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Information paper – 25
Biomass and biofuel sources

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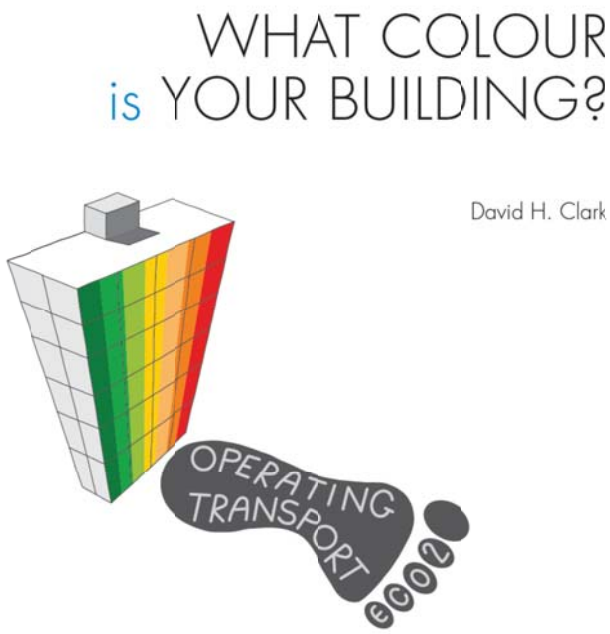
A paper referenced in the book:



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This information paper is one of a series of papers written during the preparation of the book **What Colour is Your Building?** (www.whatcolourisyourbuilding.com). The papers do not form part of the book and have not been peer reviewed. They provide further technical detail, analysis and information to support statements made in the book. All of the papers can be downloaded from www.wholecarbonfootprint.com.

Biomass and biofuel sources

This information paper provides information on the supply of biomass and biofuel in the UK. It discusses where conventional (first generation) fuels are sourced from, the land area required and socio-economic issues associated with their production. The paper then discusses the status of second and third generation fuels in 2013.

1. SOURCES OF BIOMASS AND BIOFUELS

Biomass (which includes biofuel and biogas) comes from many sources including:

- Virgin wood – from forestry, arboricultural activities or wood processing.
- Energy crops – from high yield crops grown for energy.
- Agricultural residues – from harvesting or processing.
- Food waste – from food and drink manufacture, preparation and processing.
- Landfill – from biodegradable and plastic waste.
- Industrial waste and co-products – from manufacturing and industrial processes.

2. PLANTATION AREA REQUIRED FOR BIOMASS & BIOFUEL SUPPLY

The calculation of the area of land required to produce biomass for Building X and Hotel Y, shown in Figure 7.5 in Chapter 7, is based on the energy content of the fuel and the energy yield from UK plantations. The same approach was used to generate Table I.46 in Appendix I to compare biomass and biofuel plantation areas.

What is the energy yield from plantations?

Table 1 shows estimates of yields from different biomass fuel sources in the UK. The energy yields for biofuels from plantations are much less than yields that might be realised from tropical plantations (>1 W/m^2). This is not surprising – plants convert solar energy and water into sugars (fuel) and oxygen – so plantations in wet, sunny parts of the world (the tropics) will produce the most energy.

In *Sustainable Energy – without the hot air*, David Mackay adopted a figure of 0.5 W/m^2 to represent the maximum power available in the UK from biomass/biofuel which ignored all the additional costs of growing, harvesting and processing the plants. His conclusion was: '*biofuels made from plants, in a European country like Britain, can deliver so little power, I think they are scarcely worth talking about.*'

Fuel	Net calorific value		Annual yield per hectare (t/ha)	MWh per hectare	W/m^2
	(MJ/kg)	(kWh/kg)			
Wood (forestry residues, SRW, thinnings, etc.) @ 30% MC	13	3.5	2.9	10.3	0.12
Short Rotation Coppice (Willow) @ 30% MC	13	3.5	12.9	46	0.53
Miscanthus @ 25% MC	13	3.5	17.3	63	0.72
Wheat straw @ 20% MC	13.5	3.8	4.6	17	0.19
Biodiesel (from rapeseed oil)	37	10.3	1.1	11.3	0.13
Bioethanol (from sugar beet)	27	7.5	4.4	33	0.38
Bioethanol (from wheat)	27	7.5	2.3	17	0.19
Biogas (from cattle slurry)	20	5.6	0.88	4.9	0.06
Biogas (from sugar beet)	20	5.6	5.3	29	0.33

Table 1 **Energy yields from biomass plantations in the UK**[1]

Where does the UK currently get wood fuel from?

Table 2 shows a summary of where wood fuel was sourced from in the UK in 2011 based on data from the Forestry Commission.[2] The table also provides an indication of the moisture content of each source and this was used to roughly estimate the total energy supply from wood sources as 7.4 million MWh. In comparison, data from DUKES 2012 shows that 8.2 million MWh of energy was produced from wood and wood waste in the UK in 2011.[3]

The Forestry Commission data shows that 60% of wood fuel in the UK is currently sourced from wood waste (recycled wood and sawmills) with the remainder from plantations (mainly thinnings). The DUKES data shows that 40% of wood biomass is from recycled wood. No attempt is made in this paper to reconcile the differences in data from the Forestry Commission and DUKES.

The Forestry Commission estimates that 224,000 tonnes of wood pellets and briquettes were produced in the UK in 2011.[4] These have an energy content of approximately 1.17 million MWh, representing about 16% of total wood fuel energy (and half of the wood fuel sourced from sawmills).

Wood Source	Total production (tonnes)	% for wood fuel	Total supplied for wood fuel (tonnes)	Unit	Assumed moisture content	Weight of dry wood (odt)	Weight of wood fuel	Energy supplied (MWh)	
Recycled wood			594,000	odt	20%	594,000	742,500	3,035,489	*41%*
Softwood plantation	9,723,000	9%	900,000	gt	60%	360,000	514,286	1,796,040	*24%*
Hardwood plantation	541,000	74%	400,000	gt	45%	220,000	314,286	1,097,580	*15%*
Sawmills - other products			531,000	gt	50%	265,500	379,286	1,324,580	*18%*
Round fencing manufacturers			61,000	gt	50%	30,500	43,571	152,165	*2%*
Total			**2,486,000**			**1,470,000**	**2,100,000**	**7,405,853**	

Notes:

The majority of sawmill and round fencing waste wood is used by wood-based panel manufacturer (chipboard, etc) and in pulp/paper mills.

The energy content was estimated assuming that the wood is allowed to air dry to a moisture content of 30% except recycled timber which is assumed to be 20%.

Table 2 **Estimated sources and energy supplied by wood fuel in UK in 2008 (based on wood fuel supply data from Forestry Commission)**

Can the UK provide enough biomass for 10% of its heating?

In 2011, the total gross heating energy demand in the UK was around 692 million MWh.[5] Of this 8.2 million MWh (1% of the total) was supplied by wood fuel. If 10% of the UK's heating demand was to be supplied by wood fuel (wood heaters, wood chip/pellet boilers and district heating systems) this would require new wood fuel sources to deliver an additional 69 million MWh.

If the current supply of wood to the bioenergy industry from the existing sources discussed above could be doubled (although this might be to the detriment of other industries who currently obtain wood from these sources for chipboard, paper, etc) then a further 7.5 million MWh of energy is provided giving a total of 15 million MWh. The remaining 54 million MWh would therefore need to come from new energy crop plantations. Assuming an energy yield of 46 MWh per hectare (refer to Table 1), this would require an additional 1.1 million hectares of new Short Rotation Willow coppice to be planted in the UK.

According to the Forestry Commission,[6] in 2011 the UK had 3.1 million hectares of woodland (1.6m Ha conifers and 1.5m Ha broadleaf) accounting for around 12% of the land area of the UK.[7] A further 5% of the UK land area would have to be turned over to energy crop plantation to supply just 10% of the UK's annual heating demand. To put the scale of the challenge into perspective:

- Short rotation willow coppice (SRC) has a 3 year harvesting cycle. In 2010 the UK had about 8,000 hectares of SRC.[8]

- Figure 1 shows that new forestry planting in the UK had been in steady decline since 1990, although 2011 and 2012 show a small reverse in this trend.[9] 12,700 hectares of new woodland was planted in 2012, which is around 1% of the new area required to produce 10% of the UK's heating energy if this new planting was only used as an energy crop.

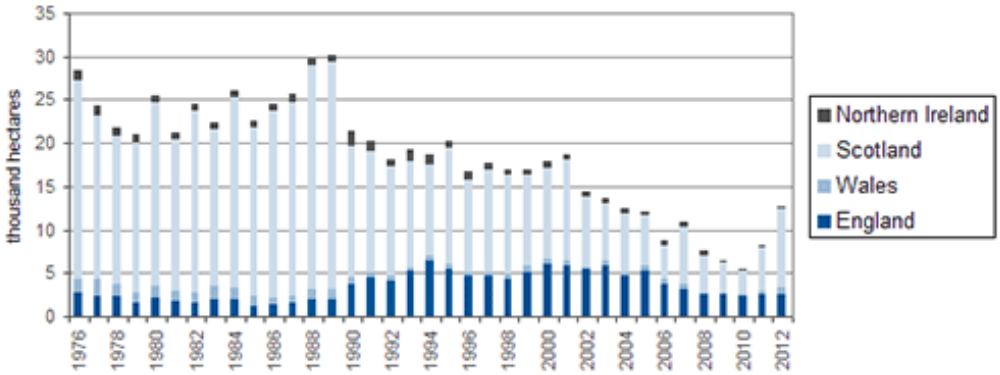


Fig 1 **New forestry planting in the UK, 1976 to 2012 (source: Forestry Commission)**

Biofuels for transport

Biodiesel represented 3.6% of the total DERV delivered in the calendar year 2011, while bioethanol represented 3.3% of the total motor spirit. Overall, biofuels represented 3.5% of the total road fuel consumption of 45,474 million litres.[10] If the UK were to supply 10% of transport fuel from biofuels then the additional area of bioethanol plantations required would be:

• Total transport energy consumption in 2011[11]	37,835,000 toe
• 10% of total transport energy	3,784,000 toe
• Total biofuels in 2011	1,063,000 toe
• Additional biofuel required	2,721,000 toe = 31,645,000 MWh
• Sugar beet plantation energy yield (Table 1)	33 MWh / ha
• **Additional area of land for 10%**	**958,946 hectares**

This is equivalent to 4% of the UK land area. If biodiesel plantation was used instead, with an energy yield of 11.3 MWh/ha then the area increases to 2.8 million hectares (11%).

2. THE SOCIAL AND ENVIRONMENTAL CONSEQUENCES OF BIOMASS AND BIOFUELS

Change in land use

As the market for biofuels has expanded, it has become clear that not all biofuels are the same, in terms of their greenhouse gas impacts from global land use. Studies have shown that when taking into account indirect land use change, for example when biofuel production causes food or feed production to be displaced to non-agricultural land such as forests, some biofuels may actually be adding as much to greenhouse gas emissions as the fossil fuels they replace.

In October 2012 the European Commission published a proposal to limit global land conversion for biofuel production, and raise the climate benefits of biofuels used in the EU.[12] The estimated global land conversion impacts – Indirect Land Use Change (ILUC) – also need to be considered when assessing the greenhouse gas performance of biofuels.

The use of food-based biofuels to meet the 10% renewable energy target of the EU Renewable Energy Directive will be limited to 5%. This is to stimulate the development of second generation biofuels from non-food feedstock, such as waste or straw, which emit less greenhouse gases than fossil fuels and do not directly interfere with global food production.

The EU's *biofuels sustainability criteria* prevent the direct conversion of forests and wetlands and areas with a high biodiversity value for biofuel production and require that biofuels must emit a minimum of 35% less greenhouse gases than the fossil fuels they replace.[13] This requirement will increase to 50% in 2017.

The social and environmental consequences of biomass / biofuels

Even if the land area could be found to generate significant quantities of energy from biomass and biofuels, would it be environmentally sustainable? Wood crop plantations such as short rotation willow coppice are usually near or total monocultures. That is, the same species of tree is planted across a given area, whereas a natural forest would contain a far more diverse range of tree species.

The growth in biofuel production globally over the last 10 years has raised a number of concerns. First generation biofuels, produced primarily from food crops such as grains, sugar cane and vegetable oils, have been increasingly questioned regarding displacement of food-crops, effects on the environment, and climate change.[14]

A report from the International Energy Agency (IEA) in 2010 stated:[15] *'In general, there is growing consensus that if significant emission reductions in the transport sector are to be achieved, biofuel technologies must become more efficient in terms of net lifecycle greenhouse gas emission reductions while at the same time be socially and environmentally sustainable. It is increasingly understood that most first-generation biofuels, with the exception of sugar cane ethanol, will likely have a limited role in the future transport fuel mix.'*

There is also currently much scientific debate on the carbon debt of biofuels – the number of years it takes for the biofuel carbon savings to displace the carbon released during the clearing of rainforest and other valuable lands. These estimates range from a year for abandoned cropland

to hundreds of years for rainforest or peat forests. Refer also to *Information Paper 4 – CO2e emissions from biomass and biofuels* for the wide disparity in emissions factors for different biofuels.

When will secondary biofuels be commercially available?

Second generation biofuels can be sourced from:

- Agricultural residues (the non-food parts of crops).
- Dedicated energy crops (e.g. miscanthus, willow coppice) which could be grown on abandoned or low value land.
- Industry waste including wood chips, paper, and skins/pulps and fish oil.

Plants are made from lignin and cellulose and splitting these enables the cellulose from the whole plant to be fermented into alcohol in much the same way as a first generation biofuel.

Second-generation biofuels are not widely produced commercially, but a number of pilot and demonstration plants have been announced or set up in recent years. The focus is initially on using agricultural and forestry residues, as they form a readily available source of biomass and can provide feedstock from current harvesting activities without the need for additional land cultivation. Supplies of oil from fish processing plants are also available in limited quantities.

Significant technical barriers for the commercial production of second generation biofuels currently exist, and while extensive research continues, full scale production is not likely until at least 2020.

Research into so called third generation biofuels also continues, the most prominent of these being growing algae (sometimes referred to as 'oilgae'). To achieve the fantastic yields claimed (between 150 to 400 MWh/hectare)[16] requires the water to be heavily enriched with carbon dioxide. The real test however is what is the net energy yield after the energy used to grow the algae (to pump CO_2 into the pond) and then convert it into a useable fuel is subtracted from the gross yield. If the technology stacks up, the future may see algae ponds clustered around power stations, with some of the flue emissions being fed into the ponds.[17]

For further discussion on energy yields from algae refer to *Sustainable Energy – without the hot air*.[18]

Notes

All websites were accessed on 20 July 2013 unless noted otherwise.

1. The data is taken from www.biomassenergycentre.org.uk/portal/page?_pageid=75,163231&_dad=portal&_schema=PORTAL.

2. Data on biomass sources and production taken from various pages on the Forestry Commission's on-line Forestry Statistics 2012 website. www.forestry.gov.uk/forestry/infd-7aqdgc

3. Table 6.1 of the Digest of UK Energy Statistics (DUKES) 2012 gives production of biomass in 2011 in tonnes of oil equivalent (toe). To convert this to MWh multiply by 11.63.
   - Wood waste = 281,000 toe x 11.63 = 3.3m MWh
   - Wood = 425,000 toe x 11.63 = 4.9m MWh
   - Total wood = 706,000 toe x 11.63 = 8.2m MWh

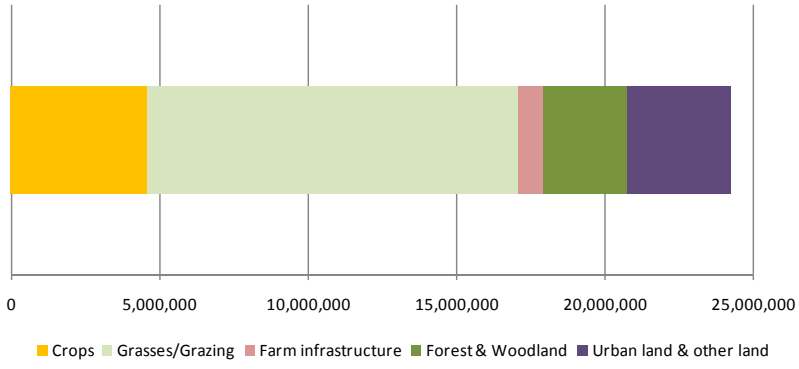
   For comparison, in 2011 straw, SRC and other plant based fuels produced 949,000 toe (11m MWh), the majority of which was used for electricity generation.

4. Woodfuel and pellets, Forestry Statistics 2012 – UK Grown Timber, www.forestry.gov.uk/website/forstats2010.nsf/LUContents/436AB0E21DFB39D3802575EE00543495

5. The DECC publication, *Energy consumption in the United Kingdom: 2012, Overall energy consumption in the UK since 1970*, Publication URN: 12D/289 states that provisional estimates for heating energy consumed in 2011 is 59,474,000 toe, which is 692m MWh. www.gov.uk/government/uploads/system/uploads/attachment_data/file/190618/chapter_1_overall_energy_consumption_in_the_uk_factsheet.pdf

6. Table 1.1, Woodland Areas and Planting, Woodland Area, Forestry Statistics 2012. www.forestry.gov.uk/website/forstats2012.nsf/LUContents/061E41873F94CC788025735D0034F33B

7. The land area of the UK is 24,251,000Ha. The breakdown of this area by land use is:



   Source: *e-Digest Statistics about: Land Use and Land Cover 2005* published by DEFRA. http://archive.defra.gov.uk/evidence/statistics/environment/land/lduse.htm#ldtb1

8. Information supplied by Dr Geoff Hogan of the Biomass Energy Centre in an email to the author on 10 January 2011. DUKES 2010 (para 7.58) also notes that 'Short rotation willow coppice plantations (SRC) have become well established but the rate of uptake of the technology has been very slow. Interest has also been shown in Miscanthus. Over 500 hectares of SRC have been have been planted in the south of Scotland and northern England to supply the Steven's Croft, Lockerbie 44 MWe project.'

9. Figure 1.6, New planting and restocking, Woodland Areas and Planting, Woodland Area, Forestry Statistics 2012. www.forestry.gov.uk/website/forstats2012.nsf/0/4F09640F0B6F8C27802573760033DE64

10. *Consumption of Biodiesel and Bioethanol in the UK*, Table 3D, DUKES 2012.

11. Transport energy consumption taken from *Renewable sources data used to indicate progress under the 2009 EU Renewable Energy Directive (measured using net calorific values*), Table 6.7, DUKES 2012

12. New Commission proposal to minimise the climate impacts of biofuel production, reference: IP/12/1112 dated 17/10/2012. http://europa.eu/rapid/press-release_IP-12-1112_en.htm

13. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

14. 'Growth in agricultural commodity use especially for biofuels, but also for heat and power generation, has begun to directly impact food markets, and the risk of trading food against fuels becomes increasingly prominent in the public discussion. At the same time, the contributions to energy security, the reduction of greenhouse gas emissions and other objectives, that today's use of agricultural commodities for bioenergy can make, are questioned.' – OECD website accessed 10 Jan 2011 http://www.oecd.org/document/14/0,3343,en_2649_33785_39633901_1_1_1_37401,00.html

    'Growing use of cereals, sugar, oilseeds and vegetable oils to satisfy the needs of a rapidly increasing biofuel industry, is one of the main drivers in the outlook. Over the outlook period, substantial amounts of maize in the US, wheat and rapeseed in the EU and sugar in Brazil will be used for ethanol and bio-diesel production. This is underpinning crop prices and, indirectly through higher feed costs, the prices for livestock products as well. Given that in most temperate zone countries ethanol and bio-diesel production are not economically viable without support, a different combination of production technologies, biofuel policies and crude oil prices than is assumed in this Outlook could to lead to lower prices than are projected in this Outlook.' – OECD-FAO Agricultural Outlook 2007-2016 published in 2007 by the Organisation For Economic Co-Operation And Development (OECD) and the Food And Agriculture Organization Of The United Nations (FAO).

15. *Sustainable Production of Second-Generation Biofuels – Potential and perspectives in major economies and developing countries* draft report published by IEA in Feb 2010. http://www.iea.org/papers/2010/second_generation_biofuels.pdf

16. According to the Oilgae Digest the 'yields of oil and fuels from algae are much higher (10-25 times) than competing energy crops.' - http://www.oilgae.com/ref/report/digest/digest.html accessed 15 Jan 2011.

17. A bubble-maker that won a £250,000 prize from the Royal Society in October 2010 for its ability to transform the cost and effectiveness of growing algae for biofuel, treating sewage and cooling computers. http://www.guardian.co.uk/environment/2010/oct/15/bubble-maker-algae-royal-society

18. Solar II chapter in *Sustainable Energy – without the hot air* by David JC MacKay, UIT Cambridge, 2009. www.withouthotair.com/cD/page_283.shtml