency is the statutory body responsible for the licensing of heat and power plants[7] and biofuels plants[8] under IPPC in England and Wales. Guidance has been issued by the Environment Agency on combustion plants and also on gasification. Some of this guidance includes specific information on biomass plants.	• The Environment Agency needs to keep abreast of progress and build up a database of information on biomass energy to understand the specific issues that must be considered under IPPC. • There is little information on emissions from biomass combustion plants or on the cost-effectiveness of specific abatement technologies for biomass energy plants.	• Central database of Environment Agency knowledge on bioenergy, perhaps linked to the Biomass Energy Centre web site. • Examination of the cost effectiveness of abatement technologies to achieve environmental emissions limits and to support provision of better advice and guidance aimed at biomass plants only.
Uncertainty in the fuel supply chain.	Bioenergy is a developing sector and fuel suppliers are operating within an immature market. Decisions made by a few key stakeholders can alter demand for fuels or feedstocks rapidly. This uncertainty is preventing market entry by key potential feedstock suppliers (for example, farmers are very cautious about growing perennial energy crops). It also means that plant developers prefer to or even need to develop a flexible	The Environment Agency deals with this need for flexibility in its licensing of bioenergy installations.[9]	Need for flexibility in fuel feedstock to respond to market conditions.	Examine possibility of issuing a biomass protocol, similar to the co-firing protocol. Maintain a database of knowledge of biomass feedstock, so that the implications of using new fuels at plants is understood. There are databases based on combustion characteristics, but

[7] Under IPPC the Environment Agency regulates installations over 50MW (thermal energy) or 3MW (thermal) if they use waste as a fuel.
[8] For biodiesel plants the Environment Agency licenses plants that produce over 5,000l/year or 100l in any one week.
[9] An example of this is the development of co-firing in the UK. In this area a pragmatic and helpful protocol was developed enabling power generators to use a range of biomass fuels that fall within the specification for biomass agreed under IPPC. This speeds the process of introducing new biomass fuels that are similar to the ones already in use and enables power stations a certain amount of flexibility in their approach to fuel procurement.

	approach to their fuel/feedstock supply.			the Environment Agency also needs data on emissions

Barrier	**Comment**	**Relevance to the Environment Agency**	**Specific issues**	**Recommendations**
Shortage of appropriate skills for all aspects of bioenergy.	A general lack of skills and experience in bioenergy in the UK means it is difficult and expensive to obtain help with IPPC applications and/ or to predict emissions from plants. For some of the more advanced technologies data is not readily available for IPPC and expertise is developed with the plant.	The lack of knowledge and skills is also important to the Environment Agency. In order to ensure that the conditions of IPPC are met the original license must be based on known potential impacts.	Lack on information on environmental emissions and other impacts.	Improve database of potential environmental impacts (for example by creating a central Environment Agency database on experience of environmental impact, particularly emissions).
Cumulative impacts for small schemes.	The cumulative impact of small biomass boilers is poorly understood. This is relevant to policies such as targets for zero carbon homes or if more councils adopt 'Merton' planning rules, requiring renewable energy on developments over a certain size.	This is a local authority issue, but the Environment Agency may be consulted on these impacts, particularly in urban areas and where larger biomass or waste plants are also proposed.	Biomass boilers can be registered for operation in smokeless zones or air quality management zones, but there are also likely to be impacts in rural and semi-rural areas. Increases in smoke, particulate matter and nitrogen oxide emissions may all impact on health.	This issue is being examined by Defra and the Scottish Executive. The Environment Agency needs to keep a watching brief on developments.
Complex legislation and regulations.	Developers find the raft of associated legislation complex and costly. They need to be familiar with IPPC, Waste Framework Directive (WFD), WID, RO, planning.	The Environment Agency has commissioned work on regulations and legislation associated with biomass development (AEA, 2006), but as regulations change this needs to be updated (both the WFD and RO have been changed since this earlier work was undertaken; and it did not include transport biofuels).	Need for regularly updated guidance to regulations.	Develop data base model on all guidance and regulations for all biomass plants, which can be easily updated.

Barrier	Comment	Relevance to the Environment Agency	Specific issues	Recommendations
Public perception resulting in delays at planning.	Public concerns regarding the implementation of bioenergy include: emissions, health impacts, number of transport movements. They are also concerned that bioenergy is a 'Trojan horse' for waste incineration. These fears relate to all biomass combustion, not just that using biomass residues classed as waste. As more biomass plants taking waste fuels (such as waste wood) are developed, this fear will grow.	Consultation with the public is important and should follow similar lines to consultation for waste to energy; community involvement is important and public concerns are legitimate and should be addressed. Defra has provided guidance in the form of a community liaison information sheet on 'Involving communities and stakeholders'.	Many myths and legends exist on the impacts of biomass plant.	Sign-post the public available good quality data - addressing public concerns is important. This data needs to be well-informed and neutral (information put out by the developers may be perceived to be biased).
Sustainability.	Sustainability of biomass feedstocks depends on the source of fuel/feedstocks. The concept has been introduced as part of the requirements for the Renewable Transport Fuels Obligation (RTFO) and reporting on sustainability of feedstocks will be required as part of the RO and the proposed Renewable Energy Directive. These initiatives will ultimately result in the development of realistic sustainability criteria, but currently there is some confusion over which feedstocks are likely to be acceptable. One key issue will be the way in which indirect effects are considered. The Environment Agency is likely to be consulted, particularly on issues relevant to England and Wales.	The Environment Agency may be asked to comment on sustainability and to provide key criteria that it considers important to sustainability. The debate on indirect effects of biofuels tends to concentrate on imported biofuels. However, there may be important indirect effects in the UK, particularly from land use change.	Sustainability reporting will be needed for biofuels and co-firing and may be required for all biomass combustion after 2010. Indirect impacts will be included where possible (for example, use of wastes/residues may displace other uses and the carbon efficiency of this needs to be examined; the cultivation of energy crops may increase pressures for intensive agriculture and increased agro-chemical inputs, resulting in potential for greater water pollution[13]).	There is a lot of recent literature on sustainability. The Environment Agency has also commissioned a software tool (the Biomass Environmental Assessment Tool, BEAT) to provide information on the environmental impacts of biomass energy. The Environment Agency may wish to consider the indirect impacts of biofuels in the UK, if any of these fall within its remit (such as water management, flood control, environmental emissions and so on).

[13] These types of indirect impacts are considered in the Defra-supported review on the International Environmental Sustainability of biofuels (AEA, 2008). In addition there is much debate on sustainability in the negotiations for the Renewable Energy Directive (published by the EC in draft form in January 2008).

Barrier	Comment	Relevance to the Environment Agency	Specific issues	Recommendations
Competition for land.	The proposed large increase in biofuels due to targets in the EU will initially come from first generation technologies and imported biofuels. The large scale expansion of crops to meet these targets will have land use change implications. As indicated above the major discussion around this topic at present centres on the indirect changes that come about as a result of the large-scale planting of biofuels crops.	Much of this debate is about planting crops abroad (for example in South America and the Far East), but there are also potential issues in the UK. For example, the recent suspension of set aside in response to high food prices and poor harvests may have environmental implications such as increased fertiliser use.	The main issues are: land use change, Intensification of agricultural production, impacts on biodiversity.	The DfT, RFA, EEA and EC are examining these issues in terms of GHG emissions, food versus fuel and socio-economic impacts. Defra has just reported on biodiversity and other environmental impacts. The Environment Agency should ensure that any concerns it has about impact are included in this debate.
Definition of waste.	Biomass residues can be used as fuels and are some of the most readily available biomass fuels; they tend to be cheaper than virgin biomass fuels and may not have a ready market. This makes them attractive fuels to developers who argue that recovery of energy from biomass residues is better than disposal to landfill.	The Environment Agency regulates sites under IPPC and has to decide if a combustion plant is burning wastes for the purposes of the WID. The EC has recently released guidance on this issue and the basic definition of waste within the Waste Framework Directive is being examined. The Environment Agency is undertaking a waste protocols project to better define the position of some residues under regulation. A protocol for waste wood[14] is under consultation. Other residues being examined as part of this project include the use of waste cooking oil for biodiesel and digestate from anaerobic digestion.	This will be an ongoing problem, particularly for residues from food, drink and fibre processing. The Environment Agency has issued guidance. Some of these materials are already used and their use as a fuel may be in direct competition with the current use (or 're-use').	Residues are cheaper than virgin biomass, some may already be used in products (for example, feed and fertiliser) and they are readily available. This means they are among the most likely biomass fuels to be used, particularly at large scale, and will be included in many developers' and generators' business plans. Clear guidance is needed on whether it is better to recycle these feedstocks or recover energy in terms of their environmental impact.

[14] Wood Waste regulatory position statement (Environment Agency, 2007).

3.3 Innovative technology

Summary

Key barrier: lack of familiarity with technology and shortage of skills, which impact on the ability to develop plants in the UK.

Requirement: Guidance documentation is provided under the Best Available Technique Reference (BREF) process and Defra guidance. Further guidance will be required for advanced technologies and for small-scale biomass heat deployed in urban areas. Consideration of the use of genetically modified organisms in advanced biofuels conversion may be required in the future.

One of the key barriers for bioenergy is the lack of familiarity with the technology in the UK. This is important in all aspects of the development of bioenergy. The issue is that there are few experts with experience of installing and operating plants and that many policy makers are not familiar with the plants (this can be important at the planning stage).

On the whole, the lack of knowledge has been dealt with in the UK by importing European expertise, technology and information or by transferring knowledge on combustion of other fuels, and this solution has proved satisfactory to date for biomass heat and power. In terms of co-firing, the power generators have conducted a number of trials of various feedstocks and developed knowledge and technical expertise through this work. Advice is also available through Defra and the Environment Agency (see box 3.1). A central database of information on environmental emissions could usefully be developed and made available through the Biomass Energy Centre web site.

Box 3.1 Guidance for biomass energy schemes

1. Large-scale biomass schemes

Guidance on large-scale energy plants that come under IPPC are available in BREF notes,[10] which are developed on an EU-wide basis. In addition the advice provided by the Environment Agency is a good source of information for developers.[11] The BREF notes are designed to ensure that there is good transfer of information in Europe and that there is advice available on the Best Available Techniques (BAT) for regulations that are introduced.

2. Small scale schemes

Advice on smaller scale applications that fall under local authority regulation is available from Defra.[12] In addition, the Biomass Energy Centre[13] has information on regulation of biomass plants.

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[10] Wood Waste regulatory position statement (Environment Agency, 2007). The most relevant BREF note is:
Large Combustion plants, July 2006, available from: http://eippcb.jrc.es/
[11] For example, see IPPC Sector Guidance Note S1.01: Combustion Activities V2.03 (27/07/05) Available from: http://publications.environment-agency.gov.uk/pdf/GEHO1205BJYG-e-e.pdf . In addition the Environment Agency provides guidance on issues such as environmental assessment and appraisal of Best Available Technologies.
[12] General Guidance Manual on Policy and procedures for A2 and B Installations. LA-IPPC and LAPPC, January 2008. Available from DEFRA:
www.defra.gov.uk/environment/ppc/localauth/pubs/guidance/manuals.htm. Defra also make Process

Currently, there are no specific biomass guidelines for small-scale combustion plants. With the growth of small-scale biomass heat and power in urban areas, it may well be time to develop biomass-specific guidance, covering issues such as the Clean Air Act (and air quality management) in particular.

Innovation in bioenergy occurs on an international scale and it is important that information is available on overseas schemes, as it is likely that developers will wish to examine the possibility of employing these innovations in the UK. Solutions for emissions control in Europe can be used in the UK and European experience of plant emissions can be helpful in developing procedures.

Relatively innovative technologies being developed abroad include advanced conversion technologies and advanced biofuels or biorefineries.

Advanced conversion technologies include pyrolysis and gasification. There are demonstration plants in Germany, Italy, Finland and Japan, but little experience of these technologies at large scale in the UK.

There is a lot of ongoing research to develop **advanced or second generation biofuels and biorefineries**. The aim of this research is to enable the use of cheaper and more available lignocellulosic feedstocks and to make best use of biomass by producing multiple products. Although the feedstocks for these plants are similar to those already used for biomass heat and power, there is little information on the potential environmental impacts of the conversion plants.

It is thought that second generation biofuels will overcome the issues surrounding the use of food crops for first generation biofuels and provide improved GHG emissions.[14] AEA (2008c) indicated that removal of residues from agricultural land for use in second generation technologies may have implications for soil organic matter and erosion; conversely the use of perennial woody crops would add to soil organic matter. It is important that clear guidelines are available on these issues.

Research is ongoing (particularly in the USA[15]) into the use of genetically modified organisms for more efficient conversion of lignocellulose to biofuels. This work does not consider the environmental impact of these proposals.

Although these technologies are beyond the two-year remit of this report, some of the early second generation processes are being demonstrated in large pilot-scale plants now and the first full scale commercial plants could be built in Europe by 2015.

Guidance notes available and there is one for Boilers and Furnaces, 20-50MW net rated thermal input (PG1/3 (95)), with amendments AQ23(04) available from www.defra.gov.uk/environment/ppc/localauth/pubs/guidance/notes/pgnotes/
In addition the Chartered Institute of Environmental Health has produced guidance on Industrial Pollution Control by Local Authorities – a management guide, 2004. Available from: http://www.cieh.org

[13] Biomass Energy Centre, 2008.

[14] The DfT and RFA RTFO web sites provide information and guidance on biofuels use.

[15] US Department of Energy, 2006. The US Renewable Fuel Standard sets targets for biofuel use. These include targets for 250 million gallons of cellulosic ethanol from 2013.

3.4 Uncertainty in the fuel supply chain

Summary

Key barrier: The current immature biomass market results in volatile prices which impact on the development of biomass fuel supplies. This makes for uncertainty in the market and can impact on supply for bioenergy plants.

Requirement: Bioenergy developers use a number of mechanisms to deal with supply issues, including direct contracts with suppliers. Another option is to build in flexibility, allowing switching between feedstocks in difficult markets. This need for flexibility has to be recognised within the IPPC process.

Biomass fuel supply chains are relatively immature and sensitive to factors that can result in supply shortages and sudden and rapid changes in price. There are relatively few players in the biomass market and decisions made by one or two of these stakeholders can cause big supply or price changes. Biomass feedstocks are also traded in other markets, which compete for supply. Examples of market perturbations are provided in Box 3.2.

Box 3.2 Examples of factors that affect biomass markets

The biomass supply market is immature and very sensitive to changes. This can result in volatile prices, which the bioenergy sector needs to be able to react to. Examples of factors that influence the market include:

- Changes in government policy. For example, the recent change in support for energy crops[16] may result in less energy crop being planted. A policy-driven push for second generation processing could influence the availability of residues to the biomass heat and power sector.
- Closure or development of plants. Closure of a board mill, for example, might result in an increased availability of wood processing residues at lower prices; conversely the development of a large biomass power plant will result in competition for biomass feedstock and may result in increased prices.
- Changes in agricultural crop production. This will influence the availability of crops and residues for the bioenergy market. For example, the olive harvest can fluctuate by as much as 30 per cent between years, resulting in very different availability of residues for bioenergy. In the same way straw availability is also affected by climate and demand in other sectors. The recent shortages of corn for feed have lead to Australia and New Zealand farmers switching to palm kernel expeller (PKE) for animal feed, with resulting increases in competition and an increase in cost for PKE used in co-firing.
- Climate impacts. A sudden cold spell in Europe has resulted in increased demand for biomass pellets, leading to decreased availability, higher prices and lower quality.

[16] The Energy Crop scheme in England was changed in December 2007. Under the previous scheme farmers were entitled to a set payment per hectare. Under the new rules payment will be based on 40 per cent of actual establishment costs. See www.naturalengland.org.uk/planning/grants-funding/energy-crops/docs/ecs-confirmation.pdf . It is thought that the grants available under the new calculations will be lower than the previous fixed hectarage rate.

One way in which the bioenergy sector seeks to 'hedge' against the worst effects of supply shortages and increased prices is to maintain flexibility of supply where possible. While this is feasible for co-firing, it is not so easy in dedicated biomass plant designed for specific fuels, such as the straw and chicken litter plants in East Anglia. However, even in these plants the operators have sought to maintain the flexibility to take in other feedstock.

The Environment Agency has to regulate these plants to ensure that they meet the requirements of their permit. For co-firing it has adopted a practical approach to permitting, allowing flexibility in fuels without compromising environmental emissions. This requires good quality information on the nature of biomass fuels, their physical, chemical and combustion characteristics and potential emissions in storage, handling and on combustion as well as the wastes produced. This information is not always readily available (although some databases on fuel characteristics have been developed[17]) and the Environment Agency has taken an empirical approach, requiring analysis of fuels and the results of trials to ensure that the biomass being burnt meets the conditions of the permit.

This is a good approach and has proved successful. It may also be useful to develop a database of information on emissions as they have been monitored by the Environment Agency (and therefore are not attributable to any specific plants), which can be used to provide advice internally for Environment Agency staff.

3.5 Complex legislation/regulations

Summary

Key barrier: The legislation in this area is complex, which adds to the cost of development of biomass energy. Frequent changes result in uncertainty, which has an effect on investment.

Requirement: Readily available information on biomass legislation, from an easily accessible source, which includes updates on changes in legislation. Recognition of the cost of compliance, particularly for biomass energy plants that need to comply retrospectively with updated emissions requirements.

Biomass energy is relevant to a number of policy areas: agriculture, forestry, waste, environment, rural development and energy. There is a wide spectrum of legislation and regulations that apply,[18] which are summarised in Table 3.2.

Table 3.2. Main legislation relevant to biomass energy

Legislation	Comments
Solid biomass plants	
Renewables Obligation Order 2007 See: www.berr.gov.uk	The Government's main mechanism for supporting generation of renewable electricity. Currently being revised to band the renewable technologies according to their development status.

[17] For example the Phyllis or Biobib databases.
[18] The 2006 AEA report on 'Regulation of energy from solid biomass plants' summarises most of these. However, that report only covered solid biomass. Biofuels and biogas were not included.

European Emissions trading scheme (EU ETS) 2003/87/EC See http://ec.europa.eu or www.defra.gov.uk	'Cap and trade' mechanism in which emission limits are set for installations as part of a national allocation plan for specific periods. Biomass heat and power count towards the cap limits but their emissions are neutral and thus one mechanism that may help installations achieve their gap.
The Waste Incineration Directive (WID) 2000/76/EC (see Guidance on Directive 2000/76/EC on the incineration of waste (2006), available from the Defra web site).	Sets emissions limits for combustion plants that use waste fuels. The WID only applies to biomass fuels that are also wastes. The Environment Agency provides a protocol on which biomass fuels are not wastes.
The Large Combustion Plant Directive (LCPD) 2001/80/EC	Sets emissions controls on large combustion plants (>50 MW thermal rated) regardless of fuel. Waste is excluded as it is covered by the WID.
Renewable Energy Guarantee of Origin (REGO). See Ofgem or BERR web site for more information.	Certificates that provide a guarantee of the renewable origin of the energy generated. Currently these have little trading value, but it is likely that their use will increase with increased pressures for Europe to achieve renewable energy targets in 2020.
Biofuels	
Renewable Transport Fuels Obligation (RTFO) Order 2007See DfT web site or www.opsi.gov.uk/si/si2007/uksi_20073072_en_1	The UK Government's mechanism for support for renewable transport fuels. Requires five per cent of transport fuels sold on UK forecourts to come from a renewable source by 2010. In force from April 2008.
Biofuels Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport. OJ L123/42. See: http://ec.europa.eu/energy/res/legislation/doc/biofuels/en_final.pdf	Member States must ensure that a minimum proportion of biofuels and other renewable fuels are placed on their markets, and that national indicative targets are set to achieve that effect. The EU recommends a "reference value" for these targets calculated on the basis of energy content, for all petrol and diesel used in the transport sector. These reference values are set at two per cent by 31 December 2005 and 5.75 per cent by 31 December 2010. The EC has recently published targets for a 10 per cent minimum for the market share for biofuels in 2020. These are mandatory targets, which will be included in the forthcoming Renewable Energy Directive (RED), see below.
Environmental Issues	
Planning consent	Onshore renewable energy proposals fall within Schedule 2 of the Town and Country Planning (Environmental Impact Assessment) (England and Wales)

	Regulations 1999 (the EIA Regulations) and are therefore likely to require an environmental impact assessment.
Proposed legislation and policies	
Proposed Directive on the promotion of the use of energy from renewable sources ({COM(2008) 30final}). http://ec.europa.eu/energy/climate_actions/doc/2008_res_directive_en.pdf This is commonly referred to as the Renewable Energy Directive (the 'RED').	Proposes a binding target of 20 per cent for renewable energy's share of energy consumption in the EU by 2020, and a binding 10 per cent target for the share of renewable energy in transport petrol and diesel.[19] The UK target has been set at 15 per cent renewable share of gross final energy consumption in 2020.
Heat Call for Evidence (January 2008) To be followed by a consultation later in the year. www.berr.gov.uk/files/file43609.pdf (call closed 31st March)	Call sought views on existing and potential policies that might reduce the carbon impact of heat. This Call considered biomass and heat from waste (including biogas/anaerobic digestion) as two of the three renewable heat technologies most likely to play a role in the UK heat sector in the short- to medium-term.

Table 3.2 shows the key role that biomass energy plays in the UK's (and EU's) strategy to achieve carbon emission reductions and renewable energy targets. However, in addition to these incentives for biomass energy, there are also regulations that control the operation of these plants, including IPPC, Health and Safety, waste treatment and disposal. These requirements add cost and complexity to the development of biomass power.

Consequently, developers often find the legislation complex, expensive and, in some cases, apparently contradictory. An example is the definition of the term 'biomass' in the RO legislation. Developers often think that if they can get their feedstock accepted as a biomass within the RO, then it will not be a waste for the purposes of combustion under WID. This is not the case, but to developers the difference in definitions is apparently contradictory. The Environment Agency, recognising this, has produced information to provide clarity on the definition of waste and a list of feedstocks that are waste for the purposes of WID and those that are not. In addition it has made various protocols and guidance available to further clarify specific applications.[20]

The legislation will be further complicated by the introduction of banding of renewable technologies under the RO. Table 3.3 shows the proposed bands in the RO consultation. In these proposals power from biomass comes into every band. BERR is proposing to provide clear definitions for each technology band within the legislation, but the situation remains complex. For example, anaerobic digestion (in one form or another) is in three of the bands in Table 3.3, all with different rewards under the RO. In fact anaerobic digestion is most likely to be used as a waste treatment process, rather

[19] Currently being negotiated and will supersede the Biofuels Directive. Currently includes the proposed 10 per cent target for renewable energy in transport and a draft target for the need to demonstrate GHG reductions from biofuels of at least 35 per cent compared to fossil transport fuels (there may be other sustainability requirements and the GHG savings may increase to 50 per cent in 2015). The wording means that renewable power can also be used for electric vehicles.
[20] For example: Protocol for the burning of biomass fuels in power stations (2004); The quality protocol for the production and use of waste vegetable oil derived biodiesel (2007); IPPC sector guidance notes (for example, S5.01 on incineration of waste and fuel manufactured from or including waste, 2004); Waste wood position statement and so on.

than an energy generation process, so these bands are important in the way in which they interact with waste policy in the UK. Most large-scale developers will appreciate these issues and have environmental (law) teams that can advise them; however, smaller players may find the situation complex and costly.
The nature of the drivers in Table 3.3, together with the backdrop of the 2020 targets means that it is likely that the Environment Agency will see more proposals for large-scale dedicated biomass plant (such as the proposed 350MW Port Talbot power plant and E.ON's proposed 25MW plant at Sheffield) and CHP (such as the proposal from Helios Energy to use biofuels residues for heat and power on the Humber).

There is also an incentive to coal power stations to source energy crops, both from the UK and abroad. The definition of energy crops within the RO may also include residues from biofuels plants in South America and Africa (for example, the use of bagasse from bioethanol production in Brazil, where there is an estimated 7.7Mt of dry bagasse residues).[21]

Table 3.3. Proposed bands of technologies for the RO

Band	Technologies	Level of support ROCs/MWh
Established 1	Landfill gas	0.25
Established 2	Sewage gas, co-firing on non-energy crop (regular) biomass	0.5
Reference	Onshore wind; hydro-electric; co-firing of energy crops; EfW with combined heat and power; geopressure; other not specified	1.0
Post-Demonstration	Offshore wind; dedicated regular biomass	1.5
Emerging	Wave; tidal stream; fuels created using an advanced conversion technologies (anaerobic digestion; gasification and pyrolysis); dedicated biomass burning energy crops (with or without CHP); dedicated regular biomass with CHP; solar photovoltaic; geothermal, tidal Impoundment (e.g. tidal lagoons and tidal barrages (<1GW)); Microgeneration	2.0

These proposed bands provide an incentive for biomass energy. However, there is also a need to consider air quality and waste quality policy, which provide barriers that have to be considered if we are to achieve Government policy on renewable power without compromising impact on the environment and human health.

In summary, the Environment Agency has a key role in regulating biomass plants, which means that it has to ensure that the plants are operated within legislative limits and that plants that use biomass waste as a fuel are regulated according to IPPC/WID. The guidance and information released by the Environment Agency on this legislation is helpful; but more information and assistance is required by biomass developers working in a complex legislative environment if we are to achieve carbon reduction without compromising other environmental emissions. In particular this includes guidance on best practice specific to biomass technologies; and a clear indication of the cost/benefits of achieving emissions control. We need clear, robust decisions on the combustion of biomass residues to prevent lengthy challenges in the courts.

[21] The definition of energy crops in the RO is: 'plant crop planted after 31st December 1989 and which is grown primarily for the purpose of being used as fuel or which is one of the following – a) miscanthus giganteus; b) salix (also known as short rotation coppice willow); c) populus (also known as short rotation coppice poplar).' We cannot tell if residues from crops used for the purpose of energy (such as for producing biofuels) are also included in this definition and advise co-firing generators to take this issue up with Ofgem.

3.6 Heat

Summary

Key barrier: Biomass is one of the key sources of renewable heat. Barriers to its use include the high equipment and installation costs when compared to natural gas and oil, the cost of heat distribution networks for medium to large-scale heat schemes, and the impact of emissions (such as nitrogen oxides) from biomass combustion in local air quality management zones.

Requirement: The Government is examining the need for policy in this area. The Environment Agency should be part of this decision-making process to ensure heat from biomass is encouraged without compromising other emissions, particularly in urban environments. Issues include transport needs as well as cumulative emissions from stoves and boilers. The role of district heating in urban environments needs to be examined (in clusters of buildings, for example on business parks, leisure complexes, council buildings or redevelopments of town/city centres and so on) for its potential to decrease emissions and transport requirements. Currently small-scale biomass stoves and boilers do not require planning permission, except for the flue in some circumstances.

There is a lack of clarity on what (if any) legislation controls emissions from the flue that needs to be addressed.

The Government's recent call for evidence on heat[22] shows that there is interest in investigating ways to decrease the UK's carbon footprint from heat generation. As part of the need to meet 2020 targets for renewable energy, the UK has to achieve 15 per cent renewable energy by 2020. This means that 15 per cent of the UK's total power, heat and transport requirements will need to be met by renewable sources in 2020. This is a challenging task that will require some heat generated from renewable sources. There are not many ways to generate heat from renewable sources, and most analysts agree that biomass is one of the most important options. The Government is currently considering its options. The recent Ernst and Young report (Ernst and Young, 2007b) examined possible support mechanisms and concluded that different mechanisms will be required by different sectors. It suggested that capital grants are more applicable to small-scale installations, while a heat obligation could be considered at larger scale (although there was no information on how a heat obligation could work). Until decisions on the type and scale of support for renewable heat are made, it is not clear how renewable heat will move forward.

In the meantime, the Bioenergy Capital Grant scheme[28] has a major influence on the biomass sector; energy prices are a major secondary incentive and, at larger scale, the need to decrease the costs of the EU Emissions Trading Scheme is driving some industries to consider renewable heat. The options for biomass heat depend on the scale of the requirement, the nature of the heat requirement and the budget. At large-scale it may be feasible to consider combined heat and power (CHP). Alternatively it may be possible to install centralised boilers serving a 'district heating network' around a plant, cluster of buildings or site. At medium- or small-scale the options are more

[22] See www.berr.gov.uk/energy/sources/heat/page43671.html

[28] See Bioenergy Capital Grant scheme web site: www.defra.gov.uk/farm/crops/industrial/energy/capital-grants.htm which details the requirements for round 3 of the scheme. This applies to industrial, commercial and community sectors. Defra hopes to issue more calls in the future, subject to available funding.

restricted. Unless there is a way in which an area can be linked (for example through shared facilities on a campus or business park) it is often too expensive to consider either CHP or district heating and choice is restricted to boilers or (at domestic scale) stoves. In addition the level of heat demand and changes with season also impact on scale and commercial feasibility. To be commercially viable most biomass CHP needs to meet a fairly constant base load for heat all year round. This means that sports centres and hospitals may be suitable for large-scale heat boilers or CHP, but domestic residences or schemes where heat demand is restricted by season are not.

These differences are important when it comes to considering biomass heat in the urban environment and potential air emissions impacts. Recent evidence has shown that large numbers of relatively small biomass heat boilers, while improving carbon emissions, could result in increased nitrogen oxide and particulate emissions, which is of particular concern in air quality management zones (AEA, 2008a). It is likely that many of these plants will not be regulated by the Environment Agency (they will be too small). However, it is probable that it will be asked for comment and assistance in providing guidance on emissions.[23] The concerns about cumulative air emissions from the installation of many small biomass boilers could be a major barrier to uptake of biomass heat.[24]

At larger-scale other issues become important, particularly the application of WID to waste wood use in boilers at industrial scale. Figure 3.1shows the use of renewable heat from 1990 to 2006, taken from Dukes. An interesting trend in Figure 3.1 is the significant decrease in industrial heat combustion from 1999. This was due (in part) to the application of WID to boilers in industry and the expense of complying with WID.[25] Many of these boilers were shut down as a result. There are now signs that there is a small revival of biomass combustion, using WID-compliant plants at board plants.[26] These are now more economic due to recent rises in fossil fuel prices and development of purpose designed WID-compliant processes. There is also some evidence that biomass heat is beginning to be of interest in the food and drink sector where the residues do not (generally[27]) come under WID (for example Scottish and Newcastle are installing three plants in England using a mixture of waste wood and distillers' grains for fuel).

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[23] Defra have issued guidance in this area: General Guidance Manual on policy and procedures for A2 and B installations, Defra (2008).
[24] For example, Dundee turned down planning on a relatively small scale boiler plant on the basis of lack of information on emissions (Dundee City Council, 2007).
[25] It was also due in part to the decrease in furniture manufacture in the UK and the closure of furniture manufacturers; at the time WID was introduced these manufacturers were facing difficult times and could not afford to upgrade their boilers.
[26] There are also examples of board mills burning their residues in non-WID compliant plant as these mills take in only clean wood processing residues for their board manufacture (that is, residues that do not contain heavy metals or halogenated hydrocarbons).
[27] Residues that are potentially contaminated with meat waste must be disposed of under the Animal By-Products Regulations in WID-compliant plant.

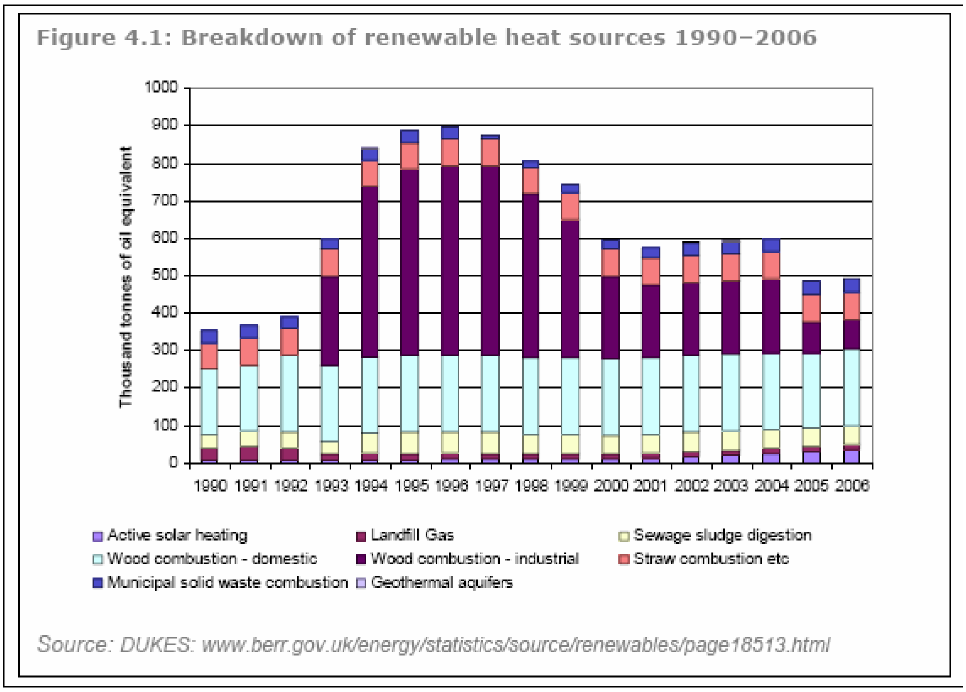

Figure 3.1. Statistics on renewable heat (from the recent Heat Call for Evidence)

One example of the issues with compliance with emissions regulations is tallow. The rendering industry has traditionally used tallow as a fuel for heat and process steam. Under the Animal By-Products Regulations (ABPR) category 1, tallow must be disposed of by incineration in a WID-compliant plant. The rendering industry is appealing against this decision and, in the meantime, in many cases continuing to use its current boilers. There are WID-compliant plants available, but the suppliers of this plant cannot sell it to the rendering industry until a final decision has been made on the requirements regarding the use of WID-compliant plant for the disposal of tallow.

3.7 Public perception

Summary

Key barrier: Planning permission delays result in additional development costs. In some cases the planning process has completely prevented development.

Requirement: Studies on bioenergy and public perception have shown that the public do not understand the term very well and are suspicious of unfamiliar development in their area. This is related to distrust of developers in general; and to concern about the impact of transport of biomass fuels on increasing vehicle movements in the area. Visual impact, noise, odours and emissions are all important issues of concern. In addition biomass is often confused with waste, resulting in the fear that all bioenergy plants will become incinerators after the installation.

The public does not always welcome biomass combustion plants. They have concerns about emissions, health impacts and transport; and environmental benefits may be challenged. There have been a number of cases in the UK where biomass developers of large-scale biomass plants have failed to gain planning permission (Howes *et al.*, 2001). The Environment Agency has been aware of these issues and has supported work on public perception since the late 1990s (for example see Petts and Leach, 2000).

The involvement of the Environment Agency is important, because it underpins work to ensure that public concerns are considered and evaluated. In turn this should enable the public to better understand the environmental benefits and impacts from major biomass schemes and to be able to judge the relative benefits without fearing the impacts. However, too frequently it is felt that the impacts of combustion are local and the benefits are national. This issue is a major barrier to the development of biomass schemes.

One of the most complex concerns about biomass plants is that they are 'Trojan horses' for waste incineration. The application of WID to many biomass residues reinforces this in the public mind. In this case the Environment Agency is likely to be asked for comment. It is unlikely that the technical (and economic) challenges in retrospectively converting a plant designed to burn biomass residues into a mass burn incinerator will be accepted as reassurance by the general public.

3.8 Sustainability

Summary

Key barrier: Information on sustainability is often incomplete. Recent concerns regarding the indirect effects of biofuels demonstrate the lack of information on the impact of some forms of bioenergy.

Requirement: Good practice guidance should be available for all forms of bioenergy. This needs to consider the whole of the biomass energy chain, from production through transport to end use. In particular this needs to consider the sources of feedstock and the impact of biomass crops on land use. Indirect land use changes are difficult to prove, monitor and control. Sustainability standards to decrease indirect impacts will need to be agreed at international level.

The term 'sustainability' as applied to biomass is currently a major concern for the public, non-government organisations (NGOs) and the Government. Essentially sustainability refers to a combination of:

- Lifecycle balance for fuels compared to fossil fuel. This is normally calculated in terms of carbon dioxide savings, although other greenhouse gases, such as methane and nitrous oxide are also usually considered. Increasingly these calculations include consideration of land use change.
- Other environmental impacts, including impacts on air, soil, water resources and biodiversity.
- Socio-economic impact, such as the impact on local people, land ownership and the local economy.
- Indirect impacts, such as the displacement of crops or other commodities to other areas.

The weight given to each of these differs depending on the interests and focus of the body concerned.

Sustainability is important for a number of reasons:

- Many biomass schemes are subsidised and encouraged by national governments with the aim of decreasing their national carbon emissions by encouraging the use of more sustainable energy use. They need to be able to demonstrate that this is actually happening.

- Analysts have indicated that the EU cannot supply all of its biomass requirements to reach its targets from within the EU. Therefore import of biomass is inevitable. There is considerable interest in ensuring that this import does not cause harm in the countries of origin.

- Biomass energy crops may displace the cultivation of other crops. Demand for these crops does not disappear and it is probable that they will need to be grown elsewhere. This may have an impact on land use and cause land use change both within and outside the EU.

In the past concern has been expressed about energy crops, such as short rotation coppice and miscanthus, proposed for Europe and good practice guidance has been developed for these crops. Since the introduction of co-firing and biofuels targets, for which large quantities of feedstocks can be sourced overseas, this concern has widened.

More recently the introduction of targets for biofuels in the EU and elsewhere[34] has caused much concern about conflicts with food production. It is estimated that the EU could import a significant amount of its biofuels from developing countries. Land use change from the switch to biofuels will have wider implications abroad. The estimate is that around 50 per cent of the biofuels produced will result in land use change outside the EU. The potential for use of tropical crops such as sugar cane, soybeans, oil palm and jatropha and temperate crops such as oil seed rape and maize for biofuels production has led to questions about:

- Expansion of land use for the production of biofuels crops. It is thought that areas such as tropical rain forests, savannahs and wetlands could all be used for biofuels crops, as these areas represent relatively cheap areas of land. Although there is little evidence that biofuels have resulted in the clearing of tropical rain forests or the drainage of wetlands to date, the fear for the future is legitimate and requires further scrutiny. For example, the cost of tropical feedstocks such as palm oil is less than European feedstocks such as oil seed rape and this means, on a cost only basis, that there would be pressure to increase the area under these tropical crops.

- There is also potential for intensification of agriculture where it was formally extensive, and pressures to improve yields using agro-chemicals and irrigation as well as more effective farming practices.

This issue has been summarised in a number of recent reports from the UN, OECD and UK Government (for example see Rajagopal and Ziberman, 2007; UNCTAD, 2006; The Royal Society, 2008; House of Commons Environmental Audit Committee, 2008).

Sustainability requirements are now proposed for biofuels and under the RO. Sustainability reporting will be included under the RTFO from April 2008 and standards will be mandatory from 2010. Research to underpin this is underway. Defra and DfID are currently supporting reviews of the sustainability of biofuels[35]; DfT is supporting

[34] For a good summary of biofuels targets worldwide see Jull *et al*., 2007.
[35] The Defra report (AEA, 2008) has just been published and is available from its web site.

work on the sustainability requirements for the RTFO. In addition work is also ongoing at European level, to establish a CEN committee on the sustainability of biomass.[28]

How sustainability will be reported within the RO is not yet clear, although BERR has indicated that the following will be required where this information is available:

- Biomass used, origin and volumes.
- Whether it is a waste/residue, co-product or energy crop.
- Whether it has been sourced under any quality standards (in particular sustainability standards under the Road Transport Fuel Obligation (RTFO), the Roundtable on Sustainable Palm Oil (RTSPO), or land use standards under the Directive on Integrated Pollution Prevention and Control (IPPC)).
- What the land use has been from 2005.
- Whether producers/generators are under any voluntary code of conduct.

How much of this information will be published is uncertain, but the information will provide a valuable indication of the environmental implications of the use of biomass energy in the UK.

The above indicates that sustainability is an important issue for biofuels and is likely to grow in importance for biomass in general. One of the key issues not dealt with in the proposed sustainability monitoring above is the issue of indirect impacts of biofuels, such as displacement of crops to different areas and displacement of commodities in various end uses. Box 3.1 provides a description of some of the indirect impacts of bioenergy.

Box 3.1 Indirect impacts of bioenergy

Direct land use takes into account the change in land use at the point of change. However, it does not include consideration of what happens to that previous land use. For example, if food was being produced on the land then, providing demand for food does not decrease, the food will need to be produced elsewhere. This may not necessarily be in the same region as the biofuels production; it may be produced some distance away or alternatively the market may switch to a substitute which is grown elsewhere. The classic example of this is displacement of cattle from the Cerrados in Brazil by soy bean production. The cattle ranchers may then move to rainforest areas, using slash and burn agriculture to provide new land for their cattle. Other examples include the switch from corn for food and feed in the USA to corn for biofuels. It is estimated that this has caused a significant increase in soybean production for animal feed in South America. This is generally referred to as ‘indirect land use change’.

The most significant indirect impacts of bioenergy result from the displacement of crops or other commodities by the cultivation of bioenergy crops. Currently most biomass heat and power is generated from residues or wastes and very little come from energy crops. However, the converse is true of biofuels and, at the moment, the debate on indirect impacts has centred on biofuels produced from crops. The major concern is that these indirect displacement effects could result in significant land use change. Such land use changes may be associated with environmental impacts on biodiversity or the release of stored organic carbon on the cultivation of previously uncultivated areas. There are concerns that indirect land use change, resulting in carbon emissions (for example deforestation or drainage of peat land) could negate the carbon savings

[28] For further information see: http://www.cen.eu/cenorm/sectors/sectors/chemistry/workprogramme.asp It is hoped that a first draft will be produced by the end of 2009. The CEN committee will examine sustainability issues for all types of biomass energy and will include environmental, social and economic criteria.

from the use of the biofuels for some biofuels systems. For this reason it is important to understand land use change and how much of the indirect land use change is caused by biofuels crops.

In theory the production of one hectare of biofuels displaces one hectare of food crops to another area. In practice, the amount of indirect land use change depends on the productivity of the land and the crop being grown. One hectare of biofuels crops may result in the cultivation of more or less than one hectare elsewhere depending on the crop, agricultural system and productivity of the land. How much this matters to biofuels emissions depends on the type of land displaced and whether or not there are associated improvements in productivity which mean that no additional uncultivated land is converted to crops. In reality it is very difficult to prove precise indirect land use change; and, in addition, some biofuel processing results in co-products that can be used for animal feed. In this case the co-products may displace soybean production in South America, resulting in lower pressures on land in that region. The complexity of the issue means that most life cycle analyses of biofuels (and biomass) have avoided the issue to date and probably under-estimate emissions as a result.

It is extremely difficult to prove causality for indirect effects. Bioenergy is not the only pressure on land use and there are many factors that result in land use change, particularly in developing countries. For example, logging is an important cause of deforestation in Indonesia. Some of this logging is associated with oil palm plantations, which also exerts a pressure on land use; some results in the increase of small-scale farms in the region. Palm oil is relatively cheap and has many uses, of which biodiesel production is only one. Currently relatively little biodiesel has been produced from palm oil. However, there are indications that the use of OSR in Europe for biodiesel is resulting in increased demand for palm oil for industrial applications in the EU. In addition ambitious plans for biofuels in the Far East could result in increased demand for palm oil. In this complex matrix of cause and effect it is very difficult to allocate the indirect impact that biofuels production in the UK will have on oil palm plantations and potential deforestation in Indonesia. Models are being proposed to provide pragmatic approaches to handle these indirect land use changes, but they are currently under debate and not accepted by all researchers involved in this work (AEA, 2008c). This issue remains a potentially important one (and could mean biofuels hit a dead end).

It is likely that sustainability requirements will provide a barrier to some sources of biomass fuel. The Environment Agency will not have a central role in deciding the requirements of such certification, but it may well have an advisory role and needs to be aware of progress in order to incorporate the latest thinking into its role as a statutory consultee in planning.

3.9 Definition of waste

Summary

Key barrier: The definition of waste on a case by case basis and the confusion over when a processed waste ceases to be a waste may prevent the recovery of energy from some biomass feedstocks.

Requirement: The issue needs to be examined in terms of environmental benefit. If energy recovery represents the best environmental choice for biomass wastes this use should be encouraged. On the other hand, processing for the sake of taking a feedstock out of the waste definition may add unnecessary environmental costs. Each feedstock will need to be examined on its own merits.

The definition of waste has been one of the most vexing issues for biomass energy; and one in which the Environment Agency's regulatory role puts it right in the spotlight. This is recognised as an issue at national and EU level and the recent publication of clarification by the EC is useful (Commission of the European Communities, 2007). Defra consulted on this issue last year (a consultation in which the Environment Agency played a key role) and we will not repeat that work here.[37] The summary of the responses to the consultation clearly states the core issues. The following are of relevance to biomass energy:

- The need for flexibility in the waste hierarchy.
- The need for a clear, extended list of excluded wastes (under the WFD).
- The need for clear definitions (specific examples quoted include the definition of 're-use', 'discard' and 'by-product').
- Proposals for end of waste criteria.
- The requirement for energy recovery to take place with a high level of energy efficiency.

The core issue for biomass energy developers is that uncertainty remains regarding some biomass residues. This means that they may or may not need to be compliant with WID if they burn these residues. The case of tallow is a good example, where tallow is not under WID but the combustion of category 1 tallow must comply with WID under the Animal By-products Regulations category. This situation is under appeal and, pending an outcome, the industry is uncertain about investment in new plant.

[37] A summary of responses to the consultation on the proposal for a Directive of the European Parliament and the Council on waste (Waste Framework Directive, Waste Oils Directive and Hazardous Waste Directive) July 2007 is available from www.defra.gov.uk.

3.10 Other issues that will be relevant to the Environment Agency

3.10.1 Small-scale biofuels

While the Environment Agency is not concerned with the regulation of small-scale biomass plant, the cumulative effects of small-scale schemes may be of importance to it. This is due to the demand for large quantities of biomass for feedstocks; and the potential for cumulative environmental impact of conversion technologies. The two technologies that are of most immediate interest are the use of small-scale heat boilers in urban environments, and the development of small-scale biodiesel plants that are not registered with HMRC or regulated by the Environment Agency. The key issues for small scale heat are the cumulative air emissions impacts, which are discussed in section 3.6 above.

The introduction of duty derogation for biofuels, the RTFO and the increase in fuels prices have made biodiesel an attractive alternative fuel. It is possible to produce biodiesel at very small scale and possible to buy the equipment to do so over the Internet. In addition the potential for use of used cooking oil for feedstock is attractive, as it is often available at very low cost. This has resulted in many plants around the country (see chapter 1). These are effectively unregulated chemical processes. Although there have been few issues with them to date, there are potential problems:

- The problems with disposal of glycerine (a by-product of the process) could result in the temptation to put it down the drain.
- The lack of supervision/regulation can result in safety problems. These include fires (cooking oil burns well) and explosions (there has been at least one explosion). In these instances there is potential for environmental impacts. In particular the spillage of large quantities of used cooking oil, which has high biological oxygen demand, into local water courses represents a hazard to the aquatic ecosystem. In addition methanol and sodium hydroxide are used in this process and incorrect storage of these chemicals represents a potential environmental hazard.

The Environment Agency has recently issued a protocol for consultation on the use of waste vegetable oil (WRAP and the Environment Agency, 2007), which clarifies the waste status of used cooking oil and the biodiesel product. It also includes a risk assessment and mitigation, which, if followed, should address concerns. The report recommends that ‘industry and the Environment Agency evaluate the residues from biodiesel production (i.e. glycerol and methanol) with a view to establishing how they can be processed to a level such that they are no longer subject to waste regulatory controls’.

3.10.2 Lignocellulose feedstocks

Lignocellulose feedstocks include woody biomass, straw and similar agricultural residues, energy crops such as miscanthus and short rotation coppice (SRC), and some of the more recalcitrant biomass wastes such as paper, wood and card. These feedstocks tend to be more resistant to degradation than other biomass (particularly when dry and under anaerobic conditions); they store well and can make relatively good fuels for heat and power. Wood fuels are of (generally) consistent characteristics and do not contain significant contaminants that cause issues in combustors. They are, therefore, the most commonly used solid biomass fuels in heat and power applications.

Lignocellulose feedstocks are also relatively plentiful biomass resources and their use for energy does not generally compete with food production (although there are parts of trees and agricultural residues that are used for animal fodder). As a result there is a lot of interest in their use for the production of biofuels through 'advanced or second generation' technologies.

If second generation processing becomes commonplace for biofuels it may well result in competition for traditional uses, such as heat and power and animal fodder (and bedding). Work is ongoing on the lifecycle analysis of the use of such fuels and to develop a better understanding of availability and the potential for conflicts in its use.

The technologies for second generation processing may well be able to take in any type of lignocellulose. This means that there is potential for mixing feedstocks and including wastes with relatively clean residues. For gasification and pyrolysis the end product of the processing will be a fuel gas and (in pyrolysis) a char. This is then either used as a fuel or a chemical feedstock for further refining. The Environment Agency needs to consider whether or not the fuel gas and char is a waste or a product and its status under the Waste Framework Directive (WFD) and the Waste Incineration Directive (WID).

3.10.3 The status of co-products

There is a need to understand the status of co-products from fuel processing. The Environment Agency has produced two position statements on glycerol from biodiesel and on DDGS from bioethanol. Co-products that may result from second-generation processing (particularly where waste feedstocks are used) will also require clarification.

3.10.4 The generation of heat and power from food processing residues under the Animal By-products Regulation (ABPR)

There is a need for guidance on the use and disposal of co-products from bioenergy processing that use ABPR wastes as their feedstock; this includes residues from anaerobic digestion, biofuels, heat and power.

3.10.5 Waste wood

Waste wood that contains contaminants such as halogenated hydrocarbons and heavy metal preservatives are classed as wastes for the purpose of combustion under WID.[38] Although this is clear, one common issue is that a significant proportion of waste wood is not contaminated, but it may be mixed with waste wood that is. The Environment Agency protocol currently indicates that this is non-virgin timber and should be treated as waste (see footnote 15). However, much wood waste will come under the Environment Agency's clean waste wood definition and the Environment Agency allows

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[38] The Environment Agency's Regulatory Position Statement on the Environmental Regulation of Wood (Environment Agency, 2007) defines non-virgin timber. It also indicates that 'there are many information gaps concerning what systems of quality control should be put in place and what standards should be adopted when reprocessing waste wood in order to ensure that the outputs do not pose a risk to human health or the environment.' For this reason the Environment Agency said that 'it has not been possible to produce a Quality protocol which would identify the point at which waste wood may cease to be waste.' See: http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/BEC_PRACTICAL/POLICY%20AND%20LEGISLATION/REGULATIONS%20AND%20DIRECTIVES/EA%20POSITIONV7_1870672.PDF We understand that the Wood Recyclers Association has started to develop a protocol which may challenge the current situation. See http://www.woodrecyclers.org/

the flexibility to use such waste wood, providing an agreed sampling protocol is in place to demonstrate that contaminated waste wood is not present.

The Waste and Resources Action Programme (WRAP) has supported some work in this area to develop tests to demonstrate the presence of heavy metal contaminants. Further work is needed to enable the re-processing, recycling and energy recovery industries to sample their waste wood feedstocks and to establish the status for the WFD and WID. The Waste Recyclers Association is beginning to examine this issue, but we understand that it will need funding to undertake all of the work that is necessary. The Environment Agency also needs to follow the work that is being done and provide comment on procedures that are proposed.

3.10.6 Pellets

It is likely that wood pellets will become an increasingly popular fuel in the UK. At the moment UK production of wood pellets is low and in the near future increasing demand will be met through imports from Europe, the Baltic, Russia and North America. In addition the vast wood processing industry in China is also investing in pellet production. It is important to know whether the pellets contain waste wood (as defined in WFD and for the purposes of WID). Currently the Environment Agency's view is that the contract for supply of pellets must clearly state that the pellets are from uncontaminated wood and an agreed sampling protocol must be in place.

If pellets are produced in the UK there are two potential environmental impacts: noise during production, and the control of the plume from high temperature drying processes.

3.10.7 Storage

As more biomass is used in the UK, particularly in large power stations such as the co-firing power stations and the proposed 350MW power station in South Wales, there will be an increasing need to store large quantities of biomass fuels. Apart from the size of storage facilities there will be other issues including:

- Degradation of wet biomass, which may result in self-heating and the danger of spontaneous combustion. In addition degradation can result in increased microbial spores, and runoff containing organic acidic residues.
- Odour.
- Dust, resulting in potential explosion hazards and respiratory problems. These will be particularly important in conditions of high winds. Residues that may be associated with explosive dust clouds in storage include DDGS and fine sawdust. There is some guidance on dust from wood processing on the Environment Agency web site.
- Toxins: some plant residues contain toxins. Some plant residues produce toxins on combustion (for example, combustion of glycerine may produce acrolein (which is toxic) and formaldehyde.
- Some biomass fuels are hygroscopic and need to be stored in specific conditions to prevent uptake of water and degradation.
- Some biomass feedstocks may stimulate allergic reactions (for example, peanut husks).

- Many of the residues that could be used for fuels are currently used for animal feed. This means that there is experience in their transport and storage and some guidelines are already available. Many of the above issues are covered by Health and Safety (COSHH regulations). The key issue that concerns the Environment Agency relates to emissions to air, land and water. These are described in the IPPC Technical Guidance note for the Combustion Sector (see Environment Agency, 2002). If large stores become common, it may be advisable to produce a protocol on storage, based on Environment Agency experience of issues.

3.11 Summary

In summary, there are key barriers to biomass development in the UK. These include:

- Uncertainty regarding the classification of biomass residues under WID.
- The need to ensure that biomass use is sustainable and the definition and regulation or auditing of sustainability. The need to consider both direct and indirect land use changes.
- The cumulative impact of small-scale plants on air quality in local environments.
- The cumulative effect of small-scale biodiesel plants, which are currently not registered.
- The public perception of combustion plants, which leads to delays and additional costs in the planning permission process.
- The range of legislation and regulation applicable to biomass energy, and the complexity of some of this legislation. The cost of employing assistance to interpret legislation and the risk of misinterpretation.
- Uncertainty regarding biomass heat (the lack of current support outside the capital grants scheme and the effect of support that may be introduced to encourage renewable heat).
- The need to introduce innovative technologies to improve the efficiency of biomass use (such as gasification, second generation biofuels, biorefineries and so on), but the lack of information on emissions from or BAT for these technologies.
- Lack of skills for installation.
- Unreliable supply chains.
- The need to develop procedures to enable more advanced protocols regarding the use of waste wood in the energy sector.
- The recognition of the potential environmental impact of biomass in storage and ensuring that protective measures are put in place.

4 Assessment of the likely biomass utilisation in 2010

4.1 Introduction

This section looks at what might happen in the near future to biomass energy to enable an assessment of what the key issues could be for the Environment Agency. At the moment there are a number of drivers and pressures on biomass energy, as has been seen in the previous chapters. This means that there are a number of ways in which biomass energy could develop and a number of uncertainties and barriers influencing this development. We undertook analysis of the situation by developing a number of scenarios for future development of biomass energy. These scenarios are summarised below in Table 4.7 and Table 4.8 and then the results of the analysis are presented.

4.2 Methodology

To provide an indication of the pattern of biomass development that are likely to occur in England and Wales in the near future, we developed a model of bioenergy at present and then examined the increase in bioenergy that could develop given a range of circumstances as indicated in each of the scenarios.

4.2.1 Development of scenarios

The data in chapter 1 was used to provide an indication of biomass energy in 2006, including the fuels used, the area of land take for these fuels and the GHG savings that result. 2006 was chosen as the base year as it was the last year for which we have comprehensive data. We then developed scenarios and examined what biomass energy trends may occur for 2010 and for 2015. The model used for this work was based on a 'bottom up' approach, in which data for current biomass plant were used for the baseline analysis and the future analysis was based on the rate of increase (or decrease) in plants. This approach works well, but does rely on our estimates of the size and nature of plants that may be developed. If biomass energy is scaled back (for example if the proposed biofuels plants are not developed) we have to make judgements about which plants may go ahead and which may not. This all requires a good understanding of biomass energy, the fuels that are used, the drivers for biomass and the markets in which bioenergy is operating. For this reason when developing the scenarios we also examined pressures on biomass development in detail for each scenario, including SWOT (strengths, weakness, opportunities and threats) analysis of each sector and an examination of the literature for information on how other analysts consider the sectors will develop. This provided us with an appreciation of how we might expect the whole sector to react to the scenarios (a 'top down' approach). This was not conducted in detail, but did provide a means of double-checking the results from the scenarios.

The model developed required information for all plants operating in each scenario and this included:

- The annual output of the plant as MWh of heat, MWh of electricity or million litres of transport biofuel (based for future years on its capacity and an estimate of its load factor).
- The mixture of feedstocks used in the plant (for example 50 per cent imported wood chips, 50 per cent short rotation coppice from the UK).

Large plants were modelled individually, smaller scale plant in tranches.

4.2.2 Estimation of feedstock requirements, land take and GHG savings

In each scenario the model assesses:

- The quantity of fuel or feedstock required.
- The land take for crops in England and Wales (if relevant).
- The total GHG savings.

Calculation of these three parameters is based on data extracted from the Biomass Environmental Assessment Tool ($BEAT_2$) developed by AEA and North Energy for the Environment Agency and recently updated for Defra and the Environment Agency. $BEAT_2$ uses a lifecycle analysis approach to estimate the total greenhouse gas emissions associated with producing a megawatt hour of heat or electricity (or thousand litres of biofuels) for a number of feedstocks and different technologies (co-firing, biomass power stations, industrial CHP schemes, industrial and small scale heating schemes, centralised and small on-farm anaerobic digestion schemes). The emissions are estimated for a typical process chain, through from cultivation and harvesting of a crop, to processing, combustion (or transformation to biofuel) and disposal of waste products such as ash. Defining this process chain means that $BEAT_2$ also calculates the amount of feedstock required to produce a megawatt hour of heat or electricity (or thousand litres of biofuels), and the land area that is required to produce that feedstock. These numbers were combined with the calculated outputs of plants to give estimates of total feedstock and land take requirements. Key elements of the methodology used in $BEAT_2$ and key assumptions are contained in Box 4.1. The most significant assumptions in relation to this study are:

- For waste materials, $BEAT_2$ does not include any emissions associated with producing the waste (as it would have been produced anyway). It does include a ‘credit’ for the avoided disposal of the waste. For waste wood (including chipboard and medium-density fibreboard (MDF)) and food waste (to anaerobic digestion) this is assumed to be to landfill. For animal waste, it is assumed that they would otherwise be disposed of to land. Including the credit means that, for example, the GHG savings associated with using waste wood are particularly high as there are avoided landfill gas emissions, as well as avoided fossil fuel emissions.
- Emissions from any land use change which occurs as a result of growing bioenergy crops are not taken into account. Since $BEAT_2$ was developed, there has been a growing awareness, particularly in the case of feedstocks for liquid biofuels, that the emissions from land use change can be significant and can significantly reduce or even negate GHG savings from biofuels (for some feedstocks and particular types of land use change, for example, when permanent grassland is converted to arable land to grow wheat or oil seed rape). Even when feedstocks for biofuels are grown on existing agricultural land there is concern that this may cause land use change elsewhere (indirect

land use change), as the previous agricultural production is transferred to another location. GHG emissions from land use change are particularly high if the previous land use was a high carbon store (such as forests). For example, the conversion of rainforest to produce palm oil, which could be imported as a biodiesel feedstock, are associated with high GHG emissions. In the context of this modelling work, this means that the emissions savings from biofuels may be overestimated.[39]

Values of the carbon dioxide emissions from different process chains and the carbon dioxide savings these represent compared to conventional fossil fuel technologies are given at the end of Appendix 9.4. $BEAT_2$ also provides an estimated uncertainty in the emission value, but this is not an estimate of variability in reality, rather an estimate of the process chain chosen in $BEAT_2$. The table in Appendix 9.4 shows that the range of uncertainty in the figures for biofuels is between 1.8 and 20 per cent, depending on the feedstock; for heat and power the figures are generally low, but for some feedstock they can be as high as 20%. These figures are indicative only: they are average for a typical process chain and they do not take account of factors that can vary for individual feedstocks, such as variations that are dependent on location.

The conventional technology against which the biomass technologies were compared to derive GHG savings are shown in Table 4.1. Lifecycle emissions for the comparison technology were used to calculate savings.

Table 4.1. Comparative Technologies used to Estimate GHG Savings

Biomass technology type	Comparison technology
Co-firing	Coal fired electricity production
Electricity production	Gas fired CCGT
Combined heat and power (CHP)	Gas fired CHP unit
Heat production	Oil fired boiler
Biodiesel	Diesel
Bioethanol	Petrol

Box 4.1 Key assumptions in $BEAT_2$

The $BEAT_2$ analysis examines the bioenergy process chain from cultivation (including preparation of the ground and planting), through to production of energy/fuel and disposal of waste products (such as ash). It includes all intermediate stages such as harvesting, transport, pre-processing (such as chipping, pelleting, drying), the production process for liquid biofuels, and combustion for heat and electricity production.

All direct fossil fuel energy inputs to the process (for example fuel for agricultural equipment, electricity and heat used in processing) are accounted for, as are indirect energy inputs in other materials used in the process, such as fertilisers and materials used to construct the power plant.

For energy inputs, the associated GHG emissions are on a fuel cycle basis, that is, they include the emissions associated with producing the fuel as well as burning it.

Emissions of the GHG nitrous oxide from the application of nitrogen to the soil are accounted for.

[39] This is a rapidly developing field and other methodologies that calculate the GHG emissions and savings from biofuels, such as that recently developed by the Renewable Fuels Agency to support the Renewable Transport Fuels Obligation, do not include emissions from land use change in their default values.

Land use change and associate GHG emissions are not considered.

Each process chain is associated with a reference system. This is an assumption of what would have happened to the waste if it had not been used for energy production (for example, disposal to landfill) or what land use would have been if the feedstock had not been grown (for example, it is assumed that wheat for bioethanol is grown on land which would have been set-aside). The process chain receives a credit for the 'reference' system. This can be large where the reference system is disposal to landfill.

In the case of biofuel production (and some other biomass energy chains), co-products or by-products are produced (for example glycerine from biodiesel production and dried distillers' grains from bioethanol production). In these cases it is necessary to allocate the GHG emissions from the process between the main product and co-products. There are several ways to perform such allocations and they can have a significant effect on the results. In $BEAT_2$, allocation by price is adopted for the co-products and by-products of liquid biofuels and some other biomass energy technologies. A mixture of allocation by price and substitution is applied in relation to the other biomass energy technologies. In particular, allocation by substitution is adopted in cases where the displaced product can be identified easily and unambiguously.

4.3 Scenario development

The first stage in development of the scenarios was assessment of the likely make up of bioenergy in England and Wales in 2010. This was based on:

- The drivers for bioenergy and the RTFO, RO, GHG targets. What is needed to meet these targets?
- Biomass strategies for England and Wales.
- Individual bioenergy options. Which of these are likely to be important up to 2010? For each option we estimated GHG savings, environmental impacts and costs for individual plant using $BEAT_2$.
- The critical issues for bioenergy to 2010.

4.3.1 Drivers and targets – their influence on bioenergy

Table 4.2 shows the current energy use (from chapter 1) and the targets for bioenergy. Table 4.3 shows other related targets.

Table 4.2. Summary of current use and targets for bio-energy

	Current UK production	2010 Target	Long term target	Incentives
Transport biofuels	0.6%(291 million litres)	5% (2,450 million litres) (2.5% UK production[1])	10% by 2020 (~4,900 million litres)	RTFO, tax breaks, energy crops payment, RED
Electricity (targets for all renewables)	3.5% all renewables. 0.7% biomass, 2.5TWh	10%	20% (possibly 30-40% by 2020)	RO, energy crops payment, energy crops infrastructure scheme, RED

	Current UK production	2010 Target	Long term target	Incentives
CHP			There is a target to achieve 15% renewable energy in the UK by 2020. It is probable that part of this target will need to be met by renewable heat and biomass heat and CHP will play a significant role.	Good quality CHP scheme. High band support for CHP from biomass and energy from waste in the proposed changes to the RO, RED.
Heat	0.6%, 4.5TWh			Bio-energy capital grants, energy crops payment, energy crops infrastructure scheme, RED

[1] Information from Biomass Strategy.

Table 4.3. Additional targets that may also impact bioenergy

	Current UK production	2010 Target	Long term target	Incentives
GHG emissions		12.5% reduction(Kyoto)	26-32% by 2020 60% by 2050	CCL, ETS, CCA, UK Climate Change Bill
Good quality CHP (CHPQA)		10,000 MWe 15% electricity on Government Estate[1]		CHPQA
Forestry Residues			Extra 1m odt/y[2]	
Perennial energy crops			350,000ha[2]	

[2] Stated in the Biomass Strategy

The current targets for transport biofuels of five per cent by volume by 2010 are provided in the RTFO. The Renewable Energy Directive (RED) proposes a target of 10 per cent biofuels by 2020, although this is under debate.

We have assumed that the 2010 target will be met from first generation transport biofuels. It is generally agreed (and supported by the calculations in chapter 1) that about 2.5 per cent of transport fuels by volume could be produced using UK feedstocks. The amount of wheat and OSR required to achieve this was calculated in the Biomass Strategy as shown in Table 4.4.

Table 4.4. UK land requirements to produce 2.5% transport fuels by volume (Defra, 2007a)

Crop type	Amount of UK crop required, thousand tonnes	Amount of UK land required, thousand ha
Wheat	1,715	214
Oilseed	1,680	525

The other 2.5 per cent required to meet the five per cent target is assumed to be imported. In our 2010 scenarios we assume a lower proportion of home grown OSR and a higher proportion of imported oils, consistent with the current sourcing of transport biofuels for the UK. This leads to a lower predicted land take for transport biofuels. This scenario assumes that first generation transport biofuels will be able to meet the GHG savings requirements likely to be implemented through the RTFO and/or the Climate Change Bill.

To meet higher targets would require additional imports, or development of next generation transport biofuels using lignocellulosic feedstocks. There is a strong development effort for next generation transport biofuels in Europe and the USA, and the National Non Food Crops Centre (NNFCC) is working in the UK to develop advanced biomass to liquid (BTL) technology. We have assumed that next generation technologies will not be commercially available before 2015, and so they are not included in our analysis. However, the Environment Agency may be consulted on proposals for demonstration plants. Technologies for fuel densification such as pyrolysis and torrefaction may be developed on this timescale to enable the large scale fuel supply required for a next generation plant. In particular transport of large quantities of bio-oil produced by pyrolysis may be an issue.

There is no specific bio-energy target for electricity; it is part of the renewable energy target with other technologies. The current target is set by the RO, with an aspirational target of 20 per cent by 2020. When the RED comes into force, the UK will need to produce 15 per cent of all energy requirements from renewable sources by 2020. Current opinion in the UK is that in order to meet the overall target, the UK will need a higher proportion of electricity from renewable sources, with figures of 30-40 per cent by 2020 suggested.[29] In addition, the targets for transport fuels mentioned above will also need to be met predominantly using biomass.

The biomass technologies which could make an increased contribution are starting from a very low base, with only co-firing making a significant contribution (see chapter 1). Co-firing has a technical limit of 10 per cent of coal generation capacity unless there is considerable investment on site. For stand-alone electricity generation from biomass, there is no information on market potential in the public domain. It is our view that current incentives will bring on all realistic combustion projects, so that our potential for 2010 assumes that all currently planned projects will proceed. Additional resources for R&D could lead to development of advanced thermal conversion processes, although it is unlikely that any demonstrations will be in place in 2010.

There is no specific target for biomass heat, and to date progress has been very slow. The main incentive for a biomass heating scheme remains economic (compared to fossil fuel systems). In fact, compared on a lifetime basis, the economics of biomass heat is becoming favourable for some industrial boilers and in some medium- and small-scale applications, particularly with the recent high cost of fossil fuels.

There are several upcoming incentives which may support biomass heating. The Carbon Reduction Commitment of the Climate Change Bill may support development

[29] It is thought that more than 15 per cent renewable power will be needed to compensate for difficulties in achieving 15 per cent renewable heat and transport biofuels. This is explained in the recent Renewable Energy strategy consultation document.

of biomass heating schemes for large non-energy intensive organisations. The proposed zero carbon homes policy, which will affect homes built after 2016, may support biomass heating, depending on the final form of the proposals. BERR is currently examining support mechanisms for heat, and a low carbon heating consultation was due in September/ October 08. It is our view that any support mechanism for heat other than the Bioenergy Capital Grant scheme could only be implemented in 2009 at the earliest, too late to create a large influence by 2010. However, it may increase the number of schemes coming to planning in 2010.

4.3.2 Upper limits

The potential for biomass schemes requires consideration of the markets, feedstock availability and cost. Consequently many estimates of biomass potential start with the resource potential and then examine how market factors might limit this potential, resulting in a more realistic market potential.

Several recent studies have estimated UK biomass potential. The most relevant are the UK Biomass Strategy (Defra, 2007a), the Waste Strategy for England (Defra, 2007b), FES study on renewable heat and heat from CHP (Brown, 2005) and the Ernst and Young report on renewable heat support mechanisms (Ernst and Young, 2007b). The biomass potential presented in these reports depends on the assumptions made about what the total resource may be, and the amount of this resource that could be made available for bio-energy use. In chapter 1 we estimated both the total resource and the availability of biofuels in 2010. We believe the availability for biofuels is broadly equivalent to the available biomass resource discussed in the various biomass strategies, which start with the total arisings and take into account how much of this would be available for bio-energy once technical constraints such as extracting the residues and competing established markets for biomass are considered.

The Biomass Strategy estimates that **350,000ha of energy crops could be available by 2020**. We believe this is an upper limit. Currently 5,000ha are growing, and approved grants mean this may rise to 15,000ha by 2010 and optimistically could rise to 73,000ha by 2010 if there is sufficient market pull from co-firing and biomass power plants. Import of energy crops, biomass residues and wastes is technically very likely, but possible constraints due to sustainability concerns make this a very difficult area in which to make predictions.

The market potential in the FES and Ernst and Young reports take both the resource available for bio-energy and the size of the potential markets in the UK into account. The figures in Table 4.5 show the market potential estimated in the FES work; these are broadly consistent with the Ernst and Young estimates.

Table 4.5. Biomass heat current demand and market potential in 2010

Description	Current demand TWh/y	Current biomass input TWh/y	Market potential 2010[1], TWh/y	Projected contribution in 2010[1], TWh/y	Increase to achieve market potential
Large scale Industrial heat	271	1.6[2]	7.6	1.9	X5
Small scale heat (service sector)	148	0.2	3.0	0.7	X15
Domestic heat	487	0.02[3]	19.1	0.3	X1,000
Industrial CHP		1.0	3.7	0.9	X4

Description	Current demand TWh/y	Current biomass input TWh/y	Market potential 2010[1], TWh/y	Projected contribution in 2010[1], TWh/y	Increase to achieve market potential
District heating	0	0	0.3	0.3	
Total			**33.7**	**4.1**	

[1] From Brown, 2005.
[2] Wood, straw, animal products and energy crops only.
[3] Modern biomass boilers only.

In our current work, the market potential is taken to be an upper limit which might be achieved with the most optimistic assumptions, but we do not believe it is realistic for 2010 and it has not been met in any of our scenarios. The projected contribution in 2010 is generally believed to be achievable, although for some markets, such as CHP and small scale heat, we believe that more incentives are required to reach the projected contribution in 2010.

The market can be limited by a number of factors:

- **Domestic heating market.** The technical potential for the domestic heating market is limited by the number of homes available for installation of biomass heating. The technical potential is estimated in the following way (Brown, 2005): 4.42 million houses off gas grid + 160,000 new homes by 2020. Each house is estimated to use 18,000kWh/y, giving a technical potential of 78.5TWh/y by 2020. Assuming an optimistic scenario whereby 25 per cent of existing houses and new homes use biomass heating gives a market potential of 19.6TWh/y by 2020. Taking into account current constraints, FES believes that 5,000 units might be installed annually up to 2010, giving 10,000 installations in 2010, supplying 0.2TWh/y, and 0.7TWh/y in 2015.

- **District heating**. There is a possibility that biomass CHP may arise either for replacement of existing community heating schemes, such as replacement of coal fired schemes pioneered in Yorkshire and Humber, or in new build schemes where there are targets for building zero carbon homes. Such schemes are less likely to have air quality impacts due to increased abatement measures and optimal management of the system. CHP is limited, however, by the need for constant heat load and the current uncertainty about the requirement for on-site generation for the zero homes initiative.

- **Industrial heating market**. In theory, the technical potential for biomass heat comprises industry replacing old boilers or being able to use biomass as a fuel in existing boilers. This is constrained to those industries where biomass is appropriate (in terms of heat load and the temperature required). The primary driver for a switch to biomass will be the cost of fossil fuels and the cost and availability of biomass fuels. We expect an increase in on-site use of biomass residual and waste fuels. CHP systems may be built instead of heat-only boilers, since the RO provides strong incentives to generate electricity. However, we believe this is unlikely to happen for medium size industries, as power generation is not their core business. Some people in the biomass heat sector predict a large increase in the use of CHP. We have therefore modelled this in the focus on electricity and heat scenario, using waste wood and solid recovered fuel (SRF) as the preferred fuels.

- **Use of biomass fuels**. The technical potential for a range of biomass fuels is discussed in chapter 1 and above.

- UK-produced fuels: there is an upper limit on waste fuels and biomass residues depending on the quantity produced and competition with other possible uses. We expect the waste wood resource to be taken up by the biomass electricity generation industry and on-site industrial use.
- Refuse-derived fuels could be used in power generation and industry, depending on the categorisation of these fuels under WID and the RO.
- Imported fuels: currently imported residues are being widely used for co-firing and it is likely that they will also be used in large scale stand alone plants. There is likely to be increasing competition for this resource for alternative uses (for example for second generation biofuels and in other markets such as animal feed, fodder, fibre and industrial applications).
- Energy crops: there is a greater incentive to use energy crops under the revised banding scheme for the RO. There are a number of constraints on energy crop production, including land availability, time to crop maturity and development of a supply chain. At present there are strong indications that farmers are reluctant to plant perennial energy crops for a number of reasons. Energy crops grown abroad, including energy crop co-products are likely to increase in use, especially if we view co-products as energy crops (there is some debate over this). The main constraint on the use of these crops relates to sustainability issues (such as the potential impact of land use changes on biodiversity and socio-economic impacts), which are likely to apply to all biomass crops.

4.3.3 The scenarios

The scenarios we have developed are based on our knowledge of the bioenergy industry and the way it is developing in the UK, EU and worldwide. This includes an appreciation of supply, markets and conversion technologies. They are also informed by the strategies and studies discussed above. The assumptions for each scenario are set out below. Table 4.6 shows the issues that need to be considered in the development of such scenarios. Box 4.2 shows the current drivers and issues that will affect bioenergy. The SWOT analyses developed for the sectors and taken into consideration in the scenario development are provided in Appendix 9.3.

Table 4.6. Important issues for bioenergy

Issue	Comments
Drivers	Why is the bio-energy desirable?
Targets	Have targets been set? Do they satisfy drivers? Are they achievable?
Incentives/support schemes	How successful to date? Are they continuing at current levels/increasing/decreasing?
International trade	Does the bio-energy/feedstock have to be produced in the UK? Extent of import/export? Is import/export desirable?
Environmental considerations	Are environmental benefits a driver/target? To what extent are such benefits achieved? What are the negative impacts? Have these been mitigated?

Issue	Comments
Social considerations	Are social considerations a driver/ target? To what extent are these benefits achieved? Have negative impacts been identified? Have these been mitigated?
Scope for improvements due to development/adoption of new technologies?	Performance of existing technologies? Rate and cost of development of new technologies? Impacts of new technologies?
Resource availability	Types of resource. Technical development. UK resource available. Imports of feedstocks. Competition between various bioenergy products. Competition from non-energy uses.

Box 4.2 Current drivers and issues identified as likely to affect UK bioenergy developments

Drivers

- Fossil fuel prices.
- RTFO.
- Renewables Obligation.
- Capital grants for Biomass Heat and CHP schemes.
- Related policies for climate change such as Climate Change Agreements and the EU Emissions Trading Scheme.
- Planning requirements.
- Regional renewable targets.

Issues

- Biomass commodity prices.
- Supply chains for feedstocks and infrastructure for distribution of electricity and transport biofuels.
- Definition of energy crops and implications.
- Use of wastes:
    - Definition of waste.
    - Availability for bio-energy projects.
    - Categorisation and possible uses of by-products from processing.
- Sustainability:
    - Feedstock production - effects on a range of sustainability indicators including bio-diversity, land use, water use, air pollution, GHG emissions.
    - Food versus fuel.
    - These issues are particularly acute for use of food crops as bio-energy feedstocks, but will also apply to lignocellulosic crops.
    - Local air quality.
    - Lack of progress with advanced conversion technologies for all types of bioenergy.

These drivers and issues were discussed in chapter 2.

Table 4.7 below provides the main assumptions for each scenario; Table 4.8 shows the scenario assumptions for 2010. For all scenarios:

- Fossil fuel prices remain at current high levels.
- Current proposals for amendments to RO are implemented (see chapter 3 for details).

Five scenarios are developed:

- Business as usual.
- Progress with barriers.
- Increase support for all bioenergy.
- Focus on electricity and heat.
- Focus on transport biofuels.

Table 4.7. Comparison of scenarios analysed for biomass use

			Scenario Assumptions		
Issue	**Business as usual**	**Progress with barriers**	**Increased support for all bioenergy**	**Focus on electricity and heat**	**Focus on transport biofuels**
Legislative drivers	Remain at current levels.	Remain at current levels.	Higher long-term targets for electricity, heat and transport biofuels confirmed.	Higher long term targets for electricity. Obligation for heat set for 2010 onwards, starting at five per cent. Target for transport biofuels remains at five per cent. Other transport solutions given preference.	Renewable electricity targets met mainly by other renewable technologies. No specific heat target. Transport biofuels target confirmed at higher level of 10 per cent by 2020.
Sustainability of bio energy production	Issues unresolved.	Sustainability criteria agreed - issues of land use and food versus fuel remain.	Sustainability criteria agreed - issues of land use and food versus fuel remain.	Land use becomes a major issue. GHG savings for bio-energy challenged. Wastes and residues are favoured feedstocks due to low costs.	Sustainability criteria agreed. First generation transport biofuels restricted to five per cent of transport fuel use. Emphasis on next generation transport biofuels eases land use and food versus fuel debates.
Feedstock costs	High for energy crops. Imports competitive.	High for crops and residues. Waste sources available at lower cost.	Increase for all feedstocks as competition for feedstocks emerges.	High as supply constrained by land use issues.	High for wheat and OSR. Large supply of by-products from transport biofuel production suitable

					as fuels for co firing or on-site industrial CHP at reasonable cost.
Definitions of waste and biomass	Confusion over what biomass and waste can be used in which situations and eligibility for ROCs delays or stops projects.	Agree biomass and waste definitions and clarify implications of these definitions to bio-energy projects. Projects proceed.	Agree biomass and waste definitions and clarify implications of these definitions to bio-energy projects. Projects proceed.	Agree biomass and waste definitions and clarify implications of these definitions to bio-energy projects. Projects proceed.	Agree biomass and waste definitions and clarify implications of these definitions to bio-energy projects. Projects proceed.
Availability of feedstocks	Low for energy crops. Imports readily available.	Low for UK perennial crops - competition from OSR and wheat. Lignocellulosic crop imports become available.	Use of all available land in UK. Output rationalised to provide maximum feedstock for all applications.	Use of all suitable land in UK. Focus on lignocellulosic crops. Use of wastes maximised. Sustainable imports only utilised.	Use of all suitable land in the UK, with focus on OSR and wheat for first generation biofuels. This leads to a large supply of by-products suitable as a fuel for co-firing or on-site CHP. Sustainable imports also in demand.
R&D effort	Low levels.	Low levels.	UK effort increased. Engaged in EU and international collaboration	UK effort increased. Engaged in EU and international collaboration	UK effort increased and concentrated on next generation transport biofuels, including EU and international collaboration.
Demonstration effort	Low levels.	Low levels.	UK demonstrators for advanced	UK demonstrator for advanced electricity	UK demonstrator for next generation

Scenario Assumptions					
			electricity production and next generation transport biofuels	production.	transport biofuels.
Local issues identified	Air quality for biomass heat. Opposition to planning applications, especially for waste feedstocks.	Clarity on developments to avoid air quality issues. Information programme minimises opposition to bioenergy plant.	Air quality and planning issues resolved. No new local issues emerge.	Air quality and planning issues resolved. No new local issues emerge. Local issues identified.	Planning for large scale transport biofuels plants. Conversion of grassland and fallow into arable production.

Table 4.8. Scenario implications for 2010

	Scenario				
	Business as Usual	**Progress with barriers**	**Increased support for all bioenergy**	**Focus on electricity and heat**	**Focus on transport biofuels**
Electricity from biomass	Co-firing remains similar to current levels, due to capping.	Co-firing similar to current levels due to capping.	Increased co-firing using energy crops including imported fuels; assume three per cent of coal capacity by 2010, rising to five per cent by 2015 (technical limit of 10 per cent output from coal fired plants).	Increased co-firing using energy crops including imported fuels; assume three per cent of coal capacity by 2010, rising to four per cent by 2015 (technical limit of 10 per cent output from coal fired plants).	Co-firing remains at current levels, using mainly imported feedstocks and some by-products from transport biofuel production.

	Scenario				
	Business as Usual	**Progress with barriers**	**Increased support for all bioenergy**	**Focus on electricity and heat**	**Focus on transport biofuels**
	Some progress with stand alone plants.	Steady progress with stand alone plant.	Steady progress with stand alone plants.	Increased stand alone power production - some additional plants realised. Advanced conversion demonstration plant 3x10MW by 2015.	Some progress with stand alone plants.
	CAD - current plant only.	CAD - current plant only	CAD- 10MWe planned using food and farm waste	CAD- 45MWe planned using food and farm waste.	CAD- current plant only.
Heat from biomass	Number of plants increases slowly. For industrial heat that is economic without subsidies; extra 5MWth from waste wood.	Number of plants increases. For industry extra 5MWth from waste wood and 10MWth from SRF.	Number of plants increases. For industry extra 80MWth from waste wood and SRF.	Number of plants increases. For industry extra 80MWth from waste wood and SRF.	Number of plants increases slowly. For industrial heat that is economic without subsidies; extra 5MWth from waste wood.
	Small scale extra 10MWth from existing grants.	Small scale extra 30MWth.	Small scale extra 60MWth.	Small scale extra 90MWth.	Small scale-extra 10MWth from existing grants.
	Domestic – current	Domestic – extra 1,200 units,	Domestic – extra 2,400units to	Domestic – extra 4,800 units to	Domestic –

	Scenario				
	Business as Usual	**Progress with barriers**	**Increased support for all bioenergy**	**Focus on electricity and heat**	**Focus on transport biofuels**
	pattern, extra 600units, 24MWth.	48MWth.	2010, then 2,400 to 2015.	2010, then 2,400 per year to 2015.	current pattern, extra 600units, 24MWth.
Transport biofuels	Quarter of proposed plants built. Current biodiesel plants run at half capacity.	Half of proposed plants built. Current biodiesel plants run at full capacity.	Half of proposed plants built. Current biodiesel plants run at full capacity. Biorefinery concept encouraged.	Quarter of proposed plants built. Current biodiesel plants run at full capacity. Biorefinery concept encouraged.	Half of proposed plants built. Current biodiesel plants run at full capacity. Biorefinery concept encouraged. Next generation transport biofuels demonstrators developed, 2 x 20 million litres. CAD – 10MW planned for biogas.
CHP	Little progress with biomass CHP. Existing industrial plants work at capacity. No small-scale CHP.	Little progress with biomass CHP. Existing industrial plants work at capacity. No small-scale CHP.	Planned industrial CHP built using available wastes including. SRF – 50MWe. No small-scale CHP.	Industrial CHP SRF – 100MWe. Small-scale CHP implemented – 0.2MW in 2010, rising to 2MWe in 2015.	Industrial CHP at transport biofuels sites using by-products. No small scale CHP.

	Scenario				
	Business as Usual	**Progress with barriers**	**Increased support for all bioenergy**	**Focus on electricity and heat**	**Focus on transport biofuels**
	Only existing on-farm CHP from AD.	Only existing on-farm CHP from AD.	Additional on-farm CHP from AD – up to 1MW between 2010 and 2015.	Additional on-farm CHP from AD – up to 1MW between 2010 and 2015	Only existing on-farm CHP from AD.
Imported feedstock	High proportion – residues for electricity, food crops for transport biofuels.	High proportion – residues and energy crops for all applications.	High proportion – residues and energy crops for all applications. Substantial pellet imports.	High proportion – residues and energy crops for all applications. Substantial pellet imports	High proportion – residues and energy crops for co-firing and transport biofuels.
UK produced feedstocks	Low proportion.	Perennial crops planted for chips and pellets. OSR and wheat production for transport biofuels.	Perennial crops planted. Easy to access waste wood utilised. Use of waste derived fuels in combustion plants. OSR and wheat production for transport biofuels.	Perennial crops planted. Easy to access waste wood utilised. Use of waste derived fuels in combustion plants. Reduced transport fuels in combustion plants. Reduced transport biofuels crop production.	OSR, wheat dominate. Some perennial crops for conversion to bio-oil. By-products DDGS and OSR cake used for CHP and co-firing.
UK land use	Low.	High – especially for OSR and wheat for transport biofuels.	High – competition between crops for transport biofuels and perennial crops.	High – focus on perennial crops for electricity and heat.	High – mainly for transport biofuels.

Scenario					
	Business as Usual	**Progress with barriers**	**Increased support for all bioenergy**	**Focus on electricity and heat**	**Focus on transport biofuels**
Business development	Low.	2-3 pellet plants each producing 50,000odt/a pellets.	Up to 15 pellet plants each producing 50,000odt/a pellets.	Up to 15 pellet plants each producing 50,000odt/a pellets. Progress of gasification to large scale demonstration.	Development of next generation transport biofuels technologies. Development of pyrolysis to produce bio-oil.

4.4 Results

The results of modelling the above scenarios are shown in Figure 4.1 to Figure 4.5, which show the energy generated, the land used and the GHG emissions reduction. A summary of the data for these graphs is presented in Appendix 9.4.

Note: in the results section the following abbreviations are used:

BAU - business as usual

PWB - progress with barriers

ISA - increased support for all bio-energy

FEH - focus on heat and electricity

FB - focus on transport biofuels

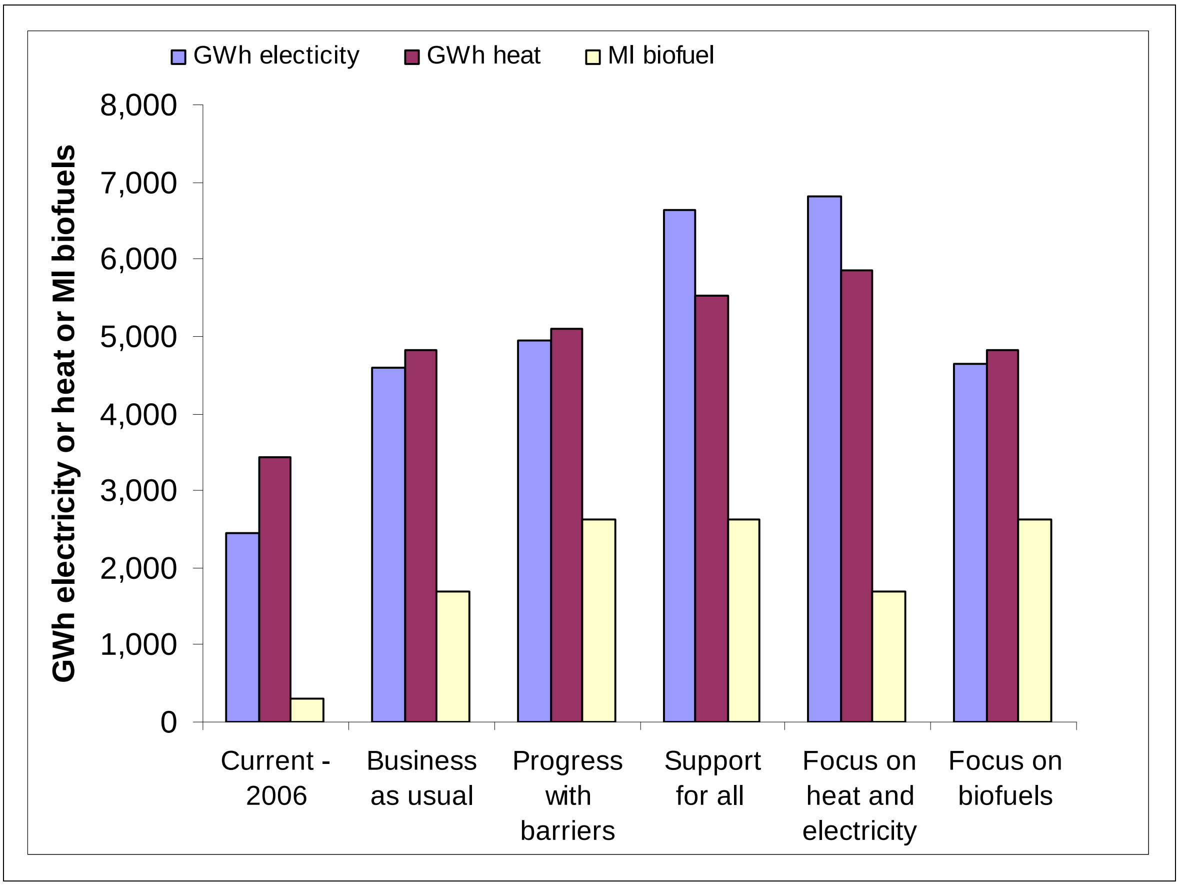

Figure 4.1. **Bioenergy in different scenarios in 2010**

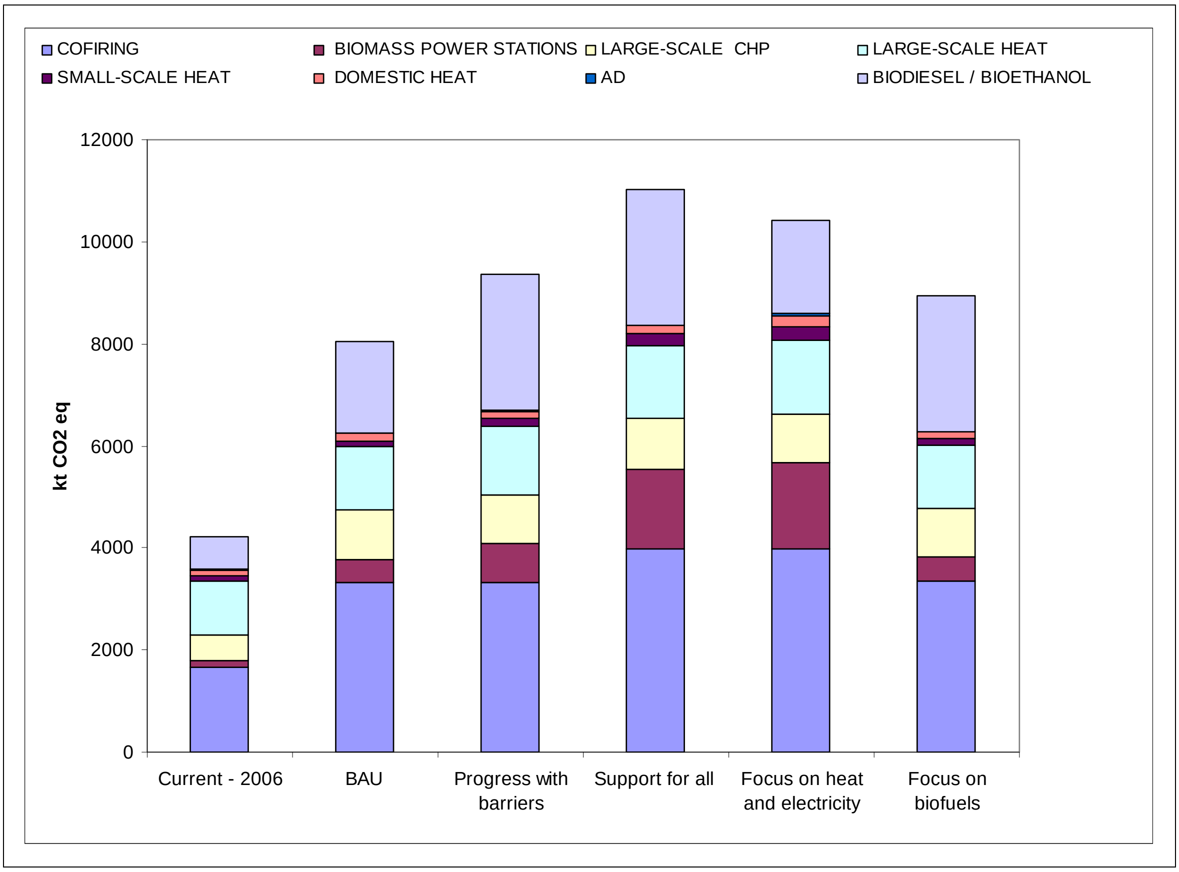

Figure 4.2. **Breakdown of GHG emissions savings in all scenarios in 2010 by technology**

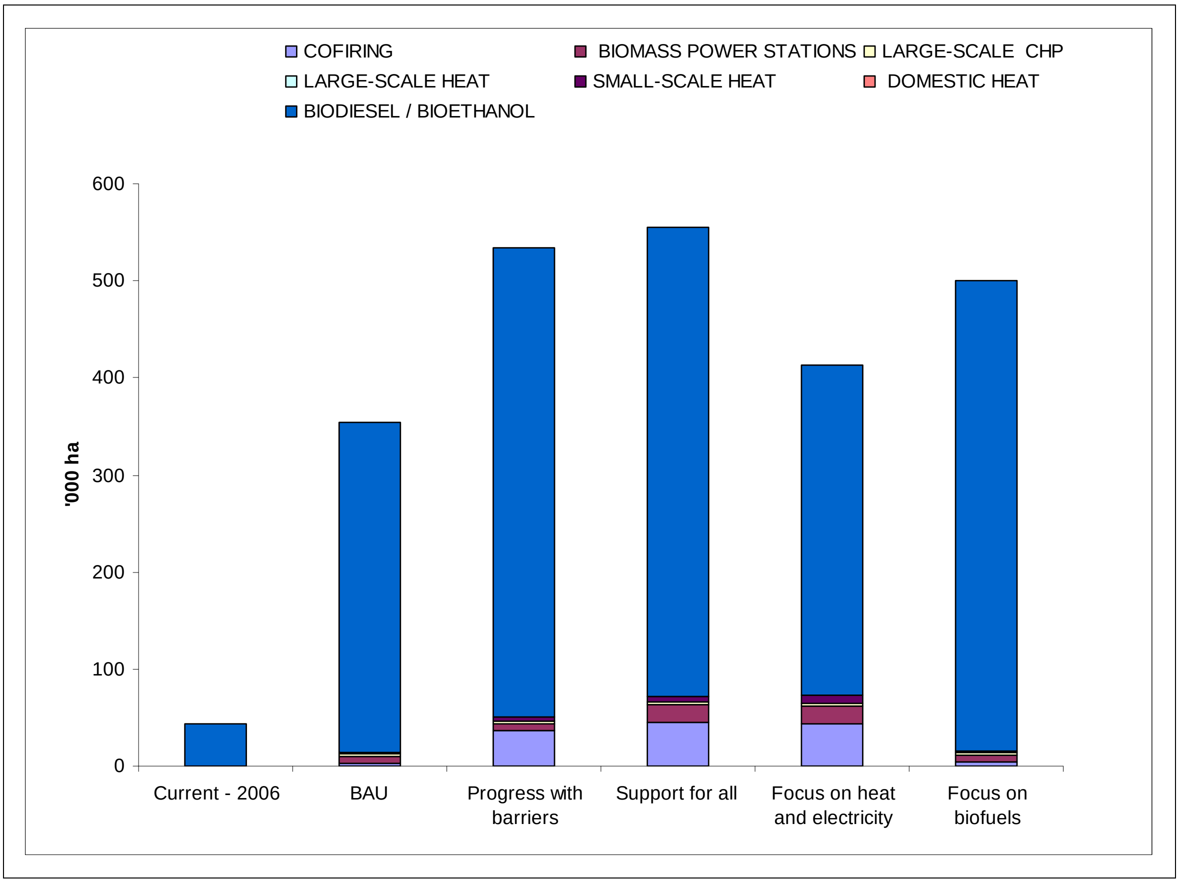

Figure 4.3. Breakdown of UK land take in all scenarios in 2010 by technology

It is interesting to compare Figure 4.3 with the estimates for biofuels from the Biomass Strategy presented in Table 4.3. The Biomass Strategy provides an estimate of 739,000ha within the UK to supply 2.5 per cent of UK biofuels. The figure above is lower than this (484,000ha). The difference is because our scenarios assume a greater quantity of imported OSR and wheat than the Biomass Strategy. This is in line with the reality of the current market.

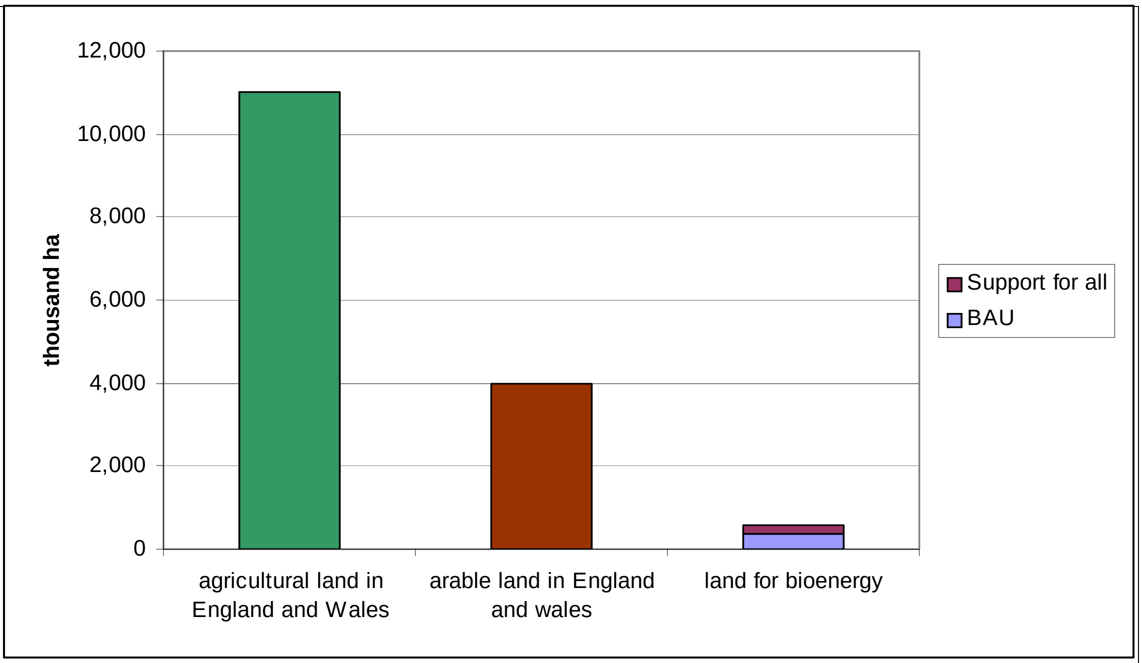

Figure 4.4. **Land take of bioenergy in 2010 in England and Wales compared with total agricultural and arable land**

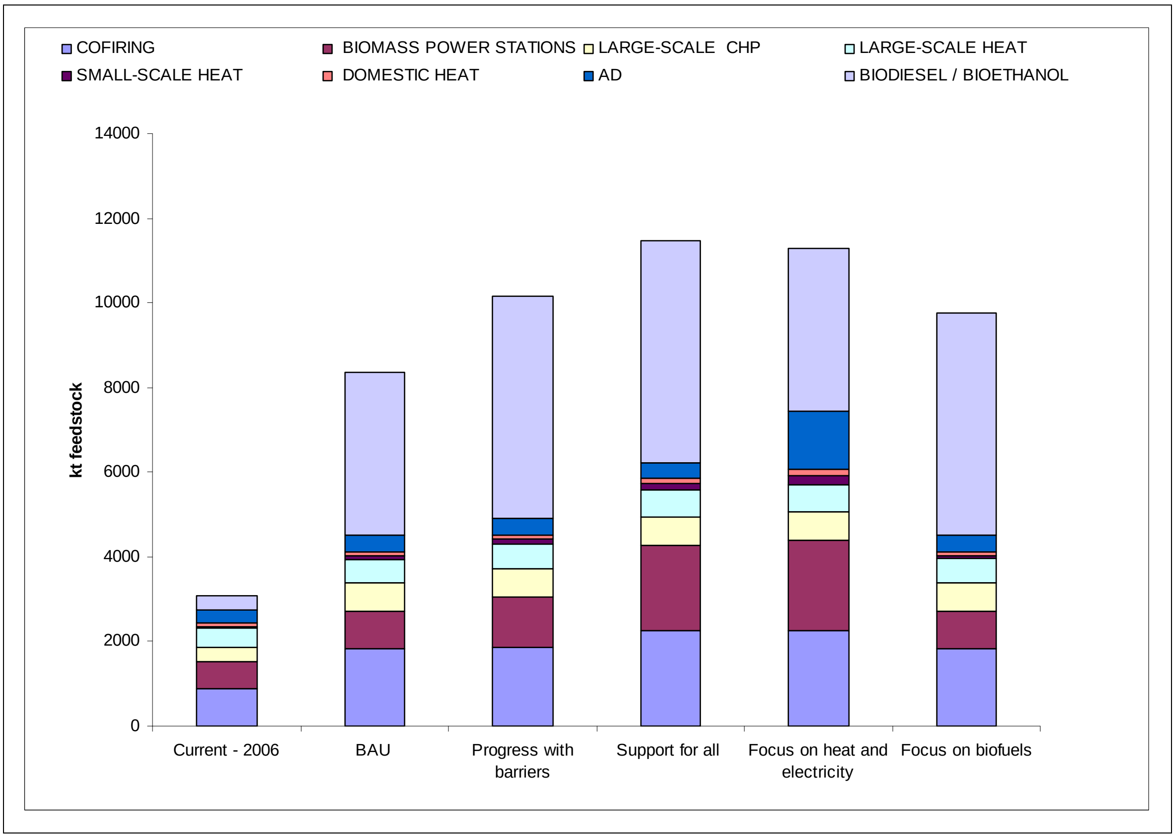

Figure 4.5. Breakdown of feedstock in all scenarios in 2010 by technology

We have examined the detailed results from the above analysis (including the data presented in Appendix 9.4). The results show that the scenarios significantly influence the energy displaced, land take and GHG emissions. These are examined in turn below.

Biomass energy and fuel production

- Bio-energy from electricity, heat and transport biofuels increases above the 2006 baseline in all scenarios. The business as usual (BAU) scenario for 2010 provides a projection assuming current conditions continue. For electricity and heat this assumes that current proposed plants are built and that current support continues. It assumes that the large stand-alone power plants currently proposed are not all built in 2010, so the impact of these plants are not included in the 2010 scenarios. The large increase in transport biofuels arises because several large scale biodiesel and bioethanol plant are due to come on line by 2010.

- Comparison of the other scenarios with BAU in 2010 provides an indication of how the uptake of technologies could be influenced by the range of possible conditions and additional measures examined in each scenario.

- **Heat.** Heat increases slowly, reflecting the issues in the development of biomass heat (such as the high capital cost of biomass boilers relative to fossil boilers, and the lack of targets and support for heat to date). Current biomass heat is dominated by the use of tallow in rendering and the use of waste wood in panel board manufacturing. For industrial heat only economic systems will be built under BAU and PWB. When more support is offered additional capacity is expected using SRF. Small scale heat and domestic heat require further incentives to increase the current rate of uptake. However, even with greater incentives in ISA and FEH there will probably be technical limitations to the rate of uptake before 2010, such as availability of equipment and fitters. We expect that CHP uptake will be led by electricity sales and will only progress in the ISA and FEH scenario. The FB scenario heat does not progress above the level seen in BAU because of lack of incentives.

- **Power.** Development of stand-alone biomass power plant up to 2010 continues at a similar rate to current in all scenarios. This reflects the number of plants in planning at the moment and the powerful incentives from the RO. Where there is more support for electricity we assume that more plant will proceed from planning to generation, some of which may be seen by 2010, and that further plant will be planned. Additional plant will include demonstration of advanced conversion plant. However, the additional plants are unlikely to be generating before 2015. In addition, we have assumed that some of the large stand-alone power plants being proposed at the moment (such as the plants proposed by Drax) will not be built before 2010 and (except for the 350MWe Port Talbot biomass plant) they are not included in this analysis, although some of these plants will be built by 2015.[30] We also assume that co-firing will increase where there is greater support for electricity.

- **CHP**. Increased support for electricity and heat may encourage both industrial and small scale CHP. Impact in 2010 will be limited, but this could be significant by 2015, where industrial CHP using SRF may be built in place of heat-only industrial plant. Increase in CHP is dominated by plants such as that at Tate and Lyle, where old CHP boilers are being replaced by biomass boilers. Small scale CHP is unlikely to progress unless there is significant support, and so appears only in the FEH scenario after 2010.

- **Anaerobic digestion**. Centralised Anaerobic Digestion (CAD) plant will require further incentives, as they are not economically viable without support at present. Additional plants are included for ISA and FEH, using a mixture of agricultural and food wastes. However, they are unlikely to make a significant contribution before 2015. Defra has recently been examining on-farm AD as a means of waste treatment and hygiene control as well as emissions reduction. If support is provided to this sector we believe that up to 1MW capacity could be installed between 2010 and 2015. Individually plants will be small, around 50-100kW, and are likely to produce both heat and electricity for use on farms. It is possible that ‘clusters’ of 10-15 local small scale on-farm installations with a total capacity of 1MWe could be installed. This follows the German model where such clusters share a common support system, decreasing maintenance and ongoing costs and increasing confidence. This technical support is important to ensure that the plants operate correctly and the potential benefits are achieved.

- **Biofuels**. Biofuels increase above BAU (2010) in all scenarios except in FEH. In BAU and FEH we assume that a quarter of proposed large scale plant are built and biofuels technologies are not developed further except to encourage the biorefinery concept to make best use of the existing feedstocks and production techniques (optimising environmental performance). For ISA, PWB and FB, half the proposed large scale plant are built, giving a five per cent contribution by volume to road transport fuels. We believe this is the maximum UK first generation biofuel production that could rely on a substantial proportion of UK produced feedstock. Again the biorefinery concept is encouraged, and this could work together with the proposed CHP plant utilising by-products of biodiesel and bioethanol production. For FB, to increase transport biofuels production further, support is directed at next generation biofuels and biogas

[30] These plants will use imported biomass forest residues and UK waste wood for fuel.

from AD. It is unlikely that these will make a significant contribution before 2010, but demonstrator projects may be in operation or planning by 2010.

- **Number of plants**. Examination of the numbers of plants indicates that the increases in energy for electricity generation come from relatively small numbers of large plants. For example, whether the 350MWe wood chip plant at Port Talbot proceeds has a large impact on electricity generation, since stand-alone biomass electricity generation starts from a small base. For biomass heat there are larger increases in the number of plants, which reflect the small scale nature of the technology and the dispersed nature of heat use. As indicated above, biomass heat is currently dominated by the use of tallow and waste wood.

In conclusion, the level of support and Government policy exert important influences on biomass use in the UK in the near term (up to 2010). For biofuels and power the increase in the number of plants is relatively small. Heat struggles to take off before 2010, which is a reflection of the lack of policy support to date (coupled with historically low fossil fuel prices). One factor that will be important in biomass heat is the treatment of residues under the Waste Incineration Directive (WID). If the industry has to comply with WID there will need to be considerable investment to ensure that the plants comply.

Biomass land take in the UK

The data presented in Figure 4.3 and Appendix 9.4 provides information on land use for energy crop production in the UK only. Our analysis is only concerned with bioenergy use in the UK. There may also be some production in the UK which is exported abroad, but it is highly unlikely.

The biomass land take data includes the land requirements for:

- Short rotation coppice - cut and chip harvesting – chips.
- Short rotation coppice - cut and chip harvesting – pellets.
- Short rotation coppice stick harvesting – chips.
- Short rotation coppice stick harvesting – pellets.
- Miscanthus – chips.
- Miscanthus – pellets.
- Miscanthus – bales.
- Biodiesel from oil seed rape.
- Bioethanol from sugar beet.
- Bioethanol from wheat grain.

Examination of this data indicates the following:

- The dominant land use is for biodiesel and bioethanol. There is a large increase for all scenarios including BAU, which assumes that at least a quarter of the currently proposed large scale plants are built, and that they utilise a proportion of UK produced feedstocks. Under these assumptions, 341,000ha UK land will be used in 2010-2015. This is not certain under current market conditions, where a large proportion of feedstocks may be imported. The PWB, ISA and FB scenarios assume that at least half of the currently proposed large scale plants are built, but there is a proportionately smaller increase in land use from BAU. The increased capacity will require a higher proportion of imported feedstock. Our prediction is that for a five per cent by volume production of biofuels 484,000 ha of UK land will be used for biofuel feedstock production in 2010, and will remain at a similar level for 2015. The remaining feedstock will be imported. However, we also believe that there will be an increase in wheat and

OSR production in the UK irrespective of whether the biofuels industry proceeds. This is due to set aside area being set to zero by the EC and the current and projected high prices for oil crops.

- There are difficulties producing energy crops for electricity and heat. Estimates of SRC and miscanthus area in the UK were about 5,000ha in 2006. We estimate that actual utilisation of these crops in 2006 was even lower, at about 1,000ha. This is despite years of effort to encourage production and utilisation of these crops. In 2010 all scenarios show an increase in perennial energy crops, with this being very modest for BAU and FB, at 14,000 and 15,400ha. For PWB, ISA and FEH scenarios areas of perennial energy crops are higher, at 50,000ha for PB and 73,000ha for ISA and FEH. The main reason for this increase is the demand from increased co-firing. Experience to date suggests that a strong market pull will be required to convince farmers to commit to these crops. This land use is likely to be in the vicinity of plants that use the biomass resource (although plant operators are finding that they have to look further afield). At the moment there are a number of plants trying to actively recruit farmers to grow energy crops, including Drax (SRC and Miscanthus) and Didcot (SRC in the South), with varying success. It is likely that up to the year 2010, increase in energy crops will be patchy and slow. However, the Environment Agency may see more developers applying for planning permission with the intention of using a significant proportion of energy crops. The co-firing power stations would like to buy more energy crops.[31] Our figures reflect the lack of success they have had so far. Progress from 2010-2015 is difficult to predict. If confidence and markets are established by 2010 there could be further increases, potentially up to the 350,000ha in 2020 suggested in the Biomass Strategy. In the current climate, however, with high grain and oilseed prices and no set aside obligation, we believe this area is unlikely to be achieved.

- The perennial biomass fuels most likely to be grown in the UK and used locally are those for heat, particularly at small-scale and domestic scale. However, these fuels are likely to be wood and residues from forestry (at least in the short term).

- A significant proportion of the increase in biomass fuels for co-firing continues to come from abroad. In the ISA scenario, stand-alone biomass plants also import a significant proportion of their fuels (~55 per cent).

In summary, these results indicate a considerable increase in the land requirement for biomass fuels in the UK, dominated by the production of biofuel crops and a continued reluctance to invest in production of perennial lignocellulosic biomass crops.

Biomass feedstocks

- Figure 4.5 shows total amounts of biomass feedstocks for each of the scenarios broken down by production category. Details of the composition of the feedstocks for each category are not presented, but can be calculated from the model used in this work. For example, the Environment Agency was interested in the use of vegetable oil for electricity generation. Our model showed that a small amount of vegetable oil is projected to be used for electricity generation in 2010, amounting to some 1,600 tonnes, and this is likely to be used in small stand-alone biomass power generators.

[31] For example, Drax has announced plans to buy 300,000 Miscanthus from Bical, and Bical state on its web site that it needs 125,000ha to meet demand from all biomass power production. (see, for example, www.fwi.co.uk/Articles/2007/04/04/102799/miscanthus-producer-bical-triples-contract-with-drax.html

- The ISA scenario shows lower land take than other scenarios, but higher total feedstocks. This is because a greater proportion of the feedstock is imported (particularly for co-firing and biofuels).

- In all scenarios feedstock for biofuels is significant. This is likely to be supplied by used cooking oil, tallow, oil seed rape, sugar beet and wheat in the near future, depending on the plants that are developed. The current situation in which food and oil prices are high and the market is swamped by US biodiesel results in lower than expected production in the UK and the importance of feedstock choices in the USA.

Greenhouse gas savings

GHG savings are calculated by subtracting the biomass lifecycle GHG emissions from the lifecycle emissions of the fossil fuel system replaced. In the results shown below, credits are included for displacement from landfill of some waste biomass sources such as waste wood. We undertook a sensitivity analysis to examine the impact of these assumptions (see below).

In the analysis below, $BEAT_2$ was used to calculate the GHG emissions for bioenergy. There are some important features of this tool apart from the displacement credits mentioned above. These include allocation of emissions between products and co-products on the basis of cost, and that there is no inclusion of land use change or the indirect impacts of bioenergy generation (due to the lack of clear data on these important aspects).

In addition, as with any model, the results are associated with uncertainty because of:

- The inherent uncertainty in estimating the GHG emissions associated with biomass supply.

- The numerous assumptions about biomass cultivation and processing and the characteristics of the conversion technologies which have to be made in order to estimate GHG emissions.

- The lack of estimates of GHG emissions if cultivation of the biomass leads to land use change.

$BEAT_2$ includes an estimate of the uncertainty in estimating GHG emissions for each biomass supply chain. These are shown in the table at the end of Appendix 9.4. These ranges, which represent uncertainties in the estimation of emissions rather than uncertainty over the characteristics of the biomass supply chain, are between 0.5 and 20 per cent.

For the purposes of this modelling exercise, we have used the default values in the $BEAT_2$ tool, which assume typical values for current practice. In reality, existing and proposed plants and biomass supply chains may have better or worse GHG emissions, depending on the actual cultivation practices and technology and operating characteristics. We were not able to model the sensitivity of the scenario results to best or worst practice for the different technologies and fuels because of the time involved in such an analysis. However, for one of the most significant sectors delivering savings, biofuels, we have looked at the difference that such changes might make and this is reported below.

$BEAT_2$ does not include emissions from land use change or indirect land use change and thus under-estimates the emissions from crop-based bioenergy (such as biofuels) where land use change potentially results from the production of feedstock. This has been the subject of much discussion recently, and has been shown to be potentially significant. If land use change is caused in a major carbon sink (such as peat land or virgin forest), the resulting emissions may negate the savings from the use of the biofuel. On the other hand, for some biofuels it is possible to use the co-products as animal feed. This avoids land use for the production of animal feed elsewhere and may decrease the indirect effects of biofuels, resulting in improved GHG emissions. A sensitivity study has therefore been carried out to look at the impact of including land use change and the results of this are provided below.

The results to the GHG analysis follow:

- The scenarios demonstrate that GHG savings are likely to increase by 50 per cent 2010 in the BAU scenario, from 4.2 $MtCO_2eq$ (in 2006) to 8$MtCO_2eq$. PWB and FB increase GHG savings (to 9.3 and 8.9 $MtCO_2eq$ respectively), mainly by increasing biofuels production. The highest savings of 11 and 10.4 $MtCO_2eq$ are achieved by ISA and FEH (respectively).
- The largest GHG savings are from co-firing, large-scale biomass heat and biofuels in most scenarios. These represent 35-41 per cent (co-firing), 13-15.5 per cent (large-scale heat) and 17.5-28 per cent (biofuels) of the total GHG savings. Biomass power and CHP provide a similar percentage of savings to biomass heat. In view of the importance of biofuels it is important to optimise the GHG savings from this source, and the use of residues for process heat and power should be encouraged in proposed plant and would significantly increase the GHG savings achieved.
- Where the focus is on encouraging biofuels production, without encouraging heat and power at the same time, the lowest GHG emissions savings are realised. This is because of the reduced contribution from electricity and heat, which are the technologies that are able to provide immediate savings. Any improvement in GHG emissions savings from more advanced biofuels or biorefinery concepts is not included, because such technologies are not likely to be in large-scale operation by 2010.
- FEH shows that increased GHG savings from electricity and heat (particularly biomass power stations) give the highest overall GHG savings even allowing for reduced transport biofuels production.

Sensitivity Analysis

As part of this work a sensitivity analysis of the impact of ‘reference’ systems used within $BEAT_2$ was undertaken. The term ‘reference’ system is given to the alternatives to the assumptions in the lifecycle assessment. It includes the alternative energy systems that are displaced by biomass energy and the alternative disposal or use of biomass if energy use does not occur. The sensitivity analysis examined:

- The impact of the reference systems for disposal of biomass wastes to landfill.
- The sensitivity of the GHG savings offered by biofuels to:
    - The energy source used for process heat and power.
    - Fertilisation rates and yield.
    - Land use change.

Avoided disposal savings

For biomass schemes using ‘waste’ materials (such as waste wood) as a feedstock, the emissions which are avoided by no longer having to dispose of the waste (for example to landfill) can contribute significantly towards the overall GHG savings of the biomass scheme. However, for materials such as waste wood, there are alternatives to disposal in a landfill (for example composting to use as a mulch), which have much lower GHG emissions associated with them, and their avoidance would not make a significant contribution to GHG savings. As a first sensitivity analysis, the 'credit' given to biomass chains utilising waste products because they avoid disposal of that waste product to landfill (hence avoiding GHG emissions from landfill) was removed. This reduced the GHG savings in each of the scenarios by about 25 per cent (Figure 4.6), but the pattern of GHG savings between the scenarios is unchanged.

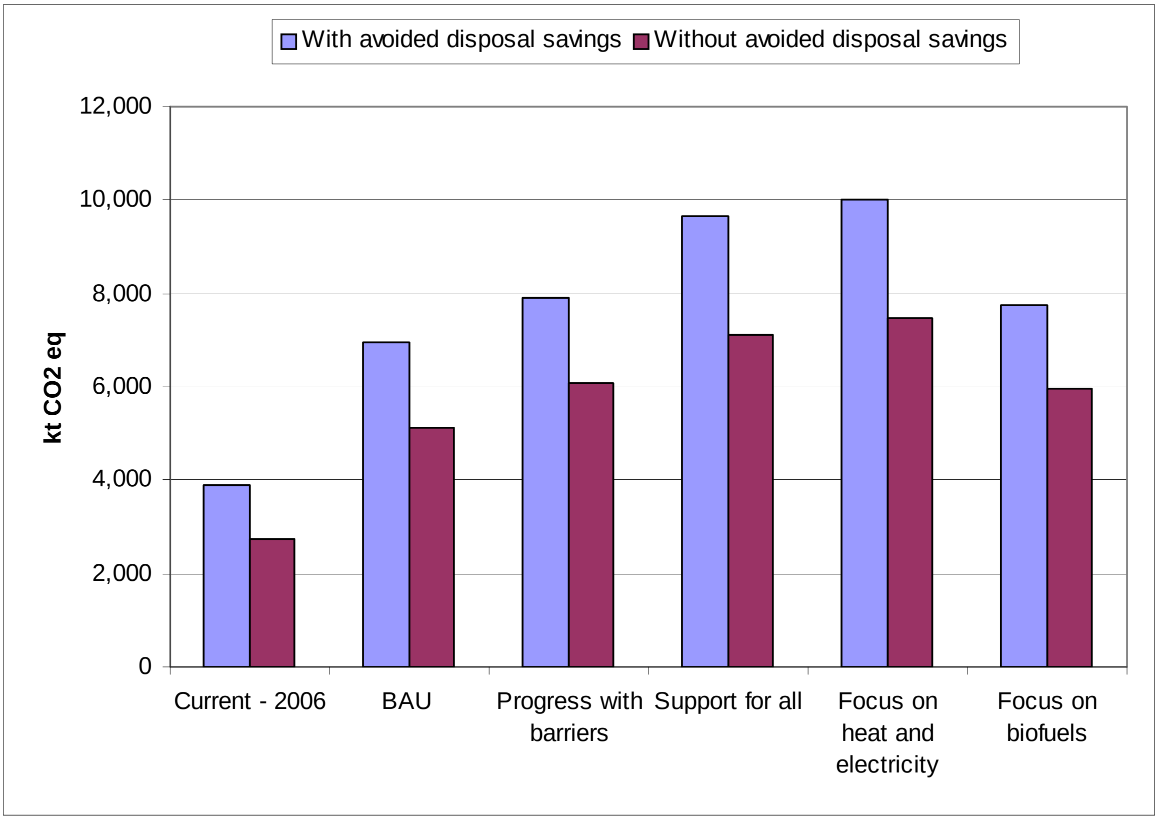

Figure 4.6. **GHG savings in 2010 without credit for avoided disposal of waste feedstocks**

Process Energy

The values used in the reference case modelling assume that for bioethanol produced from wheat and sugar beet and for biodiesel from OSR, heat and electricity for production of the biofuel are supplied by a gas-fired CHP plant at the biofuels production site. The CHP plant is assumed to be sized to meet the heat requirement of the process, with excess electricity exported to the grid. The biofuels process receives a GHG credit for the electricity which is exported to the grid. Using a gas-fired CHP plant is a more efficient way of providing heat and electricity than using power from the grid and a gas boiler for heat. Figure 4.7 shows that using grid electricity and a gas boiler rather than a CHP plant increases GHG emissions from biofuel production by 18 per cent for bioethanol from wheat and 46 per cent for bioethanol from sugar beat. The impact in biodiesel production is less significant - an increase of eight per cent in GHG emissions.

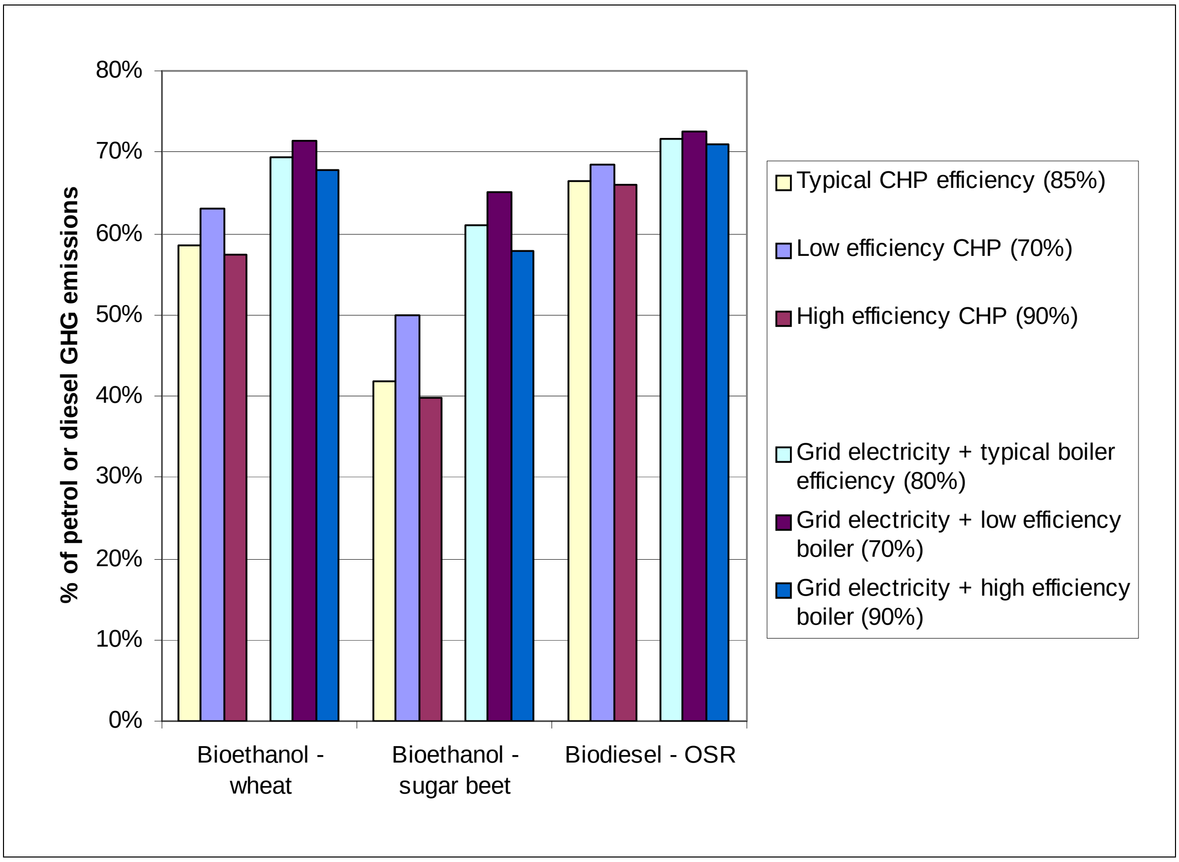

Figure 4.7. **Impact of process energy source on biofuels GHG emissions**

Note: The axes in Figure 4.7 and subsequent graphs show the emissions from biofuel production as a percentage of emissions from an equivalent amount of fossil fuel. So for example, a value of 60 per cent for bioethanol would mean that emissions are 60 per cent of those from (an equivalent amount of) petrol, and it would save 40 per cent of the emissions associated with petrol use. A value of 100 per cent means that the biofuel has the same emissions as petrol or diesel, and values above 100 per cent mean that emissions from the biofuel are greater than from conventional petrol or diesel.

Fertilisation rate and yield

The reference case modelling assumes typical nitrogen fertilisation rates and yields for the biofuel crops. Figure 4.8 shows the sensitivity of biofuel GHG emissions to changes in nitrogen fertilisation (and ensuing changes in yield). Application of nitrogen fertiliser causes emissions of nitrous oxide from the soil, and there are also GHG emissions associated with its production. Both higher and lower fertilisation rates lead to increases in GHG emissions of about seven per cent for wheat bioethanol, and up to four per cent for sugar beet bioethanol and OSR biodiesel. This is because in both cases the yield of crop (and hence biofuel) per kilogramme of nitrogen applied is lower than in the reference case, when nitrogen application has been optimised.

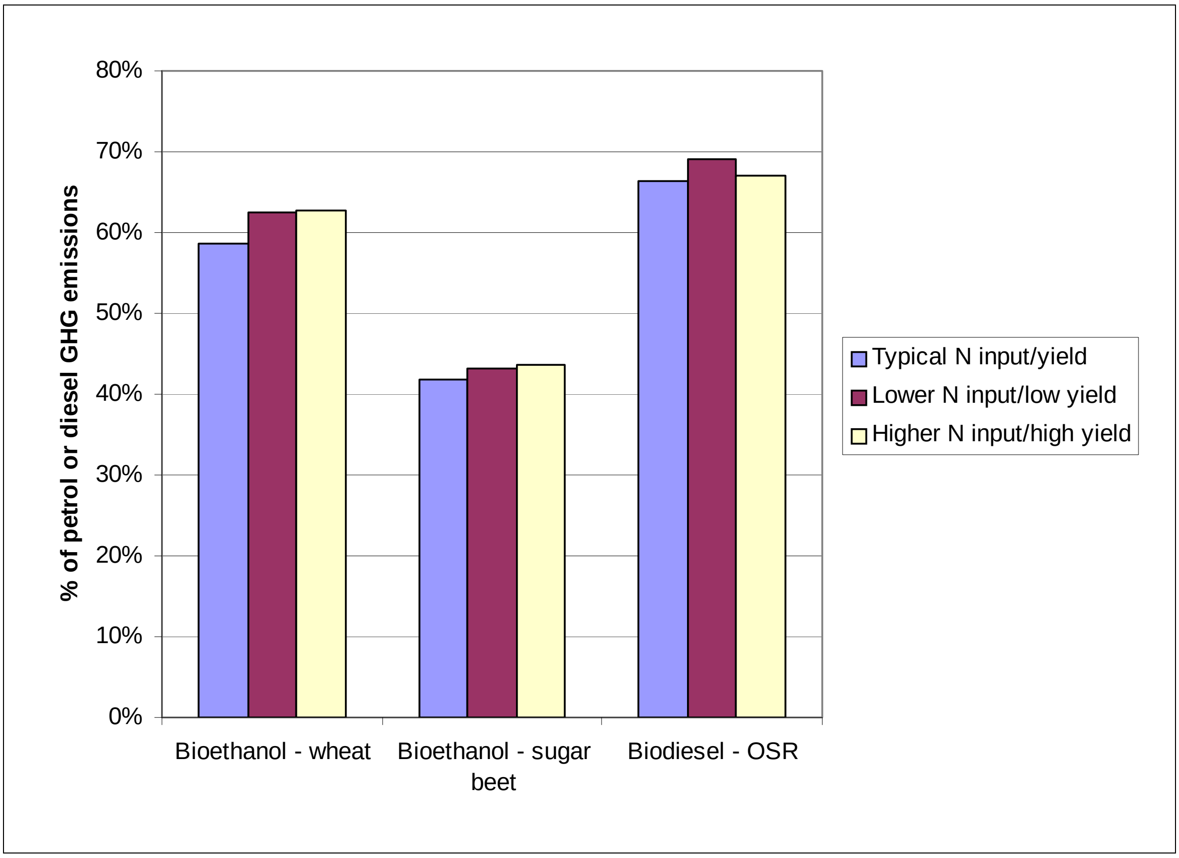

Figure 4.8. **Impact of fertilisation rate and yield on biofuel GHG emissions**

Land use change (LUC)

There has been much discussion recently about whether growing crops for biofuel feedstocks causes land use change. Analysis shows that if it does, the carbon emissions associated with this land use change can negate any GHG savings that biofuels offer (Renewable Fuels Agency, 2008).

Direct land use change occurs when feedstocks for bioenergy displace a prior land use (such as forests). This causes a direct land use change impact. One of the most important land use change impacts relates to changes in the carbon stock stored in that land, which can be significant if mature vegetation is displaced by cultivated crops, particularly annual crops. Removal of forests, drainage of peatland and cultivation of grasslands all result in removal of above- and below-ground carbon stock and therefore has the potential to change the carbon stock held in the land. Assessing the amount of carbon in vegetation pools is complex because of the inherent variability in natural ecosystems, and estimates can be very uncertain. Nevertheless, estimates of carbon stored in different types of ecosystems around the world are available and can be used to estimate emissions from land use change.

Where feedstocks are supplied from existing agricultural land, then there is no direct land use change, but there may be an ***indirect*** land use change as the commodity previously produced on that land is moved to a different location, leading to an overall increase in agricultural land use. For example, if existing oil seed rape production is switched to provide feedstock for biodiesel, then oil seed rape or other oil seed production may locate on other land to meet the continued need for oil seeds. Another example is the conversion of pasture land to soy bean cultivation, which could lead to cattle grazing being moved to other areas perhaps resulting in deforested land in the same region, or to increased production of meat in other producing countries, with land use change occurring there.

Modelling the indirect land use change that may occur from increased demand for biofuel feedstocks is complex, and ideally should reflect the elasticity of demand, interactions between different feedstock markets and possibilities for substitution, as well as potential improvements in productivity and the sensitivity of both these factors to price. It is also necessary to take account of the potential use of co-products from the biofuel production process, which can be used as animal feeds thus avoiding some land use change. In addition, in order to assess the associated carbon emissions from indirect land use change, it is not only necessary to know the magnitude of the land use change which occurs (that is, number of hectares) but also the original land use and the regional location of land which is being converted. This is because the amount of carbon stored in biomass varies significantly.

Figure 4.9 shows the impact of various types of direct land use change to cultivate biofuel feedstocks (as compared to growing on existing crop land) on UK biofuel GHG emissions. Changes in GHG emissions include carbon emissions as a result of loss of soil organic carbon when uncultivated land is cultivated, methane losses from grassland conversion, avoided nitrous oxide emissions from grassland, permanent set aside and fallow land, and avoided emissions associated with diesel used to mow set-aside or fallow land. It can be clearly seen that conversion of permanent grassland to cultivate biofuel feedstocks would negate any GHG savings from use of the biofuels (that is, GHG emissions are more than 100 per cent of the equivalent amount from petrol or diesel). Conversion from fallow land or permanent set aside almost negates GHG savings in the case of biodiesel from OSR and substantially reduces savings from bioethanol from wheat.

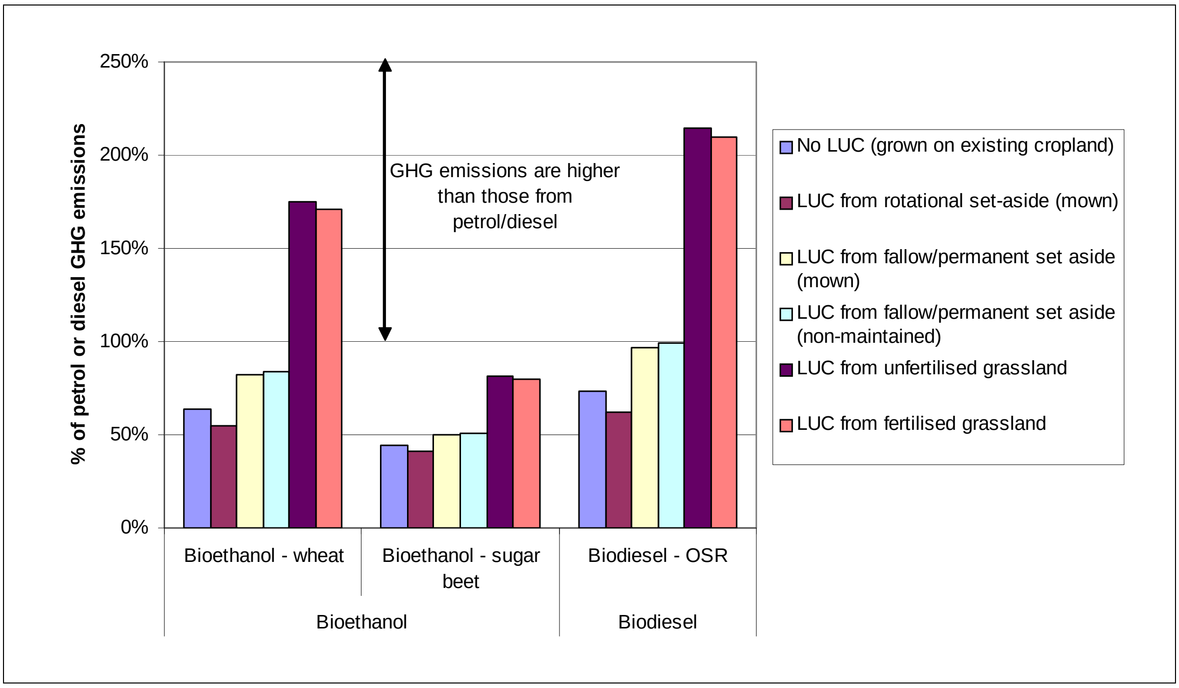

Figure 4.9. **Impact of direct land use change on UK biofuel GHG emissions**

Source: Based on data from $BEAT_2$ and North Energy, 2008.

The analysis also considers imports of biodiesel produced from soy oil and palm oil. In the case of palm oil, there has been considerable concern that deforestation is occurring as a result of expansion of palm oil plantations. Similarly in the case of soy bean production, there is concern the Cerrado are being converted to soy bean cultivation. The impact that such land use change could have on GHG emission from these biofuels is very large (Figure 4.10), due to the large amount of carbon stored in such ecosystems that leads to a high carbon release on conversion. This completely negates any GHG savings.

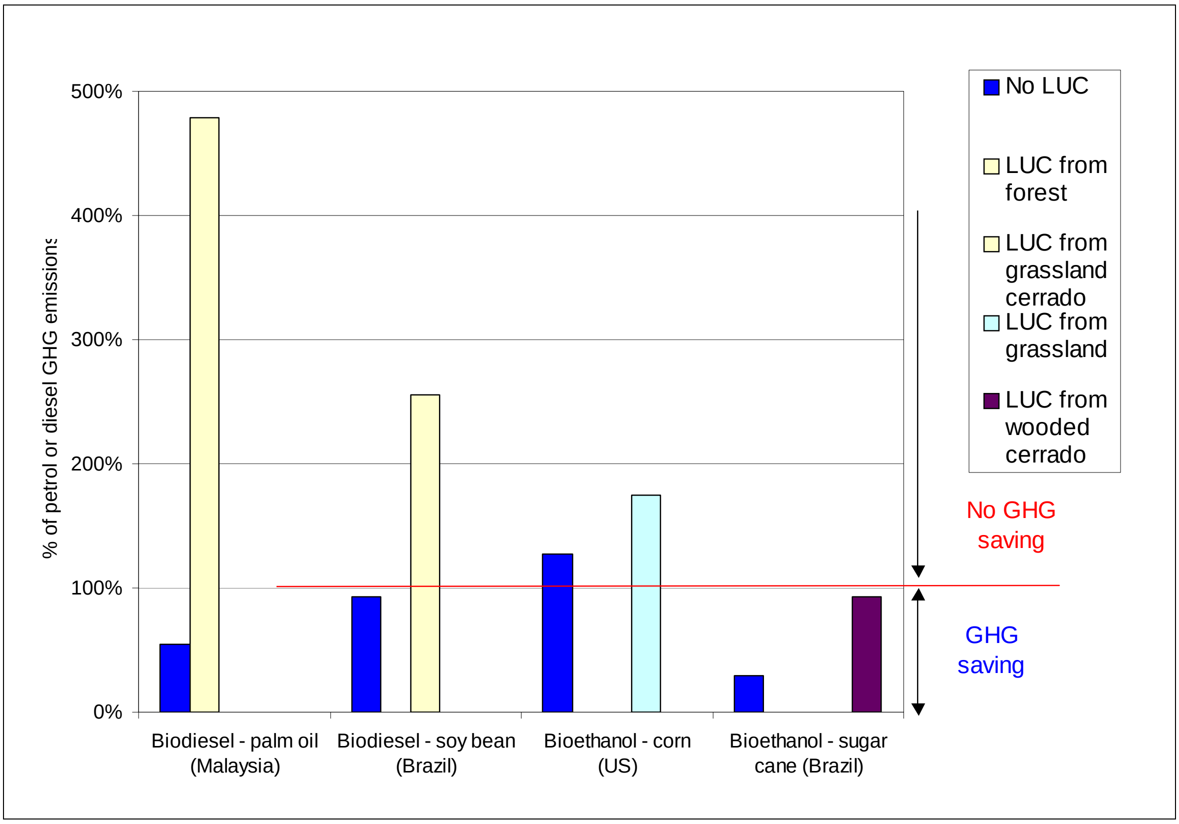

Figure 4.10. **Potential impact of LUC on GHG emissions of imported biofuels**

Source: Based on data from North Energy (2008)

Production of biofuels from OSR results in production of rape meal as a by-product, which can be used as animal feed; bioethanol production from wheat also results in production of dried distillers' grains (DDGS) which can be sold for use as an animal feed. These animal feeds can replace other products (such as soy meal) used for animal feed, and a credit can be given to the biofuel for the GHG emissions that are avoided from not having to produce this other crop. Once we begin to include the effect of land use change caused by growing biofuel feedstocks, it is important to also consider including the land use change that is avoided by using the co-products for animal feed.[32] Relatively little work has been done in this area to date, but as part of work for the Gallagher review on biofuels, AEA (AEA, 2008b) produced an estimate of the avoided GHG emissions from avoided land use change associated with the use of co-products for animal feed, based on other supporting work which had looked at the co-products issue (CE Delft, 2008; Ecofys, 2008). In the case of OSR and wheat, the work argued that it would be necessary to produce additional oil to replace the soy oil associated with soymeal production, and emissions from land use change to produce palm oil (the cheapest form of oil production) is allowed for. It is clear from Figure 4.11 that if the use of co-products prevents land use change, then this should be included in the overall estimate of GHG emissions from biofuels production as it may be

[32] The estimate of GHG emissions associated with soymeal production (which is credited to the biofuel) does not include any potential land use change potentially associated with producing soymeal.

significant. More research is however needed to establish clearly under what circumstances land use change will be avoided, and to refine estimates of the effect on GHG emissions.

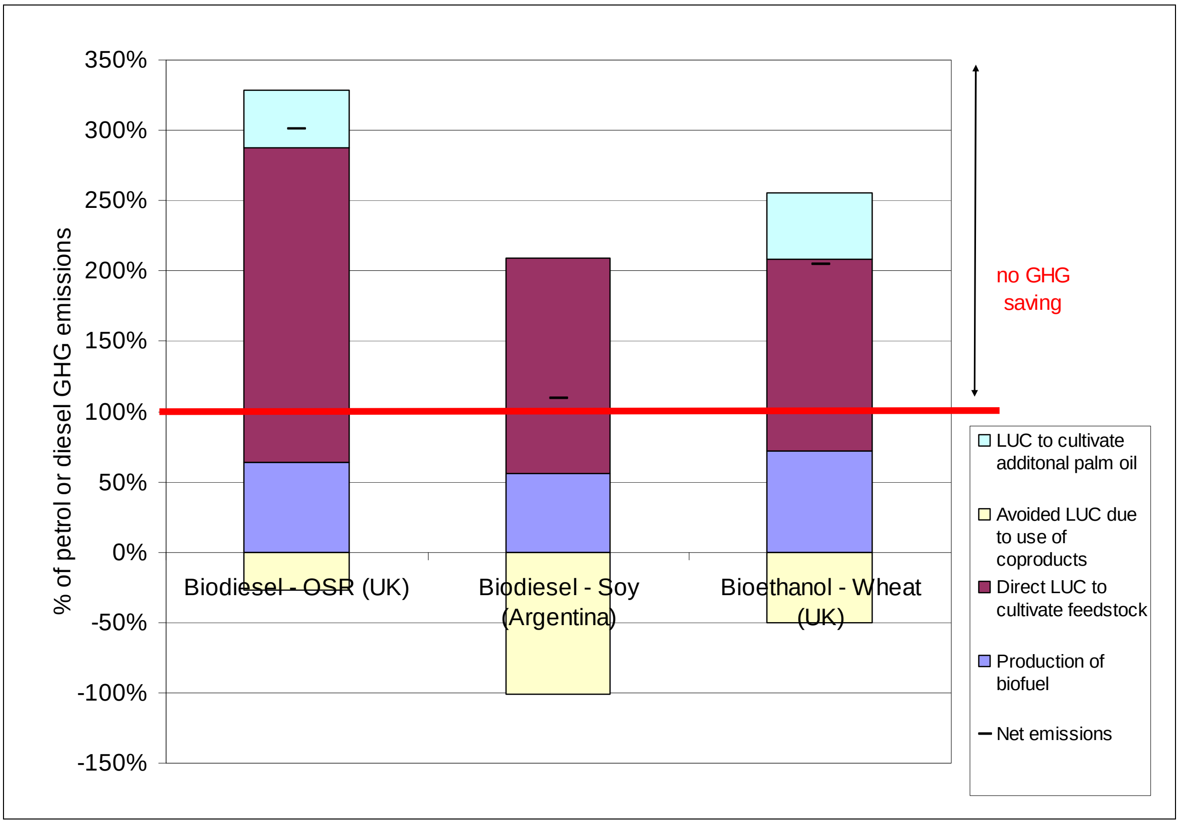

Figure 4.11. **Impact of allowing for avoided LUC from co-product used as animal feeds on GHG emissions**

Source: AEA, 2008b; assumes avoided production of soymeal by coproducts avoids conversion from grassland.

Sensitivity of overall GHG savings in scenarios to LUC emissions

It is clear that land use change has a very large potential impact on biofuels GHG emissions. We therefore explored its impact on the overall GHG savings estimated in the scenarios. We examined two hypothetical cases:

- ***Case 1.*** In this case we assumed an extreme situation where pressures on food/agricultural production in the UK are high for a number of reasons. For example, if the situation of the last two years continues such that a number of crop harvests fail internationally while demand continues to increase, then there will continue to be high prices and demand for food. In this case we have assumed that 50 per cent of biofuel crops (wheat, OSR and sugar beet from the UK and Europe) will be grown on rotational set aside, while the remainder will be grown on non-rotational set aside and fallow land. The high level of demand for food means that imported biofuel feed-stocks such as soybean and palm oil will result in land use change overseas.

- ***Case 2.*** In this case we assumed a less extreme situation, although one that is still impacted by high demand. We assumed the demand for biofuels is met by use of non-rotational set aside for the BAU scenario and only 50 per cent of production above this level requires the use of non-rotational set aside or fallow land. In addition, biofuel developers, influenced by the current demand for sustainability only import biofuel feed-stocks from sustainable supplies that do not result in land use change.

These cases represent extreme situations. In reality it is possible that the need for sustainability will influence how biofuel producers contract their supplies. This will mean that they will look to maximise sustainability and minimise impacts such as deforestation and cultivation of fallow land. Because of the current uncertainty in calculating avoided land use change from use of co-products as animal feed, we did not include this in the estimates of biofuel GHG emissions, and in this aspect, the results represent a 'worst case situation'.

Figure 4.12 shows the GHG savings or emissions from biofuels production and use in Case 1 and 2 for each of the five scenarios compared to the reference case (which assumes that UK and European biofuel feedstocks are produced on rotational set aside and that imported feedstocks do not result in land use change). It is clear that while the assumptions in Case 2 only slightly reduce GHG savings, those in Case 1 actually result in net emissions from biofuels production. In the Focus on Biofuels (FB) scenario, and Progress with Barriers scenarios, where the savings from heat and power production are smaller, the net emissions from biofuels are almost enough to totally negate the savings created by other forms of biomass use (Figure 4.13). The large GHG emissions from biofuel in this scenario are due to the emissions associated with land use change to produce imports of palm oil and soy oil for biodiesel (Figure 4.14). These are much larger than GHG savings from other types of biofuels production, even though in the FB scenario they each only account for 17 per cent of biofuels production. They would each need to account for only about six per cent of biofuels production for the GHG emissions associated with their production to be less than the GHG savings associated with the remainder of the biofuels production.

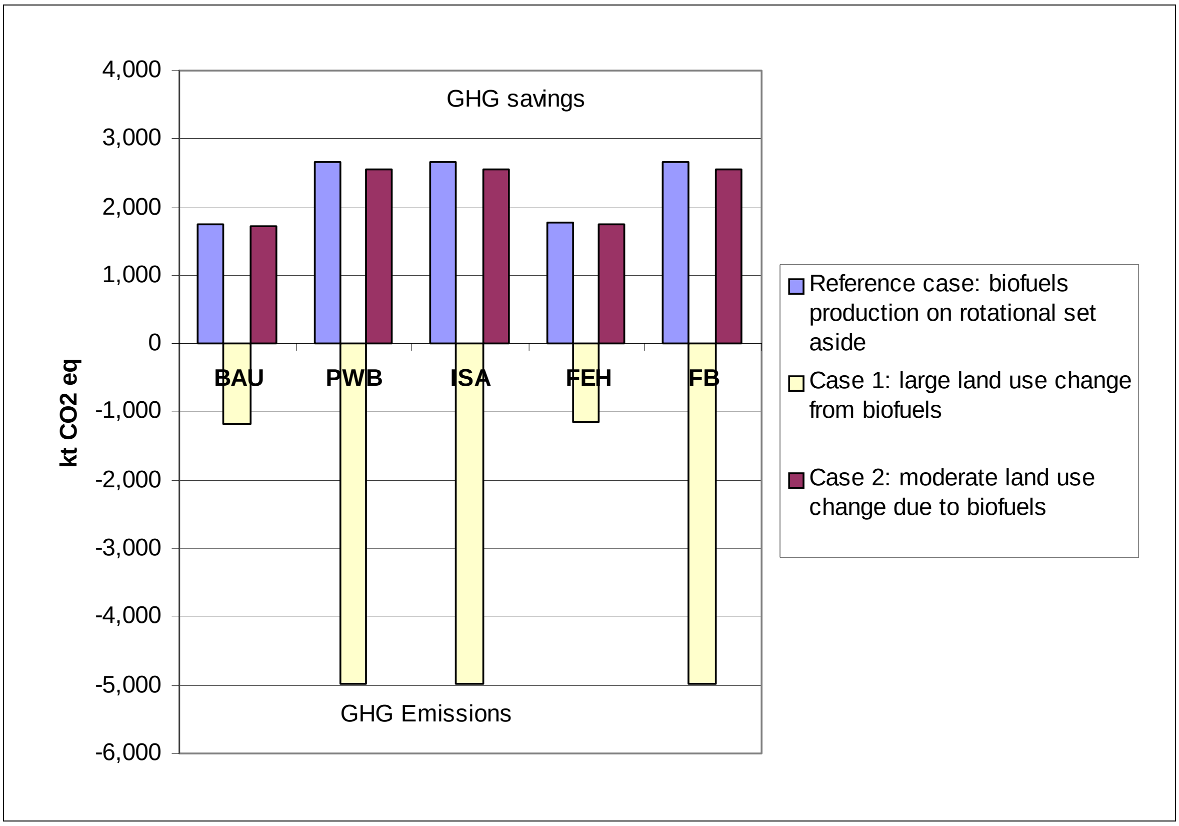

Figure 4.12. **GHG savings from biofuel production in scenarios if LUC occurs**

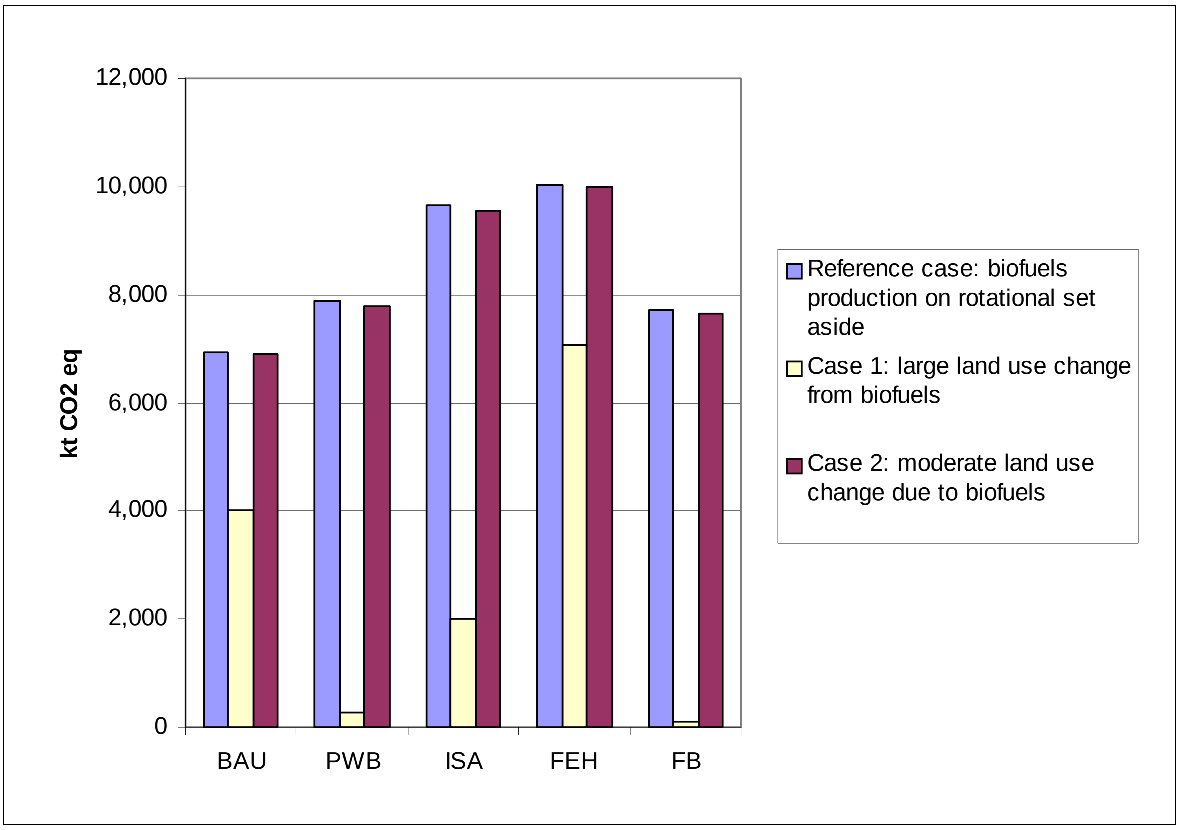

Figure 4.13. **Overall GHG savings in scenarios if potential LUC associated with biofuel production occurs**

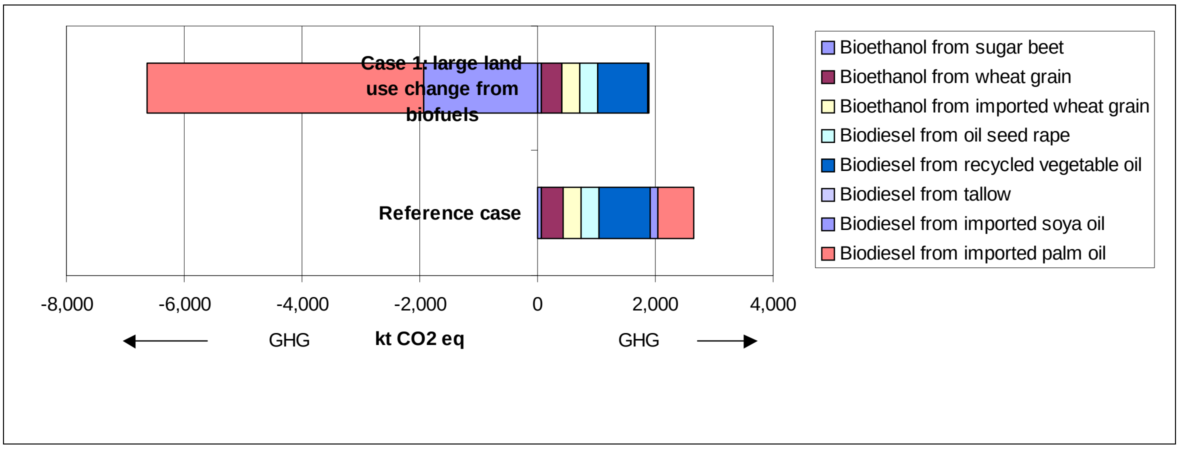

Figure 4.14. **Breakdown of GHG savings/emissions from biofuel production in the Focus on Biofuels scenario**

These sensitivity studies show that identifying whether direct and/or indirect land use change is occurring due to crop production for biofuels, and estimating as accurately as possible the GHG emissions associated with that land use change, is crucial to the assessment of the savings offered by biofuels. Imports of feedstocks which have resulted in land use change, particularly deforestation, could easily negate savings from other types of biofuel production, even when they account for a relatively small proportion of total production.

Outlook for 2015

As part of this work we also examined the outlook for 2015. This included an appreciation of the potential 2020 targets, using the Renewables Advisory Board's analysis. A summary of this analysis is:

- Under BAU we would expect the electricity and heat to continue to increase slowly from 2010 to 2015. We would expect transport biofuels to also increase slowly, up to the five per cent by volume level.

- PWB would be similar to BAU by 2015, the difference being that PWB would reach the higher levels earlier. We would expect biofuels to remain at the 2010 level of five per cent.

- In 'support for all' electricity, heat and biofuels are all likely to progress between 2010 and 2015, but more slowly than in the focussed scenarios because support has to be shared amongst all three routes.

- For FEH the progress with electricity is likely to increase after 2010, with strong drivers for additional renewable electricity as a result of 2020 targets, and with the availability of advanced conversion technologies and the uptake of CHP. Heat should also progress faster once the production and installation supply chains are established at high volumes. Transport biofuels may increase slowly to the five per cent level, or may reduce if sustainability concerns are not resolved.

- In FB the heat and electricity will again progress as in BAU. The results for 2010 look anomalous, as extra effort is put into biofuels with no observable increase in output or GHG savings. This is because the effort is directed towards next generation biofuels, which will not be available by 2010. In fact, the lead time for a large scale biomass to liquid plant is thought to be about seven years, so even by 2015 this technology will only just be starting to make an impact. Even one large scale plant will, however, require large quantities of feedstock, and this should encourage establishment of energy crops and development of densification techniques to enable economic supply to the plant.

5 GHG Emissions from waste management

5.1 Introduction

In 2005 the waste management sector accounted for 3.4 per cent of UK greenhouse gas emissions (AEA, 2007a). This section of the report examines, for four examples of biomass waste streams, whether the waste hierarchy (Figure 5.1) encourages the minimisation of greenhouse gas emissions.

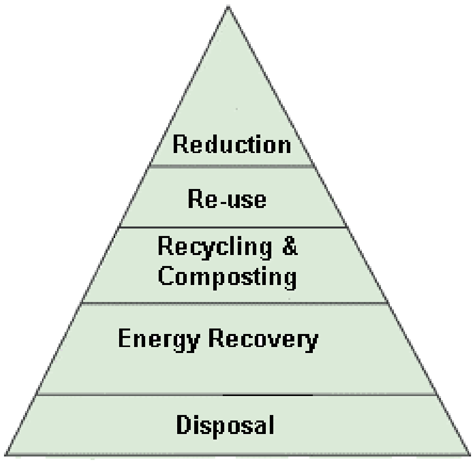

Figure 5.1. Waste hierarchy

The four biowastes chosen for study (in consultation with the Environment Agency project steering group) are:

- Kitchen and garden waste component of the municipal solid waste stream (MSW).
- 'Clean' wood processing waste.
- Cereal milling residues.
- Sludge from waste water treatment in dairies.

Waste management options from as many stages in the waste hierarchy as possible were considered for each of the wastes (Table 5.1).

Table 5.1. Waste Management Options Considered

Waste	Recycling & composting	Energy recovery	Disposal
Organic fraction of MSW	(1) Home composting (2) In-vessel composting (IVC) (3) Anaerobic digestion (AD)	(1) Incineration to produce power (EfW) (2) Incineration to produce heat and power (CHP)	Landfill
Waste wood	Composting for use as mulch Recycling into chipboard	Combustion to produce electricity in dedicated biomass power plant (as wood chips and wood pellets) Co-firing (of wood chips and wood pellets) in existing power station	Landfill
Cereal milling residue	Animal feed replacement (straw)	Co-firing of pelletised residue in power station	Landfill
Sludge from wastewater treatment in dairies		Anaerobic digestion of sludge on-site at dairy to produce heat and power	Spreading to land

5.2 Methodology and key assumptions

The greenhouse gas emissions were assessed using two software tools developed for the Environment Agency, WRATE and $BEAT_2$. **WRATE** (Waste and Resources Assessment Tool for the Environment) is the Environment Agency's lifecycle assessment (LCA) software tool for comparing different management systems treating Municipal Solid Waste (MSW). WRATE was used to assess all of the MSW options, landfill of all wastes and composting of waste wood. Specific details of the WRATE modelling are given in Appendix 9.6. In brief, WRATE uses information on waste management facilities to model all the inputs (such as fuels, electricity, operating materials) and outputs (emissions to air, water and soil) of managing waste. The tool takes into account relevant characteristics of the waste, for example its biodegradability when evaluating how much methane will be released when it is landfilled, and the carbon content of the waste when calculating carbon dioxide released when it is burnt. It also accounts for the waste management technologies, for example the efficiency of energy from waste plants in generating electricity when waste is burnt. For this analysis, examples of modern, best practice waste management plants were chosen. WRATE also calculates a 'credit' for products (electricity, heat, compost) which are produced from the waste, based on the emissions (to air, water and soil) which would have arisen if the product was produced conventionally.

BEAT$_2$ is an LCA software tool developed by AEA and North Energy Associates for Defra and the Environment Agency to assess greenhouse gas emissions and other environmental impacts from the use of biomass to produce heat, power and transport fuels. BEAT$_2$ was used to assess energy recovery options for waste wood, and cereal milling residue, and data from BEAT$_2$ was used to estimate emissions associated with the production of straw (assumed to be displaced when cereal milling residue is used for animal feed).

For recycling of waste wood into chipboard – where the waste wood is assumed to replace virgin wood – data on wood production and transport was taken from the Ecoinvent database[33]. The emissions from anaerobic digestion of sludge from dairy wastewater were estimated using an AD model developed previously by AEA when examining this issue for the dairy industry. No data on emissions from spreading the sludge to land could be found, so emissions were estimated using emissions factors recommended by the IPCC (2006) for the spreading of manures and slurries to land. It was assumed that only 0.1 to 1 per cent of the total methane, which could be released if the slurry decomposed anaerobically, was released during spreading (where the decomposition process is predominantly aerobic).

As the aim of the analysis was to rank options (rather than produce an absolute assessment), elements that were common to each of the options such as collection of the waste were not modelled.[34] Transport of the waste to the waste management options was also not included for most options, as it was considered that in general this was likely to be equivalent. An exception was recycling of wood for chipboard, as there are only a few manufacturers in the UK, so it was considered that the transport distance was likely to be longer for this option, and the additional transport requirements were included in the modelling.

For energy recovery options, assessments of greenhouse gas savings are known to be very sensitive to the carbon intensity of the heat and/or electricity production, which it is assumed to replace. The sensitivity of the results to these assumptions was therefore examined:

- Where electricity is produced in an energy from waste plant, a biomass power station, a CHP plant or in anaerobic digestion schemes, results were calculated for displacement of the marginal electricity mix (56 per cent coal and 44 per cent gas[35]), and gas-fired CCGT plant.
- Where electricity is produced by cofiring the waste in an existing power station, then results were calculated for displacement of a) coal (the normal fuel in such power stations) and b) gas fired CCGT plant.
- For CHP plants, the comparison for heat output was gas, and for electricity, the marginal mix and gas-fired CCGT plant
- For domestic and industrial boilers producing heat, the two comparison fuels were oil and gas.

[33] The Ecoinvent database contains international industrial life cycle inventory data on energy supply, resource extraction, material supply, chemicals, metals, agriculture, waste management services, and transport services. For details see www.ecoinvent.ch.
[34] An exception is home composting, which does avoid the need to collect and transport waste to a treatment plant.
[35] This is the marginal electricity mix defined in the WRATE tool for 2008. See Appendix 6 for details.

5.3 Results

5.3.1 Organic fraction in MSW

The greenhouse gas (GHG) savings/emissions for waste management options for kitchen and garden waste are shown in Figure 5.2. Additional details and a tabular version of the results are in Appendix 9.6.

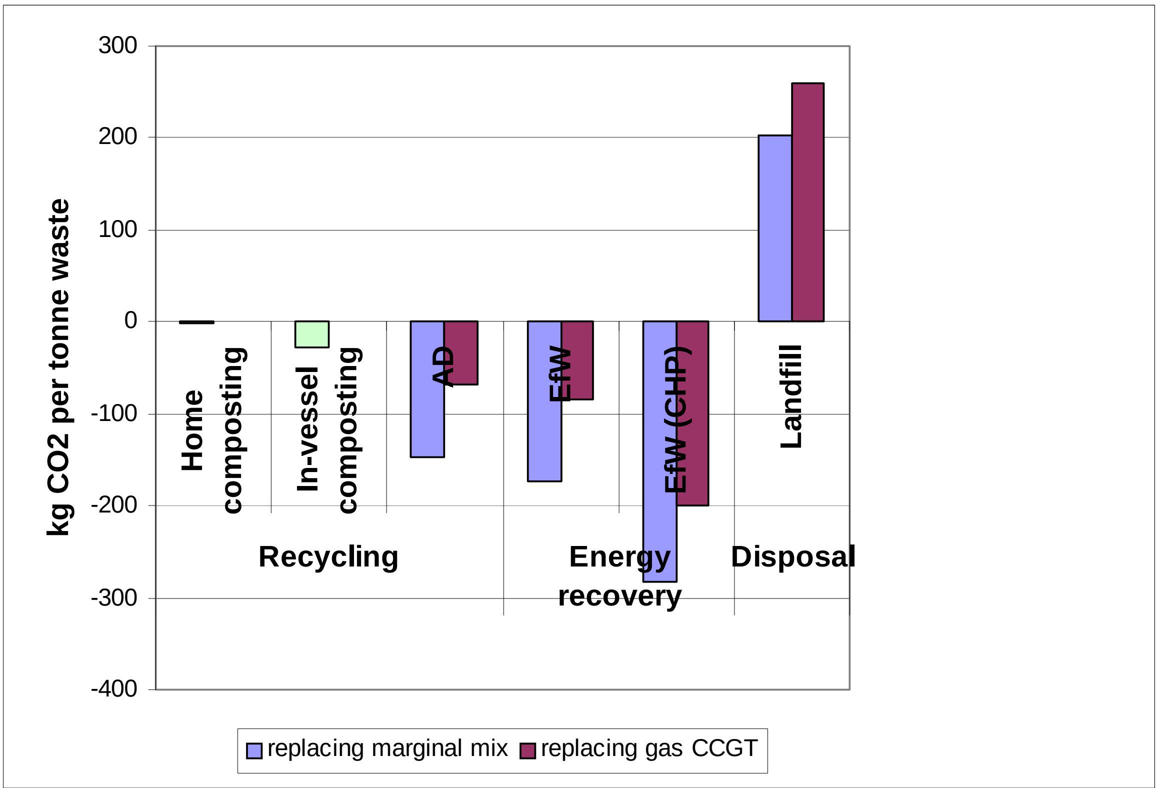

Figure 5.2. **GHG emissions from managing kitchen and garden waste (excluding transport of waste)**

In the case of composting, there is a small net saving in greenhouse gas emissions as compost from home composting is assumed to be used in the garden and replace other soil conditioners. These are mainly other waste products or residues such as bark chips and spent mushroom compost which require little energy to produce, and so have low greenhouse gas emissions associated with them. A small amount of peat-based compost is replaced (0.03 tonnes peat for each tonne of compost) and a credit is given for the avoided GHG emissions from production of the peat (including GHG releases when land is disturbed at the extraction site) and more importantly, carbon dioxide emissions as the peat degrades after application in the garden.

Compost from IVC has a variety of uses (for example in landscaping, agriculture), and in some of these its use will reduce the use of nitrogenous fertilisers as well as the use of other soil conditioners. As the production of mineral nitrogenous fertilisers is very energy intensive, this leads to greater GHG savings than for home composting. In the case of AD, the main GHG savings are from electricity produced by the plant, and these are significantly greater than those from composting.

The energy recovery options show significant greenhouse gas savings, particularly when heat as well as electricity is recovered and used. In practice, energy from waste incinerators would typically utilise the whole of the household/municipal solid waste stream. As these include fossil fuel derived materials (such as plastics), there are some carbon dioxide emissions from the incineration process which reduce the GHG savings, but (assuming the marginal electricity mix is displaced) there are still net GHG savings.

Disposal to landfill results in a net emission of GHG emissions, due to release of methane in landfill gas which leaks from the site (although most is recovered and either flared or used for electricity production).

The results clearly show that disposal (to landfill), which is at the bottom of the waste hierarchy, is also the worst option in terms of greenhouse gas emissions. However, energy recovery, which is below recycling in the waste hierarchy, performs better from a GHG perspective, due to the carbon dioxide emissions that are avoided by replacing fossil fuel-based sources of heat and electricity. The composting options in contrast involve mainly replacing soil conditioners or mulches, which are often waste products or by-products themselves (such as bark) and are not energy intensive to produce. The only 'recycling' option which approaches the energy recovery option in terms of GHG savings is AD. This is characterised in the waste hierarchy as a recycling option due to the production of digestate which can be used as a soil improver, but also includes energy recovery from the biogas produced, and it is the latter which is responsible for the majority of the GHG savings

As discussed earlier, as transport requirements would typically be of the same order for each of the options, it was not included in the comparison. On average (using data from WRATE), transporting 1t waste 100km (in a front end loader) leads to greenhouse gas emissions of 17kg CO_2 eq. Transport of materials in an articulated lorry generally has lower emission - about 8kg CO_2 eq per 100km. In terms of the energy recovery options, it can be seen that transport emissions are likely to be small compared to net GHG savings; for the recycling options it could be more significant, and long transport distances could offset much of the GHG savings. Typically, however, green waste is not transported long distances, and emissions from collection and transport of green waste might be more in the order of 10kg CO_2 eq per tonne. In the case of home composting, collection and transport is avoided completely and so this option has an additional saving (of about 10kg CO_2 eq per tonne) relative to the other options.

5.3.2 Wood processing waste

The GHG emissions associated with management options for waste wood are shown in Figure 5.3.

Greenhouse gas savings from wood recycling assume that wood is sent to a particle board manufacturer, and that it replaces UK roundwood (softwood).[36] GHG emissions associated with production of wood were taken from the Ecoinvent database. As no value was available for the UK, a range was used based on values for wood production in Scandinavia and Germany. These assumptions give a range of values between 24 and 49kg carbon dioxide saved per tonne of wood. As the GHG emissions associated with wood production are low (17kg CO_2 eq/t for German production, 4 kg CO_2 eq/t for Scandinavian production), the transport element is more significant in this route than in some of the other disposal routes, and the results are very sensitive to the net balance of transport distances (that is, the distance virgin wood is transported, compared to the distance recycled wood is transported). As there are only a few particle board producers in the UK, recycled wood may have to travel some distance. Under a 'worst case' scenario where virgin wood only travels 100km and recycled wood an additional

[36] In 2006, about one-third of wood supplied to panel mills was UK roundwood, and the remainder was sawmill products or recycled wood (Forestry Commission, 2008).

300km, using the lower value for wood production net emissions savings from recycling are reduced to 2kg CO_2 eq per tonne. Overall it is recommended that a more detailed assessment of wood recycling is carried out before firm conclusions are drawn about the extent of the greenhouse savings it offers, but it is clear from this simple analysis that savings are likely to be relatively low.

Similarly, composting of wood waste to produce a material which can be used as mulch gives very low greenhouse gas savings for the reasons discussed in composting of organic waste.

As with organic household waste, the largest GHG savings come from the energy recovery options, and the highest GHG emissions from disposal to landfill. The energy recovery options assume that the waste wood is chipped and then (for all options apart from the biomass power station) are pelletised to produce a more convenient, denser fuel form. This introduces an energy penalty, as heat is required for the pelletisation process, and GHG savings if wood chips were used would be higher (see Appendix 9.6 for results for wood chips).

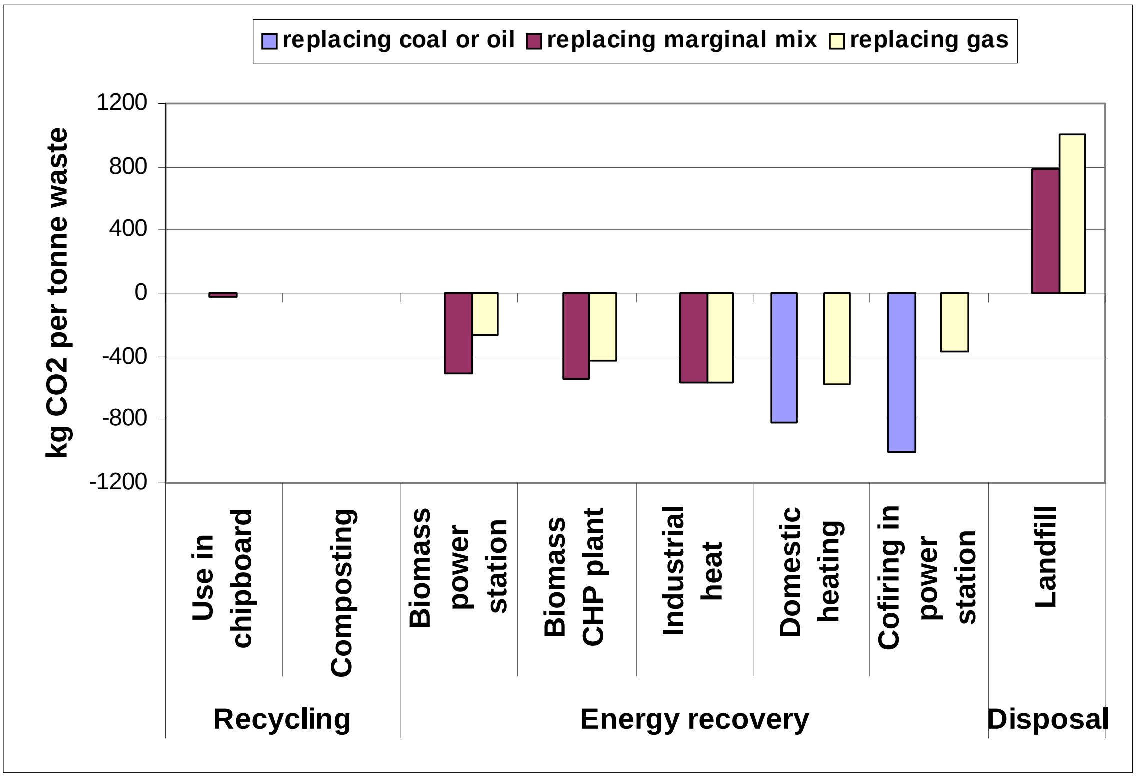

Figure 5.3. GHG Emissions from managing clean wood waste (excluding common transport steps)

5.3.3 Cereal milling residues

Cereal milling residue is the husks and other detritus produced during milling and can be used as an animal feed. As it has a low nutritional value, it was assumed that it would replace a 'filler' type animal feed, straw, rather than one with a high protein or fat content. It is assumed that using the residues as an animal feed requires no further processing of the cereal milling residue, and that the residues are ground and pelletised before cofiring. Figure 5.4 shows the GHG savings from energy recovery options are greater than from recycling, and landfill has the highest greenhouse gas emissions.

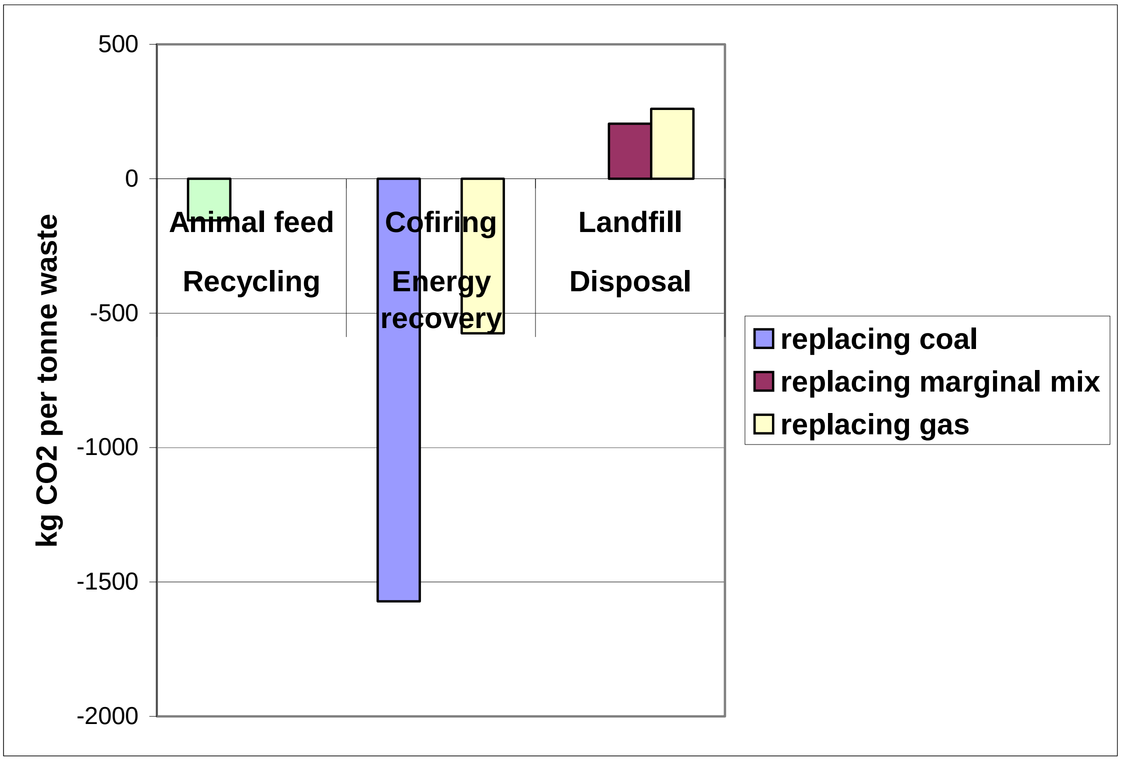

Figure 5.4. **GHG emissions from managing cereal milling residue (excluding transport)**

5.3.4 Sludge from dairy waste water treatment

Figure 5.5 shows the GHG emissions from anaerobic digestion of the sludge from dairy wastewater treatment plant (and then spreading the digestate to land), compared to simply spreading the sludge on land. As for the other waste streams, the energy recovery options give greenhouse gas savings, whereas spreading to land leads to a net emission. No allowance has been made in either options for soil improvers or fertilisers which might be replaced through spreading of the sludge or digestate to land, but as any GHG saving from this replacement would be similar for both options it does not affect the ranking of the two options.

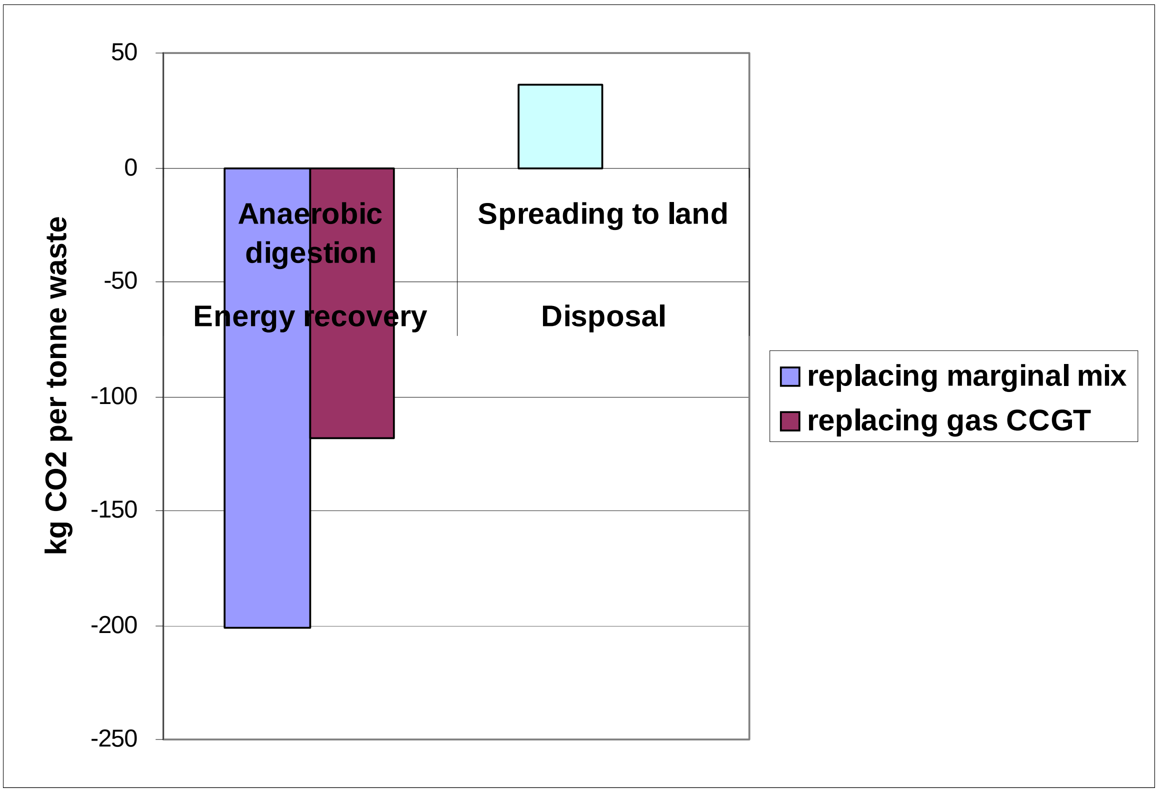

Figure 5.5. GHG emissions from managing dairy waste water sludge

5.4 Conclusions

The analysis has examined whether the waste hierarchy minimises climate change impacts for recycling, energy recovery and disposal options for four biowaste streams (kitchen and garden waste, clean waste wood, cereal milling residue and sludge from dairy waste water treatment). The analysis was carried out in a comparative way, that is, elements of the treatment options which were common to all options (such as transport to collect the waste) were not included, so the values presented do **not** provide an absolute assessment of GHG emissions associated with management options, but an assessment of the relative differences in GHG emissions from each management option.

For all four wastes, disposal, which is at the bottom of the waste hierarchy, had the worst climate change impact, and led to net emissions of GHGs. Energy recovery options always led to a net reduction in GHG emissions, due to the displacement of fossil fuels. This reduction was substantially larger than the reductions offered by recycling options, apart from anaerobic digestion of organic wastes – because the latter also incorporates an energy recovery element. The 'climate change' ranking of these two options (for these wastes and the options considered) is thus the reverse of their ranking in the waste hierarchy.

It should be remembered, however, that climate change is not the only environmental impact associated with waste management. Each of the waste management options considered also has other environmental impacts; for example, energy from waste schemes and the combustion of wood wastes for electricity and heat lead to emissions of a number of other air pollutants and to emissions of pollutants to water, for example from flue gas cleaning systems. There may also be other beneficial environmental impacts from the option considered; for example the application of composts to soils increases the organic content of the soil and can lead to improvements in soil quality.

These initial results suggest however that waste management options could help contribute to greenhouse gas reductions, and it would be worth examining this area in more detail, for example by expanding the analysis to cover more types of waste, and by more detailed analysis of some of the recycling options where the analysis was based on relatively simple assumptions.

6 Discussion and conclusions

The UK is an island restricted in size and subject to many conflicting demands for land use. According to Defra statistics the area of the UK is 24,251,000ha; the area regulated by the Environment Agency (England and Wales) represents 15,101,000ha. Agricultural land use (including arable, grazing and set aside land) in England and Wales represents 72.8 per cent of this land (10,998,217ha) and forestry a further 9.4 per cent of the land (1,418,207ha).

The UK Biomass Strategy indicates how the Government believes it is possible to achieve its targets for biomass in a sustainable manner without detrimental effects on food supplies and the environment (see Box 6.1 for an extract from the Strategy), but this is based on the assumption that half our biomass energy feedstock needs are imported.

Box 6.1 Extract from UK Biomass strategy (Defra, 2007a)

It is acknowledged that increasing the supply of biomass will have implications for land use, biodiversity, landscape and a range of other environmental factors. We believe that a significant increase in sustainable UK biomass production, taking full account of the lessons we have learnt from more traditional forms of agriculture and our emerging understanding of how ecosystems work, is achievable. We believe there is significant potential to expand the UK supply of biomass without any detrimental effect on food supplies and in a sustainable manner by:

- Sourcing an additional one million dry tonnes of wood per annum from currently unmanaged woodland in England, and from increasing the recovery of wood for energy from managed woodland and other sources of wood waste products across the UK.
- Increasing the amount of perennial energy crops produced in the UK to meet market demands – with the potential to use up to a further 350,000 hectares across the UK by 2020. This brings the total land availability for biofuel and energy crops to around one million hectares, equivalent to 17 per cent of total UK arable land.
- Increasing supply from organic waste materials such as manures and slurries, certain organic wastes, source separated waste biomass and waste derived Solid Recovered Fuels (SRF).

By expanding existing biomass supplies in this way we estimate the potential future biomass resource in the UK to be a total of approximately 96.2 TWh (8.3 million tonnes of oil equivalent, Mtoe). If it is assumed UK biofuel crop production can supply half of the five per cent (by volume) target for 2010, this gives a total predicted theoretical biomass resource level in the UK of around 10.0 Mtoe. This compares with a total UK energy need of currently 165 Mtoe.

Table 6.1 summarises our findings on current use of biomass in the UK (in fact figures are for 2006 as this is the last year for which complete figures are available).

Table 6.1. Summary of current (2006) bioenergy use in the UK

Sector	Installed capacity 2006 (MW)	Generation 2006 (MWh/y)	Thousand t feedstock 2006	Land take in UK in 2006 (ha)	GHG reduction 2006 (kt CO_2)
Co-firing power	19,496[1]	1,533,960	872	487	1,650
Stand alone biomass power and CHP					
a) Combustion	118	610,707	643	179	149
b) Gasification	0	0	0	0	0
Large-scale CHP	80	296,699 (+1,187,00MWh_{th})	340.	0	484
Biomass heat					
Large-scale heat	168 MWth	1,680,000 MWh_{th}	443	0	1,064
Small-scale heat	32MWth	200,000	51	0	96
Domestic heat	132MWth	376,000	95	0	128
AD – power	6.301	12,032	291 wet tonnes		11
AD – heat	0	0	0		0
Transport biofuels	1,688 Ml	296 Ml	340 ktonnes	43,241	626

Note: total land take for SRC and Miscanthus is of the order of 5,000-7,000 ha (2007). Total land take for OSR declared under the Energy Aid Payment Scheme was 617,000ha in 2006 of which only 100,000ha was for OSR for the UK. The rest was probably exported.

[1] This is total capacity of the power station, not just the capacity for co-firing.

In this report we have shown that by 2010 around 300,000t SRC (~30,000ha), 300,000t Miscanthus (~25,000ha for established crop), 1,600,000t wheat (~190,000ha), 700,000t sugar beet (~12300 ha) and 1,200,000t OSR (~375,000 ha) could be used for energy, depending on the way in which the bioenergy industry develops. This represents a significant proportion of the UK surplus wheat in 2006, all of the OSR grown for energy purposes and around 632,000ha dedicated to bioenergy crops - a significant proportion of the UK arable production. To put this into context, much of the 550,000 to 800,000 ha[37] that has been typically set aside until 2008 could be used for bioenergy crops. Furthermore, the analysis in the Bioenergy Strategy indicates that

[37] From Defra statistics. The UK grain surplus was around 3.5 Mt of wheat grain in 2006.

around 0.8Mha could be used to grow bioenergy crops in the UK in 2010 in an environmentally compatible manner.[38]

Our report also shows that there is considerable potential to use residues for bioenergy, as shown in Table 2.24. Currently around 2.8M odt of residues are used for biomass energy out of a resource potential of some 18Mt of dry biomass.[39] There is considerable potential to increase the use of forestry and other wood processing residues, straw, waste wood, secondary recovered fuel (from MSW) and paper recycling products. In addition, waste represents a considerable potential of some 36Mt (this includes 29Mt of animal manures and slurries).

A further source of biomass fuel comes from abroad. The co-firing generators have successfully imported large quantities for power generation over the past few years (an estimated 720,000odt in 2006). In addition, there is a large potential to import biofuels from abroad, such as bioethanol from Brazil and the current import of biodiesel from the US.[40] It has been estimated that a significant proportion of the EU's biofuels target would be met by imports (EC, 2006).

Use

Our figures show that around 2.5million odt biomass plus some 290,000t of wet slurries, manure and so on and 340,000t of biofuel feedstocks were used in 2006 to provide 3.1 million megawatt hours of thermal energy, 2.45 million megawatt hours of power and 296 million litres of biofuel. In the most optimistic of the scenarios for 2010, we have shown that around 5.8 million megawatt hours of heat, 6.8 million megawatt hours of power and 2.6 million litres of biofuels could be generated in 2010, a considerable increase for power and biofuels. This would require around 7.5Mt of biomass for heat and power, and 5.3Mt of feedstock for biofuels. Our figures indicate that this need could be met by the potential for production in 2010 discussed above, from a mixture of crops, residues, wastes and imported crops. We estimate that around half of the biofuels feedstocks and approximately 50-70 per cent of co-firing fuels will be imported and would comprise olive residues, palm kernel expeller, wood processing residues, wood pellets, and potential energy crops, depending on the definition of energy crops that is acceptable to the regulator. These may include residues from biofuel production overseas.

The market for biomass fuels

The current market for biomass fuels is dictated by supply issues and the cost of the biomass fuel. In general biomass residues are cheaper than crops. Residues are frequently available at transport costs, although some residues that already have a use

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[38] This analysis is drawn from the European Environment Agency, 2006 report, which showed that the UK's environmentally compatible biomass resource was 13.5 Mtoe in 2010, made up of: 3.4 Mtoe from agriculture, 1.5Mtoe from forestry and 8.6 Mtoe from waste. The agricultural potential comprised dedicated bioenergy crops plus cuttings from grassland. Agricultural residues such as straw and manures are part of the waste category. The forestry potential included residues from fellings and complementary fellings.

[39] The figure for biomass resource potential was taken from the UK Biomass Strategy (Defra, 2007). The figures for England and Wales will be lower. Realistically not all of this resource is available. The Biomass Strategy figures include sewage sludge and energy crops, for example, and generous estimates of available straw. Our estimates are that there are around 11-12Modt of dry biomass that are practically available.

[40] The import of US biodiesel has raised concerns that some biodiesel plants in the UK could be under threat unless the import of cheap US biodiesel is addressed (see, for example, the Guardian, 8 March 2008, 'US dumping of biofuels will ruin us, says UK firm.' www.guardian.co.uk/environment/2008/mar/08/biofuels.oil. It is estimated that some 1 million tonnes of biodiesel was imported into the EU in 2007 and the EU is investigating the subsidies associated with this (see European Union, 2008)

(for example for animal feed, fodder, in oleochemicals or panel board manufacture) will have a higher market value.

The current high food and animal feed prices have had an impact on feedstock for co-firing and biofuels production. Biofuels plants in particular are suffering from high crop and bio-oil prices, causing construction of a number of proposed plants to be postponed for the time being.

Wood fuels are thought to be consistent in quality and in price. In fact neither is true. The price of pellets can vary widely depending on demand; the quality can deteriorate significantly at times of high demand. The price of wood chip can also fluctuate considerably depending on demand and can rise steeply at times of shortage. Consequently, many heat and power generators are considering the use of relatively clean waste wood and are designing plants to take waste wood fuels that come under the Waste Incineration Directive.

In this immature and volatile market there are a number of potential issues that the Environment Agency should be aware of. These are the need for fuel flexibility at bioenergy plants, the temptation of bioenergy plants to take waste fuels because of their cheaper price, and the potential deterioration in quality of fuels used at times of scarcity.

Drivers

Many biomass energy technologies are not competitive with fossil fuels on cost alone (there are exceptions for heat plant, but even here the capital outlay can be a drawback). Thus Government policies are significant drivers. These include the Renewables Obligation (RO), the Renewable Transport Fuel Obligation (RTFO) and a number of other initiatives such as a drive for anaerobic digestion and the DfES Building Schools for the Future programme (which estimates that 25 per cent of schools will have biomass heat (4,000 schools)). The Government is also currently examining potential heat support mechanisms. The amount of fuel required to meet the RTFO is estimated to be 0.68Mtoe bioethanol and 1.1Mtoe biodiesel by 2010. Use of bioethanol was 0.05Mtoe in 2006 and 0.14Mtoe of biodiesel (representing 0.2 per cent and 0.3 per cent respectively of total transport fuel sales in 2006).

In addition, the Government has introduced policies to accelerate the supply of biomass, including ambitions to achieve an additional 1M dry tonnes of wood from under-managed woodland, promotion of the use of forest residues, and policies aimed at increasing perennial energy crops to 350,000ha by 2020 (the estimated land suitable for energy crops in the Biomass Strategy (Defra, 2007a)). The use of residues and wastes are to be further encouraged through greater separation of wastes such as food and wood for energy recovery, and promotion of measures to divert waste from landfill to more sustainable management routes (including energy generation from biodegradable wastes that cannot be sustainably re-used or recycled).

Barriers

We have demonstrated in this report that there are some important barriers to the use of biomass energy in the UK. These include many issues in supply and use that the Government is attempting to address through policy (see above). However, we are still seeing issues that are creating problems in the marketplace, some of which are relevant to the Environment Agency. These are examined in detail in chapter 3 and summarised in Table 6.2:

Table 6.2. Barriers to biomass energy

Barrier	Recommendation
Lack of data on the use of bioenergy, including potential environmental impact and abatement of emissions.	Central database of information on bioenergy, linked to Biomass Energy Centre. Examination of the cost effectiveness of abatement technologies. Guidance and advice for biomass energy plants.
Uncertainty in biomass supply, resulting in a volatile market and fluctuating prices.	Biomass protocol. Database of biomass feedstocks.
Little information on the cumulative impacts of small schemes (in fact very little information on small-scale schemes at all).	There needs to be a register of small biofuels plants. Keep abreast of work undertaken by Defra and Scottish Executive.
Complex legislation, particularly that relevant to wastes containing biomass.	Develop web-based database model to provide access to all guidance and regulations relevant to biomass energy. This will need to be updated and should be designed with this in mind.
Public perception of biomass plants, including serious concerns regarding the potential use of waste biomass.	Signpost public to good quality data on biomass plants, indicating how good practice is good for the environment.
Sustainability issues, such as land use change, impacts on biodiversity, and impacts on soil and water resources.	Keep abreast of developments in this area. Examine indirect effects on water management, quality and environmental emissions.
Competition with land – potential conflicts with the production of food and animal feed.	This issue is being examined at national and international level. The Environment Agency should review this work to understand issues that may be relevant to its remit.
Definition of waste impacting on the large potential for the use of biomass residues for energy.	Clear guidance on definitions (perhaps through web-based tool suggested above). Clear guidance on whether it is better to recycle or recover energy from these feedstocks.

What are the key issues for development of biomass by 2010?

We examined the potential for the development of biomass to 2010 under a series of scenarios. These were developed by considering targets, barriers and issues such as economics, sustainability. They are described in chapter 4 and summarised in Table 6.3:

Table 6.3. Summary of scenarios for bioenergy development

Scenario	Concise description (for more information see chapter 4)
Business as usual	Extrapolation from current situation; uptake of current proposed plants only; taking impact of current market issues into account; low availability of UK feedstocks; low UK land use; low business development.
Progress with barriers	Legislative drivers remain as present; sustainability criteria agreed; waste and biomass definitions agreed; low availability of UK feedstocks; low R&D; clarity on air emissions; steady progress with stand-alone biomass heat and power plants; progress with biofuels plants; high proportion of imported feedstocks; significant use of UK land for wheat and OSR for biofuels; some pellet plants constructed.
Increased support for all bioenergy	Higher long-term targets for power, heat and transport fuels from biomass; sustainability criteria agreed; waste definitions agreed; air quality issues resolved; increased costs for feedstocks due to competition in the short-term; high proportion of imported feedstocks; up to 15 pellet plants constructed; UK effort in R&D increased and collaboration internationally; increased co-firing of energy crops; steady progress with stand-alone plants; steady increase in biomass heat; half proposed biofuels plants built; current biofuel plants operated at capacity; biorefinery concept encouraged; centralised AD planned.
Focus on power and heat	Higher long-term targets for power and heat from biomass; biofuels targets remain at five per cent; GHG savings from biofuels challenged; land use for bioenergy is a major issue; increased costs for feedstocks due to land constraints; wastes and residues favoured as feedstocks; agree waste definitions; UK effort in R&D increased and collaboration internationally; air quality issues resolved; increased co-firing of energy crops; steady progress with stand-alone plants; advanced conversion demonstrated; steady increase in biomass heat; centralised AD planned; industrial CHP plants built; up to 15 pellet plants constructed.
Focus on biofuels	No heat target; renewable power targets met mainly by other renewable technologies; increase of biofuels target to 10 per cent; sustainability targets agreed for biofuels; first generation biofuels restricted to five per cent, emphasis on next generation; feedstock costs for biofuels high; land demand high; biomass and waste definitions agreed; UK production mainly wheat and OSR, but encouraging establishment of perennial crops for next generation biofuels; UK R&D concentrated on next generation biofuels including densification technologies such as pyrolysis; co-firing uses

	mainly imported fuels and some co-products from biofuels plants; some progress with stand-alone power plants; slower progress with heat than in other scenarios; little industrial CHP.

The modelling of these scenarios showed that

- All scenarios result in an increase in land use for bioenergy compared to 2006, the highest increase being stimulated by the 'support for all' scenario and the lowest by support for heat and power only (UK land use only was considered; it is likely that considerable quantities of biomass feedstock will be imported into the UK for co-firing and biofuels in particular and perhaps also for pellets for small scale heat).
- Heat, power and biofuels generation increase above the 2006 baseline in all scenarios. Heat increases at a much slower rate than power or biofuels for a number of reasons related to the past low price of fossil fuels for heat and lack of Government support. The scenario where there is most progress with heat and power is 'support for heat and power' (the biofuels target is not extended in this scenario). In all other scenarios, biofuels exert a strong influence on the use of land and in terms of investment. This may be a short-term effect; as the 2020 targets begin to have effect the dominance of biofuels may diminish.
- In most scenarios biomass power continues to develop (except in the support for biofuels scenario).
- Most of the gains in output generated are made from a few large-scale plants. However, the numbers of small-scale plants and their contribution to emissions may be significant.
- Greenhouse gas savings are highest for the scenarios that address barriers to development of heat and power, which are dominated by co-firing, biofuels and large-scale power. In these scenarios, biomass heat and CHP also make significant contributions to GHG emissions savings.
- Biomass heat is currently dominated by the use of tallow in the rendering industry and waste wood in the panel board manufacturing industry. These are both classified as waste fuels and their use is compromised by the application of the Waste Incineration Directive (which impacts on the economics of their use). It is likely that the best opportunities for large-scale biomass heat will continue to be industrial use of residues.
- Biomass CHP is not thought to make a large contribution on the time scale examined in this report. However, if there is support for heat under the 2020 targets this, combined with incentives for CHP in the RO, should mean that the significance of CHP will grow. Currently large manufacturers (particularly in food processing) are considering switching to biomass when boilers need to be replaced or refurbished. Changes in policy may encourage this trend and bring decisions forward.
- There are inherent uncertainties in the estimation of GHG emissions from bioenergy. Estimation of GHG emissions was undertaken using the Environment Agency's assessment tool, $BEAT_2$. This tool provides an indication of GHG emissions for the specific process chains examined (see section 4.2.2). The uncertainties in the GHG emissions estimated for each biomass supply chain in $BEAT_2$ are presented in Appendix 9.4, and vary between 0.5 and 20 per cent of the GHG emissions.

- $BEAT_2$ does not assess whether biomass production causes land use change[41] and hence does not include any estimation of emissions from either direct of indirect land use change. Direct land use change occurs where biofuel feedstocks are grown on land which has been converted from a prior use (such as grassland or forest). Indirect land use change occurs where feedstocks are grown on existing cropland, displacing food or feed production to elsewhere because demand for food or feed does not decrease. There is concern that this may result, in some circumstances, in the cultivation of crops in developing countries with a resultant chain of indirect impacts leading to the destruction of tropical rain forest or drainage of peatlands and large releases of GHG gases. However, there are many pressures on such habitats and many pressures for increased cultivation of crops at present (including population growth and increased demand fuelled by growing affluence), which means that causality is difficult to prove and controversial. Nevertheless this is an important area which requires further research, because release of carbon from the cultivation of such areas may negate carbon savings from biofuels in Europe. A full analysis is complex both because of the global nature of the agricultural commodities market, which means that food/feed production may be displaced to other countries, and because it is also necessary to take account of the land use change which may be avoided by the use of co-products. For example the co-product DDGS from wheat bioethanol production can be used as an animal feed which could avoid the use of soy meal and land use change to grow soybeans in South America. This important area was considered in some depth by the recent Gallagher review on the indirect impacts of biofuels by the Renewable Fuels Agency (2008), and its findings will influence biofuels policy in the UK in the immediate future.
- We carried out additional modelling to illustrate the impact on GHG savings if biofuel production was causing land use change. In our extreme hypothetical case, where we assumed that imported palm oil and soy oil had caused land use change, the resulting emissions were much larger than the GHG savings from other forms of biofuel production. Indeed, in the focus on biofuels scenarios, the emissions almost completely negated the savings from other forms of bioenergy use as well. This highlights the need to develop robust methodologies for establishing the likelihood of direct and in particular indirect land use change and estimating associated GHG emissions. It also suggests that strict sustainability criteria may be necessary to ensure that biofuels do actually result in GHG savings.

We also examined the **GHG emissions from waste management** compared to the use of specific waste streams for energy recovery.

The analysis examined for four biowaste streams (kitchen and garden waste, clean waste wood, cereal milling residue and sludge from dairy waste water treatment). Whether for recycling, energy recovery or disposal options, the waste hierarchy minimises climate change impacts. The analysis was carried out in a comparative way; that is, elements of the treatment options that were common to all options (such as transport) were not included, so the values presented do **not** provide an absolute assessment of GHG emissions associated with management options, but an assessment of the relative differences in GHG emissions from each management option.

For all four wastes, disposal, which is at the bottom of the waste hierarchy, had the worst climate change impact, and led to a net emissions of GHG. Energy recovery options always led to a net reduction in GHG emissions, due to the displacement of fossil fuels. This reduction was substantially larger than the reductions offered by

[41] It is assumed that biofuels feedstock production is on rotational set-aside.

recycling options, apart from anaerobic digestion of organic wastes because the latter also incorporates an energy recovery element. The 'climate change' ranking of these two options (for these wastes and the options considered) is thus the reverse of their ranking in the waste hierarchy.

It should be remembered, however, that each of the waste management options considered also has other environmental impacts, for example energy from waste and combustion of wood wastes for electricity and heat leads to emissions of a number of other air pollutants and to emissions to water for example from flue gas cleaning systems. There may also be other environmental benefits, for example the application of composts to soils increases the organic content of the soil and can lead to improvements in soil quality.

These initial results suggest however that waste management options could help contribute to greenhouse gas reductions, and it would be worth examining this area in more detail, for example by expanding the analysis to cover more types of waste, and by more detailed analysis of some of the recycling options where analysis was based on relatively simple assumptions.

Box 6.1 Future development in bioenergy

The analysis in this report is based on realistic trends in bioenergy, based around a series of scenarios. The analysis concentrates on developments that are important to Environment Agency decision making in the near term (to 2010). The following summarises changes that may happen in technology in this time scale.

Power

The current trends in biomass power are for the continued development of co-firing and development of relatively large stand-alone bioenergy power plants. In co-firing developments are in place to enable plants to be able to use energy crops. Use of UK energy crops is limited by the availability of these crops. We have examined various scenarios which might enable the planting of energy crops in the UK, but there is a lead in time for most perennial crops and unless the market and Government initiatives for planting change it is unlikely that we will see large-scale co-firing of energy crops by 2010.

There are a number of stand-alone biomass power plants and more are in planning. On the whole these plants use wood fuels. Current trends are towards flexibility in supply and the potential use of waste wood fuels, some of which will be WID-compliant. The major barrier to these plants is planning at local scale, although there has been some success at gaining planning permission recently. The next hurdle will be the establishment of a viable fuel supply chain.

Heat

This market has lagged behind other biomass markets because of the lack of incentive to install plants. The capital cost is high compared to conventional heat boilers and even though the life-time costs can be lower (due to lower fuel costs) the high capital cost has been a deterrent to investment. Recent fossil fuel price increases and potential support mechanisms for biomass heat could increase the interest in biomass heat at all scales over the next few years. After investment/finance the next major issue is security of supply. Our analysis has shown that there is potential biomass supply in the UK suitable for biomass heat plants. There is also a potential for expansion of biomass pellet production both in the UK and abroad. The successful development of biomass fuel chains will be a significant factor in the success of biomass heat in the UK. We have not seen any proposals for WID-compliant biomass heat boilers. However, future incentives for renewable heat may make this more cost-effective.

There is a concern that biomass heat plants, particularly large numbers of small scale plants in urban areas, may have an impact on air quality in these areas. This is a potential barrier for biomass heat development.

Combined heat and power

Biomass CHP has suffered in recent years. There are issues with deployment related to the need for constant heat loads and it has not been an attractive option. We do not see this changing significantly over the next two to three years, although fossil fuel prices and Government policies may change this in the longer term.

Most CHP plants use clean biomass fuels. However there is the potential at large-scale where the economics allow for WID fuels to be considered for biomass plants, particularly the WID fractions of waste wood.

Biofuels

Biofuels were increasing rapidly in the UK but recent price hikes in feedstock, coupled with the flooding of the EU market with US biodiesel slowed this increase during 2007-8. Future increases will be dependent on Government support and the level of confidence in the market. A number of large-scale plants are planned that will split their use of feedstock between locally grown British crops and imported feedstock. These developers also plan to use co-products efficiently as animal feed and as a fuel for bioenergy. Even in the absence of further development of biofuels in the UK it is likely that UK crops will be used in biofuels plants abroad, such as planned plants in the Dutch ports.

Anaerobic Digestion (AD)

Apart from land fill gas and sewage gas, AD has not grown in the same way as other bioenergy technologies in recent years. However, there is currently renewed interest in the potential for AD to treat high strength organic wastes and to generate renewable heat and power. Coupled with the potential support for renewables and the increase in fossil energy prices this may enable AD of food processing residues and farm wastes to take off in the UK.

6.1 Conclusions

A number of issues that are relevant to the Environment Agency come out of this work:

- There is the potential for large land changes in the UK from the use of biomass energy, amounting to some 17 per cent of agricultural land in the long term (data from Biomass Strategy). However, in the short term, to 2010, these changes will not be as significant, except in the locality of specific plant (for example some of the proposed biofuels plants or stand-alone power plants). Our estimates of land use by 2010 show an increase to between 350,000 and 560,000ha for energy crops (up from ~45,000ha in 2006), which is dominated by the use of wheat and OSR for biofuels. There will also be land use change from the growth of perennial energy crops for co-firing and stand-alone heat and power plants with 73,000ha estimated in the most optimistic scenario.

- The current suspension of set aside will also have an impact on land use. Set aside was suspended in response to the need to build up stores and supplies of grain, not for biofuels. Given the high prices currently achieved for grain and oil seeds, farmers are likely to plant these crops where possible. This means that it will be more difficult to find land and enthusiasm for establishing perennial energy crops.

- We have not witnessed a surge in perennial crops, nor do we foresee one before 2010. Farmers do not show enthusiasm at present and are cautious of volatile markets in which they would be tied to a few dominant customers for long periods. However, the diversification of local markets, as could happen as a result of support for development of local biomass heat use, may allow more players to enter the market, stimulate the development of wood pellet plants and provide more secure conditions for farmers. Under these circumstances more SRC could be planted. In addition, second generation biofuels will develop alternative markets for perennial lignocellulose crops in the long term. Thus there could be an increase in energy crop planting, but not until both heat support and second generation biofuels become important, around the middle of the next decade. One issue with energy crops is that alternatives to SRC and miscanthus are being considered, such as reed canary grass or eucalyptus. The impact of these crops on water and soil resources or on biodiversity is poorly understood.

- For 2010 there will be a number of key developments. These will include the development of a number of large-scale biomass power plants. Some of these plants are in planning, but we believe more will be proposed. They will mainly use waste wood and residues from the UK and imported forestry residues as fuel. Biofuels will be developed to meet current targets, using a combination of feedstocks dominated by imported feedstocks and wastes (for example, recovered vegetable oils). This development is dependent on Government policy and on the impact of imports from the USA. The increase in small-scale heat may accelerate in response to planning regulations and local authority initiatives. These plants will operate on wood chips and/or pellets and will stimulate the construction of pellet plants. There will also be large-scale import of biomass feedstocks for co-firing and biofuels, bringing with it issues for storage and transportation of these fuels. In addition there will be large quantities of residues from biofuels plants that will be sold as animal feed or used to generate heat and power for the biofuels plants. Any remaining residue may be sold to large power generators for co-firing.

- The key issues for the Environment Agency will be the permitting of plants operating on mixed feedstocks, which include residues and waste fuels. Waste fuels will include wood wastes, rejects from paper and card recycling, co-products from biodiesel production (particularly if recovered vegetable oil is used as a feedstock). The Environment Agency will need to provide advice on the status of such plants under WID and on emissions and their potential impact. In addition, they will need to understand the impact of storage of the feedstocks and the disposal of ash.

- There is a growing demand for waste wood for fuel and a need to develop recovery of this important feedstock. There is also a need to develop techniques to detect the presence of contaminants in the feedstock, which at present is difficult.

- The cumulative impact of small-scale plants may become an issue, particularly in urban areas for heat plants and all areas for biofuels plants. Although small-scale biomass plants are not strictly under the Environment Agency's remit, air quality is and the Environment Agency may become involved in provision of guidance.

- There is an urgent need to examine the potential for use of certain waste streams for energy recovery. Our analysis has shown that there are circumstances in which the GHG emissions from treatment higher up the waste hierarchy are higher than emissions from energy recovery. This benefit from energy recovery needs to be balanced against potential negative effects, such as other air emissions, but the situation requires more detailed attention. In all cases the emissions from landfill were shown to be significantly higher than other options. However, we believe that this is not universally true for all waste feedstocks and that lifecycle analysis is necessary to demonstrate GHG emission reductions on a case by case basis.

6.2 Priorities for the Environment Agency

- A large proportion of the potential for bioenergy lies in co-firing. To achieve this, potential co-firing power stations need to develop flexible biomass procurement and handling, and an understanding of the impact of biomass fuels on emissions from their plants. There is quite a lot of information on co-firing in the public domain, but the data on emissions can be confusing. This could be usefully brought together and reviewed. The Environment Agency may have considerable expertise and experience to contribute here.
- Large-scale biomass plants (stand-alone or co-firing) will require considerable storage facilities for fuels. These will need to be designed to ensure that pollution of local water courses and emissions of dust and odour are minimised.
- The cheapest biomass feedstocks are often residues. Clear advice on the WID-status of these potential fuels needs to be publicly available. In addition the Environment Agency's input into the discussion about whether it is better to recycle or recover energy from these residues in terms of GHG emissions and general environmental considerations would be welcome.
- There is considerable land requirement for first generation biofuels crops, both in the UK and abroad, but little work has been done to examine the environmental impact of this land use in the UK. The Environment Agency may wish to examine the impact on water and soil resources, particularly from the impact of intensification of farming and the loss of set aside.
- There is interest in developing advanced or second generation biofuels technologies in the next 10 years across Europe. Guidance on these technologies will be required. This should include consideration of emissions, the status of co-products and the potential for use of genetically modified micro-organisms in the production of biofuels.
- There is a potential for cumulative environmental impacts from small-scale biomass use, particularly from air emissions from biomass boilers and stoves in urban environments and the potential increase in transport for delivery of biomass fuels.
- There is no central register of small biodiesel plants. Proliferation of these plants could result in disposal issues for stockpiled co-products such as glycerine, and in potential water pollution issues if there are spillages of chemicals used in the plants.
- There is a role for biomass district heating in urban areas. It would be useful to provide information comparing the potential environmental performance of district heating with individual small-scale boilers providing equivalent heat.
- The complexity of legislation adds costs to development of bioenergy plants. The Environment Agency could consider providing a software tool on relevant

legislation linking types of bioenergy plants to relevant legislation, with the potential for provision of readily available data and relatively rapid updates.

- There is little information on the impact of WID on the costs of biomass development and the effect on take-up of biomass heat and power.
- The sustainability debate has begun for biofuels but has not been so relevant to biomass heat and power to date because of the dominance of the use of residues. The Environment Agency interest in this sustainability debate will be to ensure that emissions to air, soil and water in the UK are included.
- There is currently a great deal of interest in the use of waste wood as a fuel. However, it may prove difficult to separate waste wood from mixed waste streams without including some contaminated waste wood. There needs to be a methodology to detect this wood, or an agreed sampling protocol and methodology to demonstrate the absence of contaminated fractions.

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8 List of abbreviations

ABPR	Animal By-Products Regulations
AD	Anaerobic Digestion
AR	As Received (i.e. not oven dried tonnes)
BAT	Best Available Techniques
BAU	Business as Usual
BEAT	Biomass Environmental Assessment Tool
BERR	Department of Business, Enterprise and Regulatory Reform
BREF	Best Available Technique Reference Notes
CAD	Community Anaerobic Digestion
CCA	Climate Change Agreement
CCGT	Combined Cycle Gas Turbine
CCL	Climate Change levy
CHP	Combined Heat and Power
CHPQA	Good quality combined heat and power
CV	Calorific value
DDGS	Distillers' Dried Grains with Solubles
DEFRA	Department for Environment and Rural Affairs
DfES	Department for Education and Science
DfID	Department for International Development
DfT	Department for Transport
DM	Dry matter
DTI	Department of Trade and industry
DUKES	Digest of UK Energy Statistics
EC	European Commission
ECA	Enhanced Capital Allowance
EEA	European Environment Agency
EfW	Energy from waste
ETS	Emissions Trading Scheme
EU	European Union
FB	Focus on Biofuels (scenario)
FC	Forestry Commission
FEH	Focus on electricity and heat (scenario)
FES	Future Energy Solutions
GHG	Greenhouse Gas
HMRC	Her Majesty's Revenue and Customs
IEA	International Energy Agency
IPPC	Integrated Pollution, Prevention and Control
ISA	Support for all bioenergy (scenario)
IVC	In-vessel composting
kTOE	Thousand tonnes oil equivalent
kW	Kilo Watt
LCPD	The Large Combustion Plant Directive

Ml	Million litres
MSW	Municipal Solid Waste
$MtCO_2eq$	Million tonnes of carbon dioxide equivalent
MW	Mega Watt
NGO	Non-Governmental Organisation
NNFCC	National Non Food Crops Centre
NOx	Oxides of nitrogen
ODT	Oven dried tonnes
OFGEM	Office of Gas & Electricity Markets
OSR	Oil Seed Rape
PKE	Palm Kernel Expeller
PWB	Progess with barriers (scenario)
RDA	Regional Development Agency
RED	Renewable Energy Directive (proposed)
REGO	Renewable Energy Guarantee of Origin
RESTATs	Renewable Energy Statistics Database
RFA	Renewable Fuels Agency
RO	Renewables Obligation
ROCs	Renewable Obligation Certificate
RTFO	Renewable Transport Fuels Obligation
RSPO	Roundtable on Sustainable Palm Oil
RVO	Recycled Vegetable Oil
SRC	Short Rotation Coppice
SRF	Short Rotation Forestry
SRF	Solid Recovered Fuels
SWOT	Strengths, Weaknesses, Opportunities, Threats
Tpa	Tonnes per Annum
TSEs	Transmissible Spongiform Encepalopathies
TWh	Tera Watt hour
US	United States of America
USDA	United States Department of Agriculture
WFD	Waste Framework Directive
WID	Waste Incineration Directive
WRAP	Waste and Resources Action Programme
WRATE	Waste and Resources Assessment Tool for the Environment
WVO	Waste Vegetable Oil

9 Appendices

9.1 Summary of additional information on biomass projects

Table 9.1. Schemes supported under the Bioenergy Capital Grant scheme

Scheme	Cluster ?	Proposed total capacity MWth	Number installed to date	Capacity installed to date, MWth	Typical capacity	Comments
Industrial						
B101/00/00001/00/00: Industrial Ecoheat Development Project		6.1				
URE/1/000321410: 3G Energi Woodheat		1.6				
BI05/00016: Stansted Airport Arrivals Extension, Stansted Airport Limited		2.1				
Total		**9.8**				
Commercial						
URE/1/000321408: Dulas Biomass	Y	1.4	0	0	150kWth	
B101/00/00006/00/00: Nottinghamshire Woodheat Project (RENU)	Y	0.20	2	0.2	100kWth	
BI01/00/00019/00/00: Scottish Biomass Heat Clusters	Y	1.25	0	0		
URE/1/000321364 (Fund): Ecoheat Clusters Development Project	Y	13.90	83	9.66	100kWth	
URE/1/000321366 (Fund): Rural Energy East Midlands Wood Heating Network	Y	28.26	75	7.64	140kWth	
URE/1/000321367 (Fund): SE Regional Heat Supply Company	Y	7.50	0	0		Project closed
URE/1/000321365 (Fund): Biomass Heating Clusters in South West England and Lincolnshire	Y	6.58	74	9.06	large range 10-1300kWth	
URE/1/000321369 (Fund): The Wales Biocluster Project	Y	7.00	18	3.5	200kWth	
URE/1/000321378: Buccleuch BioEnergy Heat Clusters	Y	8.30	0	0		Project closed
URE/1/000321424: Midlands Wood Fuel	Y	2.30	4	0.33	100kWth	
URE/1/000321428: Nottinghamshire Woodheat Programme	Y	10.00	4	0.44	100kWth	
URE/1/000321429: The NATHAN Project – National Trust	Y	2.08	1	0.04	35kWth	
URE/1/000321431: Highland Wood Energy	Y	1.90	1	0.15	150kWth	
U/REN/2006/0039: Alexander Park District Heating Scheme		1.00	0	0		Design stage
U/REN/2006/0042: Southampton District Energy Scheme Biomass Boiler		1.10	0	0		In planning
U/REN/2006/0056: South Gloucestershire Biomass Schools	Y	1.99	1	0.25	250kW	8 installations planned
BI05/0002: Wood fuel conversions, Suffolk County Council	Y	1.99	0	0	?	3 more planned
BI05/0003: Installation of 1.1 MW Biomass Heating, Talbotts Heating Ltd		1.10	0	0		
BI05/0004: Nottinghamshire Woodheat Programme extension	Y	0.44	0	0	220kWth	2 in design for schools
BI05/0005: Energy Innovations Biomass Heating Group, Energy Innovations (UK) Ltd	Y	1.66	1	0.05	50kWth	6 installations planned
BI05/0006: Biomass cluster, Wood Energy Ltd	Y	1.40	0	0		
BI05/0007 Castle Howard Estate Ltd						Project closed
BI05/00013: Kirkdale Manor Biomass Heating Scheme, Hardey House Construction Ltd		0.25	1	0.25	250kWth	
BI05/00017: West Dean College - upgrade of Biomass District Heating, The Edward James Foundation		1.00	0	0	1MWth	
BI05/00019: Bosmore Park Farm District Heating Project, Red Kite Farms Ltd		0.25	0	0	250kWth	Boiler ordered.

BI05/00020: University of Leeds Biomass Project, University of Leeds		0.37	0	0	400kWth	Boiler ordered
BI05/00021: Newcastle Building New Schools for the Future, Newcastle City Council	Y	1.88	0	0	?	Boilers installed.
BI05/00024: Marsden Farms		0.26	0	0	?	Construction phase
BI05/00025: District Heating, Heveningham Hall Estate		0.90	0	0	900kWth	construction
BI05/00026: Woodchip District Heating at Summerend Farm, Westacre Estate		0.24	0	0	240kWth	Boiler ordered
BI05/00027: Woodchip District Heating at Kelling Estate, Kelling Hall Farms		0.55	1	0.55	550kWth	
BI05/00029: Replacement of oil boilers with biomass, Harewood House Trust		0.32	0	0	320kWth	delayed
BI05/00030 Sharpham Trust		0.23	0	0	230kWth	Boiler ordered
BI05/00032 University of Bradford		0.50	0	0	500kWth	
BI05/00035 Alscot Estate		0.25	0	0	250kWth	design
BI05/00037 Hever Castle Limited		0.80	0	0	800kWth	design
BI05/00038: New England Quarter (Blocks E & F), Brighton, Crest Nicholson BioRegional Quintain		0.50				
BI05/00040: Developing a biomass cluster, Bristol City Council	Y	2.20	0	0	?	tendering
BI05/00041: Queens Court Biomass project, Newcastle City Council		1.00	0	0	?	Not yet in contract
BI05/00042: Crawley Library and Administration Offices, West Sussex County Council		0.15	0	0	?	
BI05/00043: Essex CC Primary Schools, Essex County Council		0.19	0	0	?	
Total		**111.78**	**266**	**32.12**		

Note: Cluster refers to whether or not the scheme is supported as part of a cluster or as a single plant. Applicants such as equipment suppliers can apply for grant support for clusters of schemes to be installed. Y=Yes.

Table 9.2. SW thermal biomass schemes

Project name	Owner or developer	Detailed description of project and any additional comments
Urchfront Community Shop	UCSA	5kw log stover connected to underfloor heating
Tiverton	Residential Building	11kW biomass boiler
Tiverton	Residential Building	15kw Pellet boiler - Eco Exmoor
Tiverton	Residential Building	15kW biomass boiler
Lands End Farm House	Residential building	20kw biomass boiler installed by Econergy
Taunton	Residential Building	25kw Biomass log boiler - Eco exmoor
Nr South Brent	Residential Building	25kW biomass boiler
Dulverton	Residential Building	25kw log boiler - Eco Exmoor
Nr Wadebridge	Residential Building	25kW biomass boiler
Exeter	Residential Building	25kw Biomass log boiler - Eco Exmoor
Tiverton	Residential Building	25kw log boiler - Eco Exmoor
Cirencester organic farm shop	Commercial	25kw biomass woodchip boiler
Banwell	Residential Building	25kw log boiler - Eco Exmoor
Pitts Cleave	Wood Energy Ltd	25kw pellet boiler installed by Wood Energy Ltd
Wellington	Residential Building	27kw Biomass log boiler and solar thermal - Eco Exmoor
Exmoor	Residential Building	30kW biomass boiler
Penrose Estate	Penrose Estate	30 kw woodchip boiler
Polsue Farm	Polsue Farm	30kw woodchip boiler
Stockland Victory Hall	Wood Energy ltd	30kw chip boiler installed by Wood Energy Ltd
Barnstaple	Residential Building	35kW biomass boiler
Seaton	Residential Building	40kW biomass boiler
New Museum of Science and Industry Library	New Museum of Science and Industry	40 kw pellet boiler
Mount Pleasant Eco Park	Commercial Building	Objective One scheme. Biomass boiler installed in eco building
Natsley Farm	Natsley Farm	49kw woodchip boiler
Edge Barton	Residential Building	50 Kw wodchip boiler
Caddsdown	Torridge District Council	50kw woodchip boiler - installed by Econergy
Natsworthy Farm	Wood Energy Ltd	50kw chip boiler installed by Wood Energy Ltd
Coldrenick Farm	Wood Energy Ltd	50kw wood chip boiler - installed by Wood Energy Ltd
Trenance Downs sawmill	Wood Energy Ltd	50kw chip boiler installed by Wood Energy Ltd
Nr Bridgewater	Residential Building	50kW biomass boiler
Gasper Mill	Wood Energy Ltd	50kw chip boiler installed by Wood Energy Ltd
Thurlibeer	Wood Energy Ltd	50kw chip boiler installed by Wood Energy ltd
Goblin Combe Environment Centre	Goblin Combe Environment Centre	55kw woodchip boiler
Charterhouse Centre	Mendips AONB	Installed by Econergy. Funded by Clear Skies grant and Somerset Co
New Museum of Science and Industry	Science Museum	60kw boiler installed by econergy
Tiverton	Residential Building	70kW biomass boiler
Pinkworthy Barn	Wood Energy Ltd	70kw boiler installed by Wood Energy Ltd
Ilminster	Residential Building	75kW biomass boiler
Jubilee Wharf	Andrew Marston	93 kw wood pellet boiler
Nr Dulverton	Residential Building	100kW biomass boiler
Nr Minehead	Residential Building	100kW biomass boiler
Wilderness Centre	Wilderness Centre	100kw wood pellet boiler - installed by Econergy
Exmoor	Residential Building	100kW biomass boiler
Farm Project	Commercial Building	Anaerobic digestion
Eastcourt House	Eastcourt Estate	110kw woodchip boiler
Great Farm House	Residential Building	110 kW
Greenawell Farm	Greenawell Farm	117 kw woodchip boiler
Nr Hatherleigh	Residential Building	150kW biomass boiler
Grasscott Farm	Wood Energy Ltd	150kw boiler installed by Wood Energy ltd
Tregothnan Estate	Tregothnan Estate	150kw woodchip boiler
Netham Recreation Ground, Pavillion	Bristol City Council	150 kw boiler Binder installed by Wood Energy
Westerhope Units	Wood Energy ltd	150kw chip boiler installed by Wood Energy Ltd
Home Farm	Home Farm	185 Kw woodchip boiler
Home Farm	Wood Energy Ltd	185kw chip boiler installed by Wood Energy Ltd
Chulmleigh	Commercial Building	220kW biomass boiler
Launceston	Public Building	220kW biomass boiler at Launceston College
Nr Wiveliscombe	Residential Building	220kW biomass boiler
Florence Brown School	Bristol City Council	230 kw Binder boiler installed by Wood Energy
Loyton Community	Wood Energy Ltd	250kw chip boiler installed by Wood Energy Ltd
Loyton Lodge	Alick Barnes	250kw boiler - RSWT grant - £4999
Batsford Estate	Batsford Estate	300 Kw woodchip boiler installed by Wood Energy
The Eden Project	The Eden Project	300kw wood chip boiler - installed by Wood Energy Ltd
Trelowarren Estate	Trelowarren Estate	CHP plant - Binder woodburning boiler 300kw -installed March 2006
Tiverton	Commercial Building	350kW biomass boiler
Blaise Nursery	Bristol City Council	400kw wood chip boiler - installed by Wood Energy ltd
Bath and West	Wood Energy Ltd	500kw pellet boiler installed by Wood Energy Ltd

Kernock Plants	Kernock Plants	3 MW woodchip boiler
Winterbourne Kingston Primary School	Dorset County council	
Holsworthy Bio-gas	Holsworthy Biogas Ltd	1.6mt slurry from 30 local farms; NFFO contract

Table 9.3. Yorkshire and Humber thermal biomass schemes

Plant and status	Fuel/ application	Capacity	Comments
Heat generation			
Barnsley – Sheffield Road Flats – wood heat (operating, managed by ESCO, Econergy Ltd)	Wood chip from local forestry and saw mill co-product, 350t/y.	470kWt	133 coal boilers remain in Barnsley area in council properties (mainly primary schools)
Barnsley – Smithies Lane depot (operating)	150t wood/year	500kWt	A new store for 700t of wood chip is being constructed for council tree prunnings.
Barnsley – West Gate Plaza One (in commissioning)	Wood chip or pellets	500kWt boiler installed	Provides night time heat to library. Second phase will supply heat to Town Hall.
Barnsley – Digital Media Centre (installation underway)	Wood.	320kWt boiler	Barnsley has further plans to convert two more district heating schemes and to install biomass boilers in 9 secondary schools.
Paddock House Farm, Weatherby	SRC willow grown and chipped on site.	200kWt	Provides heat for office space and on-site housing. Surplus heat used in wood chip dryer.
Kirk Balk Secondary School (trial).	Wood pellet trial	732 kWt	Successfully completed.
Ilkley Grammar School (Bradford)	Wood pellet	1.4MWt	Coal to wood pellet trial - second heat season completed and will continue to burn pellets.
Outwood Grange Council (Wakefield)	Wood pellet	832 kWt	Coal to wood pellet trial. First heat season complete and will continue to burn pellets.
Keightly Furniture Project	Wood chip	230kWt	Use of local wood.
Heighgate Barn (Calderdale)	Wood pellet	25kWt	Wood pellet stove
Sheffield – Callow Place (operating)	Wood chip	470kWt	Automatic wood chip boiler provides heating and hot water to 296 flats.
Sheffield – Carwood Estate (operating)	Wood chip	320kWt	Heat and hot water to over 100 properties.
Swinton Park (operating)	Wood chip	300kWt	Wood from the estate is used to heat the estate house in a closed loop of supply and use.
Dalby Forest Visitors centre	Local saw mill by-product	100kWt	Locally sourced/produced wood chip.
Old Moor Wetland Centre	Wood chip	100kWt	Uses chipped wood and sawmill co-product.
Haughton Farm	Wood chip	Not known.	Boiler can use wood chip and Miscanthus.
Richmond	Wood chip	500 and 300kWt	Two boilers, the larger of which uses waste wood, the other scheme uses local wood.
Masham	Wood chip	300kWt	Local wood.
Ampleforth	Wood chip	300kWt	Local wood
Pickering	Wood chip	1000 kWt	Local wood
Sickinglinghall	Wood chip	150kWt	This scheme uses local wood and SRC
Wombwell	Wood chip	100kWt	Local wood
Dry Hill Farm (Denby Dale)	Wood chip	Not known.	

9.2 Regulated biomass related activities under IPPC

Table 9.4. Summary of the regulation of biomass related activities under the PPC Regulations

Part of PPC Regulations	Regime	Regulator	Activity
Part A (1)	PPC	Environment Agency	Installations in which any Part A(1) activity is carried out, including: ▪ Combustion plants of > 50MW thermal input burning any fuel. ▪ Combustion plants of 3-50MW thermal input burning fuels containing or derived from waste. ▪ Cement or Lime kilns burning waste. ▪ Incineration of non-hazardous waste in an incineration plant[×] with a capacity of one tonne or more per hour. ▪ Unless carried out as part of an A(2) activity: incineration of hazardous waste in a plant that is exempt from the WID; or the incineration of non-hazardous waste in a plant that is exempt from WID and has a capacity of one tonne or more per hour.
Part A (2)	PPC	Local Authority	Installations in which any Part A(2) activity is carried out but no A(1) activity, including: ▪ Co-incineration of non-hazardous waste in any combustion plant associated with any Part A(2) activity and which has a thermal input of less than 50MW. ▪ Incineration of non-hazardous waste in an incineration plant with a capacity of less than one tonne per hour. ▪ Co-incineration of non-hazardous waste in a co-incineration plant which is not otherwise an A(1) or A(2) activity. ▪ Incineration of animal carcasses or animal waste in a plant which is exempt from the WID and which has a capacity of more than 10 tonnes per day but less than one tonne per hour.
Part B	LAAPC	Local Authority	Installations in which any Part B activity is carried out but no A activity, including: ▪ Combustion plants of 20-50MW thermal input, burning any fuel except that covered in Part A(1) above. ▪ Combustion plant burning fuels containing or derived from waste with a thermal input of 0.4-3MW and which is exempt from the WID. ▪ Incineration of non-hazardous waste in a plant which is exempt from the WID but which has a capacity of 50 kilogrammes or more but less than one tonne per hour.

[×] ‘Incineration plant’ and ‘co-incineration plant’ have specific meanings in the PPC Regulations. Summarised, these definitions refer to the incineration or co-incineration of waste in plants where the WID applies. Co-incineration plant here means a plant whose main purpose is the generation of energy or production of material products and which uses waste as a regular or additional fuel.

Table 9.5. Summary of the pollution control legislation applicable to waste and non-waste biomass fuels

Fuel scenario	Plant size	Pollution regulation applicable	Regulator
1.Biomass fuels e.g. coppice willow, and fuel residues of a similar nature arising from the manufacture of these fuels.	< 20MW	No air pollution control permit required	none
	20-50MW	LAAPC (Part B PPC)	Local Authority
	> 50MW	LCPD applies (PPC Part A1)	Environment Agency
2. Waste or waste-derived biomass exempted from WID, and fuel residues of a similar nature arising from their manufacture.	< 0.4MW and < 50 kg/hr	No air pollution control permit required	none
	0.4-3MW and 50-1,000 kg/hr	LAAPC (Part B PPC)	Local Authority
	> 3MW and / or > 1,000 kg/hr	PPC (Part A1)	Environment Agency
	> 50MW	PPC (Part A1) LCPD applies	Environment Agency
3. Waste or waste-derived biomass to which WID applies.	< 3MW	WID applies PPC (Part A2)	Local Authority
	> 3MW	WID applies PPC (Part A1)	Environment Agency

9.3 SWOT analyses of bioenergy sectors

SWOT analysis of individual bio-energy markets

The table below examine the various strengths, weaknesses, opportunities and threats that influence each of the biomass energy markets. These considerations were included in our development of the scenarios in Chapter 3.

Table 9.6. Transport biofuels

Strengths	**Weaknesses**
• RTFO provides clear incentive for biofuels production. • Simple and proven technologies available for biodiesel and bioethanol production. • UK farmers can provide wheat and OSR feedstocks. • Biodiesel and bioethanol plants can be built in the UK. • Research into next generation technologies and collaboration with EU and Internationally.	• UK lags in development of next generation technologies. • UK supply chains weak for lignocellulosic crops. • Complex regulation deters developers. • Sustainability issues halt progress. • Imported finished transport biofuels are cheaper. • Feedstock prices could rise to levels that make production uneconomic.
Opportunities	**Threats**
• High fossil transport fuel costs and increasing political insecurities in the producing countries have increased interest in biofuels worldwide. • The increased interest in biofuels has increased investment in biofuels, which will pay dividends in improved crop yields and development of second generation technologies. • Use of wastes through second generation technologies provides opportunity to decrease costs and improve use of waste resources. • Development of biofuels will allow development of a large, international market in which biofuels can be traded, providing more confidence in the market in the supply sector.	• Competition for feedstocks from other areas. • Fears about sustainability, environmental and socio-economic impacts may constrain development. • Second generation costs remain high. • Lower fossil transport costs would de-rail achievements in biofuels. • Poor harvests will constrain supply of feedstocks and increase costs (particularly for first generation biofuels).

Table 9.7. Electricity

Strengths	Weaknesses

• RO in place until 2027.
• Co-firing continues to be supported.
• Electricity from biomass is not intermittent.
• Combustion technology is commercial.
• Recent changes to the RO:
  o Offer more support to stand-alone biomass electricity.
  o Encourage use of energy crops.
  o Encourage development of advanced conversion techniques.
• Utilisation of wastes gives secure supply and good GHG savings.
	• Use of land for food crops/transport biofuels stops perennial crop development.
	• Opposition to biomass plants, especially using residues/wastes.
	• Other renewables more attractive to investors.
	• Cost of biomass increases/availability reduced.
	• Sustainability issues reduce availability of imports.

Opportunities	**Threats**
• Cost of fossil power generation is increasing, making biomass power more cost effective. • Familiar, demonstrated technologies allow immediate deployment. • Increased investment in biomass power will also increase investment in advanced, more efficient and flexible conversion technologies • Secure biomass power generation market will encourage investment in development of crops and other biomass feedstocks (e.g. separation of suitable biomass fuels from mixed wastes).	• Variable energy prices could provide volatile markets for trade. • Use of biomass as fuel may increase competition for the same resource within a number of markets and increase prices. • Sustainability is likely to be an issue for biomass power fuels, just as it is for biofuels.

Table 9.8. CHP

Strengths	Weaknesses
• Most efficient utilisation of biomass. • Strong support from RO for electricity. • CAD can utilise animal and food wastes. • Biogas generated is portable. • CHP is likely to be suitable for specific conditions such as: o Small scale systems with steady local low grade heat load, e.g. leisure centres, hospitals, agriculture. This may include some residential customers. o Large scale industrial sites with a number of local customers for heat and electricity.	• Incentives mean most CHP in the UK will be electricity led. This implies that: o Constant heat load must be available locally. o Steam process requirements may reduce electrical efficiency, so CHP is not economic. • CHP is more complex to connect and operate, likely to require specialists to run. • CAD is not usually sited close to heat load. • CAD must take feedstocks with gate fee to be economic. • Investors will prefer the cheaper and simpler heat-only option. • Regulations for domestic developments may require 'on-site' generation which precludes a balanced heat load.
Opportunities	**Threats**
• The environmental sustainability will provide major drivers for its support through legislation and economic mechanisms. • The use of heat and power provide more than one income stream for the plant developer. • At large-scale, in applications where there is a good heat load, biomass is as suitable for CHP as it is for heat and power alone.	• CHP will face all the competition and sustainability issues faced by other biomass applications. • Variable energy prices and feedstock prices could combine to make difficult financial conditions for CHP. • Development of CHP dependent on one customer is risky, as the customer may pull out or close its site.

Table 9.9. Heat

Strengths	Weaknesses
• Biomass combustion is commercial and available at all scales. • Modern biomass heating systems are very efficient, easy to operate and give high GHG savings. • Wood pellets are a convenient and clean fuel. • High price of fossil fuels makes biomass an attractive fuel. • Bio-energy capital grants may be available for installations. • Industry can make use of on-site wastes, giving secure fuel supply. • Biomass can replace solid fossil fuels in industrial and district heating applications.	• No specific targets or incentives for biomass heating. • Biomass fuel requires substantial storage space. • Biomass boilers represent considerable capital investment compared to conventional boilers, due to the larger size requirement, although life time costs are cheaper than fossil fuels at present. • Boilers/installers may not be available for a large-scale domestic uptake. • Suitable fuels are used for electricity or CHP, where there are greater incentives. • Urban air quality issues arise with current commercial boilers, especially at small scale.
Opportunities	**Threats**
• 15 per cent target for renewable energy in the UK provides an incentive to develop biomass heat. • Target for zero carbon homes (new build) provides incentives for biomass heat (and district heating/CHP). • Related building regulations provide incentives for biomass heat. • Carbon Trading provides an incentive for biomass heat at industrial scale.	• There is a lack of skills for the specification and installations of biomass heat. • There is a lack of supply of biomass heat equipment in the UK and little choice in the market at present. • Issues remain with emissions from biomass combustion that may increase emissions within air quality management zones. • The fuel supply market is immature and prone to sudden price hikes at times of high demand or in response to other pressures on the market.

9.4 Results from scenario analysis, chapter 4

Business as usual (BAU)

1. Business as Ususal scenario

Assumptions

Legislative drivers remain at current levels
Sustainability of biofuels Issues unresolved
Feedstock costs High for energy crops. Imports competitive.
Definitions of waste and biomass Confusion delays or stops projects
Availability of feedstocks Low for energy crops. Imports becoming more expensive.
Grant support Low levels
R&D effort Low levels
Demonstration effort Low levels
Local issues identified Air quality for biomass heat. Opposition to planning applications, especially for waste feedstocks.

Category	*Capacity (MW)*	*No. of plant*	*Annual Output*		*Total GHG saving*	*Total amount feedstock*	*Total land area*
			GWh (elec)	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2006							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	19,496	13	1,534		1,650	877	0.487
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTI(	118	6	611		149	643	0.179
b. GASIFICATION	0	0	0		0	0	0.000
3.LARGE-SCALE / INDUSTRIAL CHP	80	5	297	1,187	484	340	0.000
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	168	87	0	1,680	1,064	443	0.000
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.000
6. SMALL-SCALE HEAT ONLY	32	265	0	200	96	51	0.000
7. DOMESTIC HEAT ONLY	132	40,300	0	376	128	95	0.000
8. AD - ELECTRICITY ONLY	6	6	12	0	11	291	0.000
9. AD - HEAT ONLY	0	0	0	0	0	0	0.000
TOTAL, excluding biofuels	*20,032*	*40,682*	*2,453*	*3,443*	*3,581*	*2,740*	*0.666*
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	1,688	21	296		626	340	43.241
BIOETHANOL	0	0	0		0	0	0.000
TOTAL, including biofuels		***40,703***			***4,207***	***3,080***	***43.907***
	Capacity (MW)	*No. of plant*	*GWh (elec)*	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2010							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	20,492	14	3,123		3,318	1,829	3.3
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTI(	187	14	944		466	881	7.1
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	193	9	511	2,043	953	674	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	225	92		2,105	1,249	565	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	42	365		267	118	69	0.8
7. DOMESTIC HEAT ONLY	156	40,900		408	138	102	0.0
8. AD - ELECTRICITY ONLY	6	6	15		14	379	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	21,301	41,400	4,593	4,823	6,255	4,500	14.0
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	2,162	22	678		1,049	871	138.4
BIOETHANOL	2,213	9	1,015		750	2,981	202.0
TOTAL, including biofuels		***41,431***			***8,054***	***8,352***	***354.4***
	Capacity (MW)	*No. of plant*	*GWh (elec)*	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2015							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	20,492	14	3,123		3,318	1,829	3.3
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTI(	812	18	4,587		2,865	3,966	30.2
b. GASIFICATION	10	1	59		27	41	2.3
3.LARGE-SCALE / INDUSTRIAL CHP	193	9	511	2,043	953	674	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	225	92		2,105	1,249	565	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	42	365		267	118	69	0.8
7. DOMESTIC HEAT ONLY	156	40,900		408	138	102	0.0
8. AD - ELECTRICITY ONLY	6	6	15		14	379	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	21,936	41,405	8,295	4,823	8,681	7,626	39.4
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	2,162	22	678		1,049	871	138.4
BIOETHANOL	2,213	9	1,015		750	2,981	202.0
TOTAL, including biofuels		***41,436***			***10,481***	***11,478***	***379.8***

Progress with barriers (PWB)

2. Progress with Barriers

Assumptions

In this scenario we think there will be more energy crops (some of which would be imported) and a lot more pellets. At least 15 pellet plants in UK and many more abroad. The UK plants will all produce around 50,000t pellets/y. The number of plants generating heat will treble under the capital grant and other schemes. OSR will become an energy crop, and wheat for biofuels+energy crop so straw will be used as an energy crop. Also: reed canary grass as an energy crop? All the biofuels plants will be built so this means that their residues will be used as energy crop fuel. Issues will be blue haze (turpines) from pellet plants, increases in energy crop planted and general air emissions.

Category	*Capacity (MW)*	*No. of plant*	*Annual Output GWh (elec)*	*GWh (heat)*	*Total GHG saving kt CO2e*	*Total amount feedstock kt*	*Total land area kha*
2006							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	19,496	13	1,534		1,650	877	0.5
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTI(	118	6	611		149	643	0.2
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	80	5	297	1,187	484	340	0.0
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	168	87	0	1,680	1,064	443	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	32	265	0	200	96	51	0.0
7. DOMESTIC HEAT ONLY	132	40,300	0	376	128	95	0.0
8. AD - ELECTRICITY ONLY	6	6	12	0	11	291	0.0
9. AD - HEAT ONLY	0	0	0	0	0	0	0.0
TOTAL, excluding biofuels	*20,032*	*40,682*	*2,453*	*3,443*	*3,581*	*2,740*	*0.7*
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	1,688	21	296		626	340	43.2
BIOETHANOL	0	0	0		0	0	0.0
TOTAL, including biofuels		***40,703***			***4,207***	***3,080***	***43.9***
	Capacity (MW)	*No. of plant*	*GWh (elec)*	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2010							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	20,492	14	3,123		3,314	1,872	36.7
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTI(	227	15	1,297		781	1,170	7.1
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	193	9	511	2,043	953	674	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	235	98		2,225	1,335	597	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	62	565		400	153	104	3.3
7. DOMESTIC HEAT ONLY	180	41,500		440	148	109	0.0
8. AD - ELECTRICITY ONLY	6	6	15		14	379	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	21,395	42,207	4,947	5,108	6,697	4,906	49.9
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	2,516	24	1,388		1,752	1,766	255.1
BIOETHANOL	2,403	10	1,235		903	3,486	229.0
TOTAL, including biofuels		***42,241***			***9,351***	***10,158***	***534.1***
	Capacity (MW)	*No. of plant*	*GWh (elec)*	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2015							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	20,492	14	3,181		3,382	1,906	37.3
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTI(	812	19	4,766		4,138	4,001	39.0
b. GASIFICATION	10	1	59		27	41	2.3
3.LARGE-SCALE / INDUSTRIAL CHP	193	9	511	2,043	953	674	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	235	98		2,225	1,335	597	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	62	565		400	501	311	6.8
7. DOMESTIC HEAT ONLY	180	41,500		440	148	109	0.0
8. AD - ELECTRICITY ONLY	6	6	15		14	379	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	21,990	42,212	8,532	5,108	10,498	8,018	88.2
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	2,516	24	1,388		1,752	1,766	255.1
BIOETHANOL	2,403	10	1,235		903	3,486	229.0
TOTAL, including biofuels		***42,246***			***13,153***	***13,270***	***572.4***

Increased Support for All (ISA)

3. Support for all

Assumptions

10x increase in heat market, mainly using wood pellets. 350MWth heat. 150 odt wood over the whole of the UK. Impact on air emissions and policy implications of deployment in urban ares. Lots of co-firing on mainly imported fuels. Wastewood cat 1 & 2 - all the easy to access waste wood resource will be used (3-4 Mt). Biofuels: assume 10% level by 2020 and ramping up to that. Biorefinery concept encouraged. Demo in 2012/2015 e.g. CT's pyrolysis work, NNFCC's Biorefining Technologies Initiative.Predict: changes to RO to encourage energy crops in co-firing and small-scale stand alone schemes. Use of wastes in combustion plnat. Demo of large scale gasification. Pilot of bio-oil as energy carrier. Heat targets are set amd additional incentives in place. AD encouraged.

Category	*Capacity (MW)*	*No. of plant*	*Annual Output GWh (elec)*	*GWh (heat)*	*Total GHG saving kt CO2e*	*Total amount feedstock kt*	*Total land area kha*
2006							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	19,496	13	1,534		1,650	877	0.5
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	118	6	611		149	643	0.2
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	80	5	297	1,187	484	340	0.0
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	168	87	0	1,680	1,064	443	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	32	265	0	200	96	51	0.0
7. DOMESTIC HEAT ONLY	132	40,300	0	376	128	95	0.0
8. AD - ELECTRICITY ONLY	6	6	12	0	11	291	0.0
9. AD - HEAT ONLY	0	0	0	0	0	0	0.0
TOTAL, excluding biofuels	*20,032*	*40,682*	*2,453*	*3,443*	*3,581*	*2,740*	*0.7*
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	1,688	21	296		626	340	43.2
BIOETHANOL	0	0	0		0	0	0.0
TOTAL, including biofuels		***40,703***			***4,207***	***3,080***	***43.9***
	Capacity (MW)	*No. of plant*	*GWh (elec)*	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2010							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	20,492	14	3,788		3,984	2,257	44.3
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	577	16	2,324		1,547	2,007	18.4
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	193	9	511	2,043	1,002	669	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	300	168		2,370	1,438	635	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	92	865		600	219	157	5.8
7. DOMESTIC HEAT ONLY	146	45,100		504	167	124	0.0
8. AD - ELECTRICITY ONLY	6	6	15		14	379	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	21,806	46,178	6,639	5,517	8,372	6,227	71.3
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	2,516	24	1,388		1,752	1,766	255.1
BIOETHANOL	2,403	10	1,235		903	3,486	229.0
TOTAL, including biofuels		***46,212***			***11,026***	***11,479***	***555.4***
	Capacity (MW)	*No. of plant*	*GWh (elec)*	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2015							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	22,526	15	5,753		5,952	3,382	67.6
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	812	19	4,766		3,859	4,058	39.0
b. GASIFICATION	30	1	129		76	53	2.3
3.LARGE-SCALE / INDUSTRIAL CHP	243	13	761	2,043	1,445	1,079	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	300	168		2,370	1,567	683	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	92	865		600	219	157	5.8
7. DOMESTIC HEAT ONLY	146	45,100		504	207	152	0.0
8. AD - ELECTRICITY ONLY	16	12	36		29	982	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	24,165	46,193	11,445	5,517	13,354	10,546	117.6
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	2,516	24	1,388		1,752	1,766	255.1
BIOETHANOL	2,403	10	1,235		903	3,486	229.0
TOTAL, including biofuels		***46,227***			***16,009***	***15,797***	***601.8***

Focus on electricity and heat (FEH)

4. Focus on heat & electricity

Assumptions

This scenario assumes failure for biofuels and greater incentives for heat and power. We have assumed that heat at least achieves the realistic figures quoted in the FES heat report (4.1 TWH/y). It could do 10x as much heat as now (i.e. grow to 350 MWth from 35MWth.). This would require at least 150,000odt wood. This would also require an increase in wood pellets for domestic/small scale use as well as logs. We are also seeing signs that relatively clean cat 1 and 2 wood waste could be used for CHP (100kWe to 1 MWe, i.e. small-scale CHP/district heating). We have assumed that there would be at least 15 wood pellet plants in this scenario, each making 50,000t pellets. In addition there is an increase in pellet production abroad and pellets are imported. Power generation increases. Co-firing as is now, but with more energy crops (often from abroad) and with imported pellets as back up fuel if the price is right. Large scale power from waste wood cats 1 and 2 and imported wood. Assume that the plants in planning are realised and that more are planned.

Category	*Capacity (MW)*	*No. of plant*	*Annual Output GWh (elec)*	*GWh (heat)*	*Total GHG saving kt CO2e*	*Total amount feedstock kt*	*Total land area kha*
2006							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	19,496	13	1,534		1,650	877	0.5
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	118	6	611		149	643	0.2
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	80	5	297	1,187	484	340	0.0
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	168	87	0	1,680	1,064	443	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	32	265	0	200	96	51	0.0
7. DOMESTIC HEAT ONLY	132	40,300	0	376	128	95	0.0
8. AD - ELECTRICITY ONLY	6	6	12	0	11	291	0.0
9. AD - HEAT ONLY	0	0	0	0	0	0	0.0
TOTAL, excluding biofuels	*20,032*	*40,682*	*2,453*	*3,443*	*3,581*	*2,740*	*0.7*
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	1,688	21	296		626	340	43.2
BIOETHANOL	0	0	0		0	0	0.0
TOTAL, including biofuels		***40,703***			***4,207***	***3,080***	***43.9***
	Capacity (MW)	*No. of plant*	*GWh (elec)*	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2010							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	20,492	14	3,788		3,987	2,257	43.6
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	717	16	2,482		1,683	2,133	18.4
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	193	9	511	2,043	953	674	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	300	168		2,370	1,438	635	0.0
5. SMALL-SCALE CHP	2	10	1	3	5	1	0.0
6. SMALL-SCALE HEAT ONLY	122	1,165		800	285	209	8.3
7. DOMESTIC HEAT ONLY	804	57,100		632	207	152	0.0
8. AD - ELECTRICITY ONLY	12	8	42		40	1,386	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	22,642	58,490	6,824	5,848	8,599	7,447	73.1
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	2,162	22	678		1,076	871	138.4
BIOETHANOL	2,213	9	1,015		750	2,981	202.0
TOTAL, including biofuels		***58,521***			***10,425***	***11,300***	***413.5***
	Capacity (MW)	*No. of plant*	*GWh (elec)*	*GWh (heat)*	*kt CO2e*	*kt*	*kha*
2015							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	22,526	15	5,753		5,946	3,383	67.0
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	967	19	5,071		4,135	4,305	40.7
b. GASIFICATION	10	1	59		27	41	2.3
3.LARGE-SCALE / INDUSTRIAL CHP	293	17	1,011	2,043	1,840	1,495	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	300	168		2,370	1,567	683	0.0
5. SMALL-SCALE CHP	2	10	4	3	27	4	0.2
6. SMALL-SCALE HEAT ONLY	122	1,165		800	633	416	11.7
7. DOMESTIC HEAT ONLY	804	57,100		632	406	295	0.0
8. AD - ELECTRICITY ONLY	37	36	151		148	5,578	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	25,061	58,531	12,048	5,848	14,730	16,198	124.6
	Capacity Mlitres	*No. of plant*	*Annual output (Ml)*		*kt CO2e*	*kt*	*kha*
BIODIESEL	2,162	22	678		1,076	871	138.4
BIOETHANOL	2,213	9	1,015		750	2,981	202.0
TOTAL, including biofuels		***58,562***			***16,555***	***20,051***	***465***

Focus on transport biofuels (FB)

5. Focus on biofuels

Assumptions

Category	Capacity (MW)	No. of plant	Annual Output GWh (elec)	GWh (heat)	Total GHG saving kt CO2e	Total amount feedstock kt	Total land area kha
2006							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	19,496	13	1,534		1,650	877	0.5
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	118	6	611		149	643	0.2
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	80	5	297	1,187	484	340	0.0
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	168	87	0	1,680	1,064	443	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	32	265	0	200	96	51	0.0
7. DOMESTIC HEAT ONLY	132	40,300	0	376	128	95	0.0
8. AD - ELECTRICITY ONLY	6	6	12	0	11	291	0.0
9. AD - HEAT ONLY	0	0	0	0	0	0	0.0
TOTAL, excluding biofuels	*20,032*	*40,682*	*2,453*	*3,443*	*3,581*	*2,740*	*0.7*
	Capacity Mlitres	No. of plant	Annual output (Ml)		kt CO2e	kt	kha
BIODIESEL	1,688	21	296		626	340	43.2
BIOETHANOL	0	0	0		0	0	0.0
TOTAL, including biofuels		***40,703***			***4,207***	***3,080***	***43.9***
	Capacity (MW)	No. of plant	GWh (elec)	GWh (heat)	kt CO2e	kt	kha
2010							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	20,492	14	3,123		3,337	1,831	3.9
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	187	14	995		485	882	7.1
b. GASIFICATION	0	0	0		0	0	0.0
3.LARGE-SCALE / INDUSTRIAL CHP	193	9	511	2,043	953	674	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	220	92		2,105	1,249	565	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	42	365		267	109	69	1.7
7. DOMESTIC HEAT ONLY	156	40,900		408	138	102	0.0
8. AD - ELECTRICITY ONLY	6	6	15		14	379	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	21,296	41,400	4,645	4,823	6,285	4,503	15.4
	Capacity Mlitres	No. of plant	Annual output (Ml)		kt CO2e	kt	kha
BIODIESEL	2,516	24	1,388		1,752	1,766	255.1
BIOETHANOL	2,403	10	1,235		903	3,486	229.0
TOTAL, including biofuels		***41,434***			***8,939***	***9,755***	***499.6***
	Capacity (MW)	No. of plant	GWh (elec)	GWh (heat)	kt CO2e	kt	kha
2015							
1. EXISTING LARGE FOSSIL POWER STATIONS - CO-FIRING	20,492	14	3,123		3,337	1,831	3.9
2. BIOMASS POWER STATIONS ELECTRICITY ONLY a. COMBUSTION	812	18	4,629		3,743	3,902	38.7
b. GASIFICATION	10	1	59		27	41	2.3
3.LARGE-SCALE / INDUSTRIAL CHP	253	11	811	2,043	1,015	1,075	2.8
4. LARGE-SCALE / INDUSTRIAL HEAT ONLY	220	92		2,105	1,249	565	0.0
5. SMALL-SCALE CHP	0	0	0	0	0	0	0.0
6. SMALL-SCALE HEAT ONLY	42	365		267	109	69	1.7
7. DOMESTIC HEAT ONLY	156	40,900		408	138	102	0.0
8. AD - ELECTRICITY ONLY	6	6	15		14	379	0.0
9. AD - HEAT ONLY	0	0		0	0	0	0.0
TOTAL, excluding biofuels	21,991	41,407	8,637	4,823	9,632	7,965	49.3
	Capacity Mlitres	No. of plant	Annual output (Ml)		kt CO2e	kt	kha
BIODIESEL	2,516	24	1,388		1,752	1,766	255.1
BIOETHANOL	2,443	12	1,275		947	3,603	229.0
TOTAL, including biofuels		***41,443***			***12,331***	***13,334***	***533.5***

9.4.1 Values for carbon savings showing ranges

The first table shows the GHG emissions, range in the emissions and GHG savings compared to fossil fuel generation for heat and power production. All values are in kg CO_2 eq per MWh produced. The following table shows the equivalent figures for biofuels in kg CO_2 eq/ per thousand litres of biofuel.

		With credit for avoided disposal of waste to landfill				***Without credit for avoided disposal of waste to landfill***		
		Emissions	***Range***	***Saving***		***Emissions***	***Range***	***Saving***
COFIRING								
Biodiesel from OSR		583	66	424		583	66	424
Biodiesel from used oil		-324	23	1331		181	23	826
Cereal milling residue		-111	6	1119		52	6	955
Clean wood waste (chips)		-876	15	1883		121	15	887
Clean wood waste (pellets)		-872	32	1879		200	30	808
Forest residues (imported)		32	5	975		32	5	975
Forest residues (imported)		106	20	901		106	20	901
Forest residues (UK)		1	4	1007		1	4	1007
Forest residues (UK)		78	19	930		78	19	930
Glycerine (from OSR)		241	26	766		241	26	766
Glycerine (from used oil)		-112	10	1119		83	10	924
meat and bone meal		14	0	993		14	0	993
Miscanthus (chips)		107	5	901		107	5	901
Miscanthus (pellets)		265	26	743		265	26	743
Olive cake		33	1	975		33	1	975
Palm kernel expeller		239	1	768		239	1	768
Sawdust		14	n/a	994		34	0	974
Shea nut meal		5	n/a	1003		80	0	928
SRC (cut and chip) chips		58	10	949		58	10	949
SRC (cut and chip) pellets		294	53	713		294	53	713
SRC (stick harvesting) chips		70	10	937		70	10	937
SRC (stick harvesting) pellets		295	53	712		295	53	712
Sunflower seeds		33	1	975		33	1	975
Tallow		3	1	1004		22	1	985
CHP								
Chipboard (pellets)	Combustion	-29	10	317		111	10	177
ChIpboard (shredded)	Combustion	-26	9	314		109	9	179
Clean wood waste (chips)	Combustion	-1421	20	1709		165	18	123
Clean wood waste (chips)	Gasification	-1607	14	1895		587	12	-299
Clean wood waste (chips)	Pyrolysis	-1615	15	1902		540	13	-252
Forest residues (imported)	Combustion	84	9	204		84	9	204

		With credit for avoided disposal of waste to landfill			Without credit for avoided disposal of waste to landfill		
		Emissions	***Range***	***Saving***	***Emissions***	***Range***	***Saving***
Forest residues (imported)	Gasification	31	3	256	31	3	256
Forest residues (UK)	Combustion	76	9	211	76	9	211
Forest residues (UK)	Gasification	19	3	269	19	3	269
High biomass RDF	Combustion	-167	15	455	229	14	59
MDF (pellets)	Combustion	56	18	232	204	18	83
MDF (shredded)	Combustion	-50	8	338	92	8	196
SRC (cut and chip) chips	Combustion	309	51	-21	309	51	-21
SRC (cut and chip) chips	Gasification	219	38	69	219	38	69
SRC (stick harvesting) chips	Combustion	314	48	-26	314	48	-26
SRC (stick harvesting) chips	Gasification	218	98	70	218	98	70
Straw	Combustion	274	12	14	274	12	14
Straw	Gasification	196	4	91	196	4	91
ELECTRICITY PRODUCTION							
Chicken litter	Combustion	24	4	387	84	4	327
Chipboard (pellets)	Combustion	-375	41	786	468	40	-57
ChIpboard (shredded)	Combustion	-357	39	768	453	38	-42
Clean wood waste (chips)	Combustion	-1276	12	1687	119	10	292
Clean wood waste (chips)	Gasification	-917	8	1327	80	6	331
Dried distillers' grain	Combustion	717	n/a	-307	717	0	-307
Forest residues (imported)	Combustion	63	8	347	63	8	347
Forest residues (imported)	Gasification	40	5	371	40	5	371
Forest residues (UK)	Combustion	20	8	391	20	8	391
Forest residues (UK)	Gasification	9	4	402	9	4	402
High biomass RDF	Combustion	-255	10	665	221	9	190
High biomass RDF	Gasification	-186	6	597	153	6	257
MDF (pellets)	Combustion	-717	14	1128	171	14	239
MDF (shredded)	Combustion	-697	12	1108	156	12	254
Miscanthus (bales)	Combustion	206	29	205	206	29	205
Miscanthus (chips)	Combustion	235	33	176	235	33	176
Miscanthus (chips)	Gasification	160	20	251	160	20	251
Miscanthus (pellets)	Combustion	273	41	137	273	41	137
Oil seed rape	Combustion	40	n/a	370	40	0	370
Palm oil	Combustion	34	n/a	376	34	0	376
SRC (cut and chip) chips	Combustion	322	55	88	322	55	88
SRC (cut and chip) chips	Gasification	224	38	187	224	38	187
SRC (stick harvesting) chips	Combustion	100	14	311	100	14	311
SRC (stick harvesting) chips	Gasification	224	36	187	224	36	187
Straw	Combustion	283	7	127	283	7	127
Straw	Gasification	199	5	211	199	5	211
Used oil	Combustion	35	n/a	375	35	0	375

		With credit for avoided disposal of waste to landfill				Without credit for avoided disposal of waste to landfill		
		Emissions	***Range***	***Saving***		***Emissions***	***Range***	***Saving***
SMALL SCALE HEAT PRODUCTION								
Clean wood waste (pellets)		-328	13	703		1553	13	-1178
Forest residues (imported)		70	10	306		70	10	306
Forest residues (UK)		46	8	329		46	8	329
Logs		34	3	341		34	3	341
SRC (cut and chip) pellets		131	22	244		131	22	244
SRC (stick harvesting) pellets		131	22	244		131	22	244
LARGE SCALE HEAT PRODUCTION								
Chipboard (pellets)		-209	4	584		54	4	321
ChIpboard (shredded)		-199	4	575		54	4	322
Clean wood waste (chips)		-380	7	755		56	7	319
Clean wood waste (pellets)		-374	14	749		94	14	281
Forest residues (imported)		19	2	357		19	2	357
Forest residues (imported)		52	9	323		52	9	323
Forest residues (UK)		5	2	370		5	2	370
Forest residues (UK)		40	9	335		40	9	335
Glycerine (from OSR)		111	12	264		111	12	264
Glycerine (from used oil)		-44	5	419		42	5	334
High biomass RDF		-85	3	460		63	2	312
MDF (pellets)		-248	2	623		30	2	346
MDF (shredded)		-243	2	618		25	2	351
SRC (cut and chip) chips		99	17	276		99	17	276
SRC (cut and chip) pellets		136	23	239		136	23	239
SRC (stick harvesting) chips		99	17	276		99	17	276
SRC (stick harvesting) pellets		136	23	239		136	23	239
Straw		82	2	293		82	2	293
ANAEROBIC DIGESTION								
Centralised								
Dairy manure	CHP	-824	32	1112		-824	32	1112
Dairy manure	Electricity	-667	11	1077		-667	11	1077
Food waste	CHP	-216	14	504		-216	14	504
Food waste	Electricity	-379	5	790		-379	5	790
Pig manure	CHP	-1783	32	2071		-1783	32	2071
Pig manure	Electricity	-1250	11	1661		-1250	11	1661
Poultry waste	CHP	-888	24	1176		-888	24	1176
Poultry waste	Electricity	-787	9	1198		-787	9	1198

		With credit for avoided disposal of waste to landfill				Without credit for avoided disposal of waste to landfill		
Onfarm		*Emissions*	*Range*	*Saving*		*Emissions*	*Range*	*Saving*
Dairy manure	CHP	-743	35	1031		-743	35	1031
Dairy manure	Electricity	-480	23	890		-480	23	890
Dairy manure	Heat	-315	11	690		-315	11	690
Pig manure	CHP	-1624	36	1912		-1624	36	1912
Pig manure	Electricity	-1062	20	1472		-1062	20	1472
Pig manure	Heat	-638	11	1013		-638	11	1013

GHG emissions and savings from biofuels (kg CO_2 eq per thousand litres of biofuels)

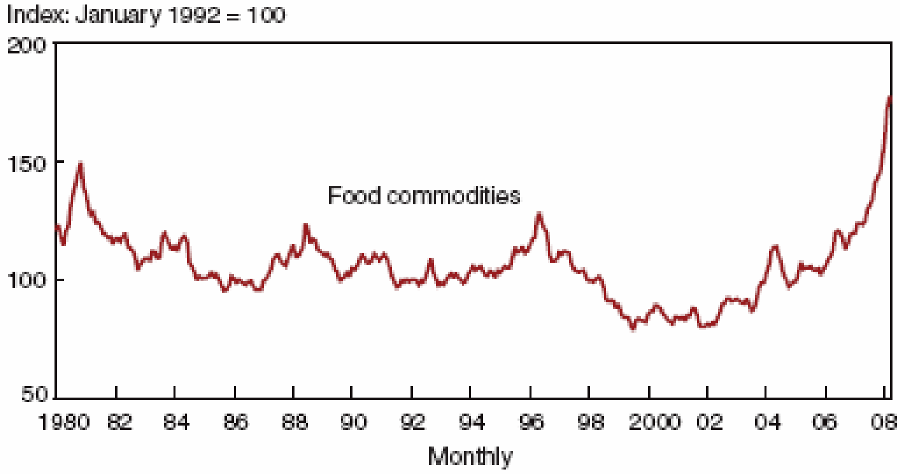
		With credit for avoided disposal of waste to landfill				Without credit for avoided disposal of waste to landfill		
		Emissions	*Range*	*Saving*		*Emissions*	*Range*	*Saving*
Biodiesel								
Oil seed rape		1859	209	1012		2049	204	822
Used cooking oil		-1034	72	3905		578	72	2293
Sunflower oil		2558	0	313		2558	0	313
Palm oil		1476	0	1395		1476	0	1395
Bioethanol								
Sugar beet		748	139	972		785	138	934
Wheat		1137	28	583		1225	26	495

9.5 Information on international crop prices

The following graphs show the recent rises in food prices. The first two are from the US Department of Agriculture and examine relative prices. The graphs beneath them show actual prices for oil and the major food commodities and the price of Brazilian bioethanol. Many analysts consider that the use of US corn for bioethanol has resulted in increases in corn prices worldwide. However, there is more debate about general food price increases, which are thought to be due to a number of issues, including poor harvests, speculation, reaction to potential supply constraints by importing nations and the low exchange rate for the dollar in addition to the effect of biofuels production (see, for example, Trostle, 2008).

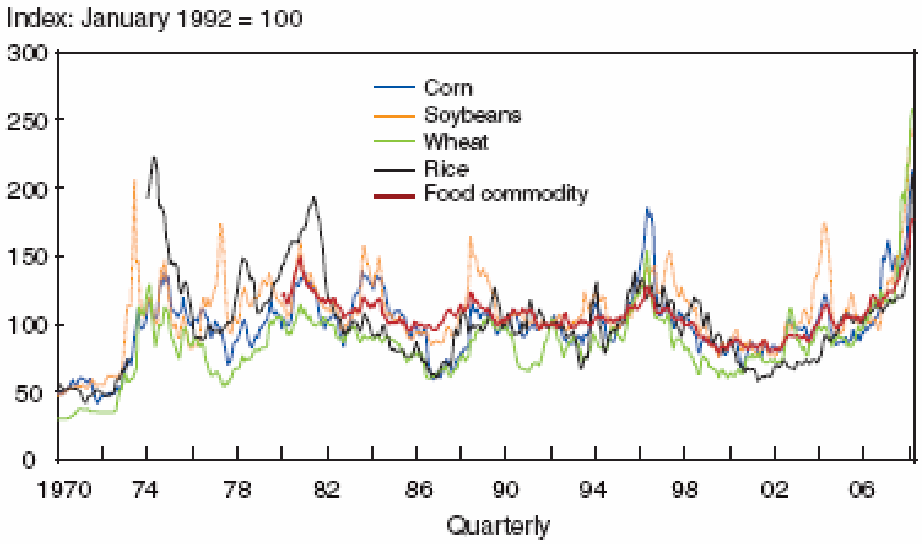
Further information on food crop prices is available from the FAO Global Market Analysis: Food Outlook May 2008 (see: www.fao.org/docrep/010/ai466e/ai466e01.htm)

Food commodity price rose more than 60 per cent in the last two years. (Trostle, 2008)



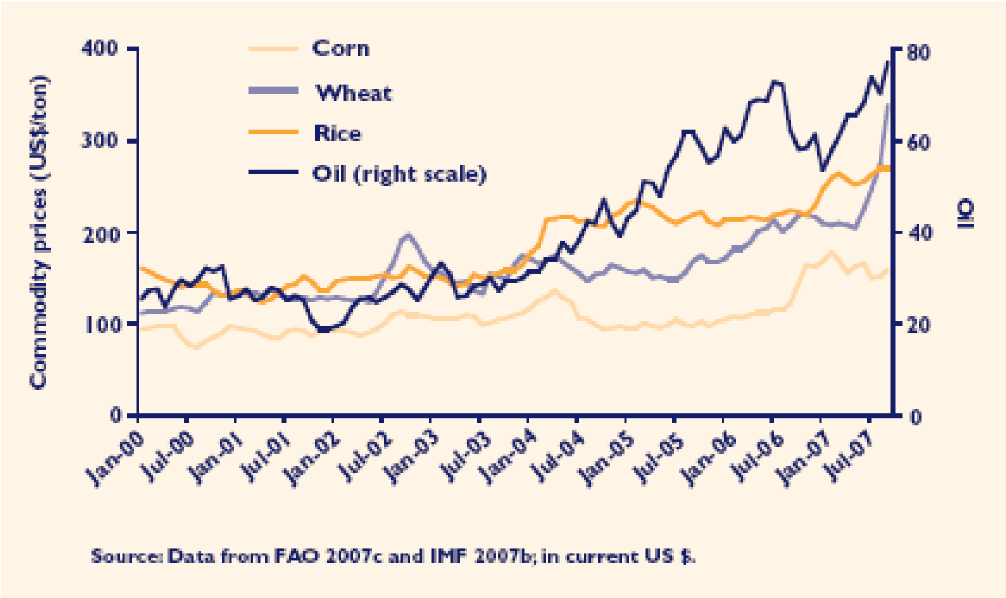
Source: International Monetary Fund: International Financial Statistics.

Food commodity trends since 1970

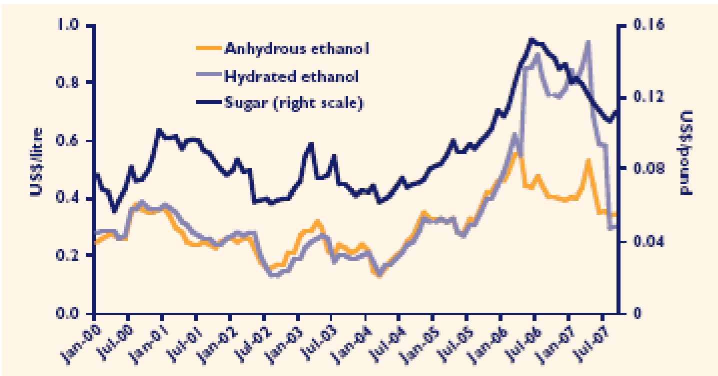


Source: International Monetary Fund: International Financial Statistics.

Commodity prices (US$/ton) January 2000 - September 2007.



Brazil: Ethanol and sugar prices January 2000 - September 2007.



Fuel ethanol prices in Brazil refer to averages for the São Paulo market. Hydrous ethanol is used as a substitute for gasoline and anhydrous ethanol is mixed with gasoline.

References

Trostle, R., 2008. Global Agricultural supply and demand: factors contributing to the recent increase in food commodity prices. USDA WRS-0801 See: www.ers.usda.gov

von Braun, J., 2007. International Food Policy Research Institute (IFPRI) 2007: The World Food Situation: New driving forces and required Actions.

9.6 Additional details and results for GHG emissions from waste management options

Electricity mix for 2008 (taken from WRATE)

Energy Source	Baseline Fuel Mix (%)	Generating Efficiencies (%)	Marginal Fuel Mix (%)
Coal	28.18	36.31	56.15
Oil	0.52	27.83	0
Gas	2.7	34.9	2.76
Gas CCGT	37.93	46.61	41.09
Nuclear	21.35	37.25	0
Waste	0.01	25.35	0
Thermal other	0.23	36.31	0
Renewables thermal	1.24	18.11	0
Solar PV	0	15.52	0
Wind	6.1	25	0
Tidal	0	82	0
Wave	0	82	0
Hydro	1.74	82	0
Geothermal	0	82	0
Renewable other	0	82	0
Total	**100**		**100**

Assumptions for management of organic waste component

Waste Management Method	Modelled in WRATE as:
Home composting	Home composting by bin
In-vessel composting	Teg IVC process
Anaerobic digestion (AD)	Dranco AD process
Energy from waste	Chineham incinerator
Energy from waste (CHP)	Chineham incinerator with additional heat outputs
Landfill	Clay lined and capped landfill with landfill gas recovered and used for electricity production

Organic waste component is assumed to be 50 per cent garden waste and 50 per cent kitchen waste (this is approximately the proportions they occur in the waste stream).

Compost from home composting is assumed to be used in the garden and is used to replace other soil conditioners and some peat-based products. Compost from IVC has a variety of uses, and in some of these its use will reduce the use of nitrogenous fertilisers.

In the incineration options bottom ash has been assumed to be recycled.

Assumptions for management of cereal milling residue

The GHG emissions associated with producing straw were taken from the $BEAT_2$ tool. Emissions from landfilling cereal milling residue are taken from WRATE, and are based on landfilling of garden waste (considered the nearest equivalent within $BEAT_2$ to cereal milling residue).

Source Separated Kitchen and Garden Waste

Recycling	Home Composting	In-vessel Composting	Anaerobic Digestion
Net GHG emissions (kg) per tonne (assuming diplacement of marginal mix)	-1.4	-28.0	-146.6
Net GHG emissions (kg) per tonne (assuming diplacement of gas)			-68.83

Energy Recovery	Energy from Waste Incinerator (bottom ash NOT recycled)	Energy from Waste Incinerator (bottom ash recycled)	Combined Heat and Power Incinerator (bottom ash recycled)
Net GHG emissions (kg) per tonne (assuming diplacement of marginal mix)	-174.4	-172.7	-283.6
Net GHG emissions (kg) per tonne (assuming diplacement of gas)	-85.62	-83.87	-199.27

Disposal	Landfill
Net GHG emissions (kg) per tonne (assuming diplacement of marginal mix)	202.9
Net GHG emissions (kg) per tonne (assuming diplacement of gas)	260.4

Wood Processing Waste

Recycling	Composting	Recycling
Net GHG emissions (kg) per tonne	0.9	- 24 to -49

Energy Recovery	Combustion of Chips - Electricity only	Combustion of Chips - Heat only (small scale/domestic)	Combustion of Chips - Electricity & Heat	Co-firing of Chips - Electricity	Combustion of Pellets - Industrial Heat only	Combustion of Pellets - Domestic Heat only	Co-firing of Pellets - Electricity
Net GHG emissions (kg) per tonne (assuming diplacement of marginal mix for electricty only, coal for co-firing, oil in case of domestic heat plant & gas fired boiler for industrial heat)	-509	-861	-537	-1,097	-561	-816	-1,007
Net GHG emissions (kg) per tonne (assuming diplacement of gas)	-266.37	-624.29	-429.87	-415.25	-561.27	-575.37	-372.70

Disposal	Landfill
Net GHG emissions (kg) per tonne	782
Net GHG emissions (kg) per tonne (assuming diplacement of gas)	999

Cereal Milling Residues

Recycling	Animal feed replacement
Net GHG emissions (kg) per tonne	-155

Energy Recovery	Co-firing of Pellets - Electricity (coal offset)
Net GHG emissions (kg) per tonne (assuming diplacement of coal)	-1,572
Net GHG emissions (kg) per tonne (assuming diplacement of gas)	-575

Disposal	Landfill
Net GHG emissions (kg) per tonne	204
Net GHG emissions (kg) per tonne (assuming diplacement of gas)	260

Dairy WWT

Energy Recovery	Anaerobic digestion
Net GHG emissions (kg) per tonne (assuming diplacement of marginal mix)	-201
Net GHG emissions (kg) per tonne (assuming diplacement of gas)	-118

Disposal	Spread to land
Net GHG emissions (kg) per tonne	36

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