Alex McBurnie
Advisor: Ros Boar
ENV-2E02 Report

THE POTENTIAL FOR ENERGY FROM BIOMASS IN THE UK

Energy from biomass is the energy liberated from the combustion of plant matter or its derivatives. This includes the direct burning of materials such as wood and the combustion of substances such as alcohol fermented from sugar cane. The use of biomass has many advantages over the burning of traditional fossil fuels; so long as the plant material used is managed sustainably and replaced at the same rate that it is being used, the fuel is renewable; biomass is roughly carbon neutral as the growing plant has absorbed the same amount of carbon as is emitted when it is used and emissions of many other pollutants are lower than with many fossil fuels; the use of land to grow biofuels can create habitats for wildlife.

Biomass is a proven technology. Wood is the oldest fuel and has been used by humans for heat and warmth since before society began. More recently, the use of bioethanol, derived from the fermentation of sugar cane or wheat, as an additive to petrol for use in road vehicles was widespread in the United States throughout the 1920’s and 1930’s and in certain parts of the US is still common today. It was also widely used in post-war Europe to extend fuel supplies. Bioethanol can be easily mixed with petrol to make up to 20% of the fuel and possibly up to 30% without modification of the engine (Energy Paper 2, 1975). The use of biodiesel, essentially vegetable oil or rapeseed oil, is common throughout mainland Europe, especially in Germany. Biodiesel can be used as a direct substitute for diesel oil; in fact, Rudolf Diesel, the inventor of the diesel engine, demonstrated it at the World Exhibition in Paris in 1900 running on peanut oil.

There is a large potential for deriving energy from biomass in the UK. Even ignoring the potential to import biofuels from abroad, where sub-tropical climates give the potential to produce far greater amounts of fuel than the UK climate, and the potential for energy from waste biomass which is currently land filled, incinerated or, in the case or straw, simply ploughed back into the ground, we could still produce a significant proportion of our energy needs domestically.

ENERGY OVERHEADS

It is very difficult to estimate how much energy would be used in processing of the biomass. A figure of 0.2 GJ/tonne (Thetford Forest Practical) would assume that the energy generation took place on the site where the trees were grown, making it quite likely a low estimate. Considering that it takes 1.25 MJ to transport each tonne of biomass one kilometre (Thetford Forest Practical) and assuming that the biomass would be unlikely to be transported more than 300km in the UK, a figure of 0.375 GJ + 0.2 GJ = 0.575 ~ 0.6 GJ/tonne would seem to be a very high estimate of the energy overheads. Therefore, energy overheads could be anywhere between 0.2 GJ/tonne and 0.6 GJ/tonne.

EXISTING BIOMASS

The first element to energy from biomass is the use of existing biomass. Britain is 12% woodland, which equates to 2.8 million hectares (Forestry Commission, 2004). It is estimated that by the year 2020, British forests will be producing 10 million tonnes more wood than is currently used, against a backdrop of falling demand for British timber (RCEP, 2004). Assuming the extracted wood is sufficiently restocked, this level should be sustainable (Forestry Commission, 2004). This is therefore a potentially substantial source of energy that will be available within the next fifteen years.

Assuming that the wood has an energy content of 20 GJ per tonne (Thetford Forest Practical), it must therefore contain 200PJ of energy per year.

			Projection
Annual Amount of Wood	10 million tonnes		
Energy Content of Wood	20 GJ / tonne	10,000,000 x 20 = 200,000,000GJ	200PJ
Energy for Extraction –			
Low estimate	0.2 GJ / tonne	0.2 x 10,000,000 = 2,000,000 GJ = 2 PJ 200PJ - 2PJ = 198 PJ	198 PJ
High Estimate	0.6 GJ / tonne	0.6 x 10,000,000 = 6 PJ 200PJ – 6 PJ = 194 PJ	194 PJ

Table 1. Estimated Potential Energy from Existing Biomass in the UK.

Therefore, the maximum energy that could be produced from existing biomass is omewhere between 194 PJ and 198 PJ per year.

NEW PLANTING

There are a number of crops that are ideal for growth as fuel and these can be cultivated in a number of ways. Willow or Poplar trees can be grown as a short rotation coppice. This means that they are cut down every four years, then allowed to re-grow for four years before being chopped down again. This cycle can be repeated four or five times before the trees must be removed and replaced. They can also be grown for longer periods of time such as fifteen years or thirty years, which has the potential to produce a higher yield for the same land area and can support more biodiversity. However, it does mean a far longer time before investments can be realised and for this reason is less financially attractive. Miscanthus grass is the type of grass that grows best in the UK climate. It is a nitrogen fixing plant, so can in some ways improve the quality of the soil in which it grows. As a grass, it is an annual crop so does not tie up the land for a long time before it can be harvested. Oilseed rape, sugar beat and wheat can all be processed into fuels for road vehicles and as such are possibly the most useful of the biomass crops. They are all also annual crops, so have the advantages of a being harvested within a year of being planted. All of these crops have broadly similar energy contents of somewhere in the region of 20 GJ/tonne and will probably give yields of between 10 tonnes/hectare and 20 tonnes/hectare, depending on many growing conditions such as soil quality, climate and use of fertilisers (RCEP, 2004).

NEW PLANTING ON CURRENT SET-ASIDE LAND

Under the European Common Agricultural Policy (CAP), an average of 640 ha of land was under set-aside from 1999-2002 (RCEP, 2004). This means that the land is not allowed to be used for the production of food crops and as such much of it lies fallow.

	Low yield 10 tonnes/ha		High yield 20 tonnes/ha	
Land area 640 ha	10 x 640 = 6,400 tonnes		20 x 640 = 12,800 tonnes	
Energy content 20 GJ/tonne	6,400t x 20GJ=128,000GJ 128,000 GJ = 0.128 PJ		12,800tx20GJ=256,000GJ 256,000 GJ = 0.256 PJ	
Overheads	Low=0.2GJ/t	High=0.6GJ/t	Low=0.2GJ/t	High=0.6GJ/t
	6400x0.2=1280GJ 1280GJ=0.00128PJ	6400x0.6=3840GJ 3840GJ=0.00384PJ	12800x0.2=2560GJ 2560GJ=0.00256PJ	12800x0.6=7680GJ 7680GJ=0.00768PJ
Total Energy	0.128-0.00128 = 0.12672 PJ	0.128-0.00384 = 0.12416 PJ	0.256-0.00256 = 0.25344 PJ	0.256-0.00768 = 0.24832 PJ

Table 2. Estimated Potential Energy from Biomass on Set-Aside Land in the UK.

Therefore the maximum amount of energy than can be produced from set aside land is between 0.124 PJ and 0.253 PJ.

<u>CHANGING THE USE OF EXISTING AGRICULTURAL LAND</u>

Agricultural land in the UK is categorised into five grades according to its quality.

Box 2B Land classification in England and Wales

Agricultural land is divided into classifications by the physical limitations of the land for agricultural use, the determining factors being climate, site and soil and how these affect the versatility of the land and the reliability of crop yields[1]. England and Wales have five classifications (or grades) and grade 3 is divided into subgroups a and b[2], the Scottish executive uses seven grades of land classification with up to three sub-categories in each[3], The first five follow roughly the descriptions and proportions set out below for England and Wales[4].

Grade 1 - excellent quality agricultural land

3% of agricultural land

Land that produces consistently high yields from a wide range of crops such as fruit, salad crops and winter vegetables.

Grade 2 - very good quality agricultural land

16% of agricultural land

Yields may have some variability but are generally high, some factors may affect yield, cultivation or harvesting.

Grade 3 - good to moderate quality land

55% of agricultural land

Limitations of the land will restrict the choice of crops, timing and type of cultivation, harvesting. Yields are generally lower and fairly variable.

Grade 4 - poor quality agricultural land

16% of agricultural land

Severe growing limitations restrict the use of this land to grass and occasional arable crops.

Grade 5 - very poor quality land

10% of agricultural land

Land that is generally suitable only for rough grazing or permanent pasture.

[1] Defra (2003). *Agricultural Land Classification. Protecting 'the best and most versatile agricultural land'*
[2] MAFF(1988). *Agricultural land classification of England and Wales*
[3] Personal Communiction, J Hooker, April 2003.
[4] Defra. *England ALC stats*

Table 3. Classes of Agricultural Land in the UK (RCEP, 2004).

These categories of land use suggest that grade four land would be ideally suited to the growing of miscanthus grass and possibly woody biomass, while grade three land would be more suited to oilseed rape and wheat. The National Farmers Union indicates that 20% of UK crops are not required for food (RCEP, 2004). As there are 18.5 million hectares of agricultural land, this suggests that 3.7 million hectares of UK agricultural land could be used to produce biomass crops.

	Low yield 10 tonnes/ha		High yield 20 tonnes/ha	
Land area 3,700,000 ha	Yield =37 m tonnes		Yield = 74 m tonnes	
Energy Content 20GJ/t	740,000,000 GJ 740 PJ		1,480,000,000 GJ 1,480 PJ	
Overheads	Low=0.2GJ/t	High=0.6GJ/t	Low=0.2GJ/t	High=0.6GJ/t
	7.4 PJ	22.2 PJ	14.8 PJ	44.4 PJ
Total Energy	732.6 PJ	717.8 PJ	1,465.2 PJ	1,435.6 PJ

Table 4. Estimated Potential Energy from Biomass Grown on 20% of UK Agricultural Land.

Therefore, the maximum total energy that could be gained by switching 20% of the UK's agricultural land to growing fuel crops is between 717.8 PJ and 1,465.2 PJ.

TOTAL BIOMASS POTENTIAL IN THE UK

	Lowest Estimate (PJ)	Highest Estimate (PJ)
Existing Biomass	194.0	198.0
Set-Aside Land	0.124	0.253
Changed Agricultural Use	717.8	1,465.2
TOTAL	911.924	1,663.453

Table 5. Estimated Total Potential Energy from Biomass in the UK.

The total potential energy from biomass in the UK is therefore between 911 PJ and 1,664 PJ per year.

HOW THIS ENERGY IS USED

How this energy is used could have a large impact on the eventual useful energy we derive from biomass. Efficiency in electricity generation from biomass can be as low as 30%, while heat production or combined heat power (CHP), where both heat and electricity are produced, can be as much as 85% efficient.

	30% Efficiency	85% Efficiency
Lowest Estimate (PJ)	**273.6**	775.1
Highest Estimate (PJ)	499.0	**1,413.9**

Table 6. Estimated Potential Useable Energy from Biomass in the UK Given Upper and Lower Limits of Efficiency of Conversion to Useful Types of Energy.

Taking these as the two extremes, we could therefore derive anywhere between 273.6 PJ and 1,413.9 PJ of energy could be provided per year from biomass.

WHEN WE COULD GET THIS

Energy from biomass is a proven technology; therefore, no period is required to develop ways to exploit it. Biomass can also be widely used in existing power stations, such as in co-firing, and in existing vehicles, with few of no adaptations, so no time is really required to built the technologies in which it would be used. Land set aside under CAP could be brought into cultivation immediately, while on other agricultural land possibly one year would be required to finish cultivating current crops and move onto fuel crops. The length of time from the start of cultivation to the start of harvesting varies depending on the crop and the rotation period chosen. In the case of wheat for bioethanol, rape seed for biodiesel and miscanthus grass for power plants, the rotation period would be just one year. If Willow or Poplar were to be grown under a short rotation coppice, then four years is required between planting and harvesting, while a more mature forest could need up to thirty years to mature. The energy to be provided from existing forests will be gradually available depending upon the surplus supply, rising to the estimate of ten million tonnes per year in 2020 and possibly rising further than this further into the future, it demand for timber continues to fall.

	Existing Forest	Set-Aside	Agricultural
Wheat / Rape Seed		One year (2006)	Two years (2007)
Miscanthus Grass		One year (2006)	Two years (2007)
Short Rotation Coppice (4 year cycle)		Four Years (2009)	Five years (2010)
Mature Forests	(2020)	Thirty years (2035)	Thirty years (2035)

Table 7. Estimated Earliest Time that the Different Classes of Biomass could be Available.

Year	2010	2015	2020	2025	2030
Energy (PJ)	215.4 to 1,245.6		Full amount = 273.6 to 1,413.9		

Table 8. Estimated Amount of Energy from Biomass that Could be Available by Specified Years.

<u>REFERENCES</u>

Forestry statistics 2004, Forestry Commission, Edinburgh.

Royal Commission on Environmental Pollution, Biomass as a Renewable Energy Source, 2004.

Energy Paper Number 2, Methane derived alcohols: their use as blending components of petrol, Report by a Working Party, Her Majesty's Stationery Office, London, 1975.

Renewable Energies: Success Stories, European Environment Agency, Luxembourg, 2001.

Cost/Benefit Analysis of Production and use of Bioethanol as a Gasoline Additive in the European Community, Commission of the European Communities, Luxembourg, 1987.