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Information paper – 4
CO_2e emissions from biomass and biofuels

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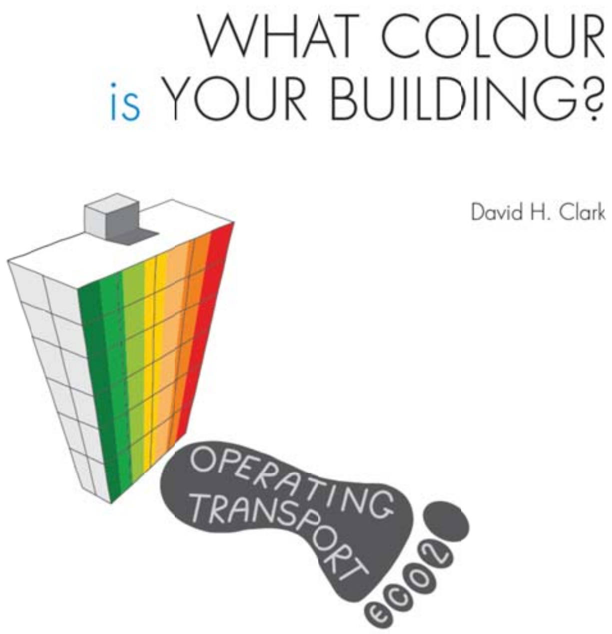
A paper referenced in the book:



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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 The papers do not form part of the book and have not been peer reviewed.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.

CO_2e emissions from biomass and biofuels

This information paper provides a brief overview of the CO_2e emissions due to biomass and biofuels. In this paper biomass means solid fuels (wood pellets, wood logs and wood chips) while biofuels are liquid or gas fuels which are derived from organic materials such as crops, anaerobic digesters and recycled vegetable or animal oils (biodiesel, bioethanol, biomethane and biogas).

1. BIOMASS

Is biomass carbon neutral?

Biomass is generally considered to be close to carbon neutral because the CO_2 emitted to the atmosphere during combustion is absorbed while growing the replacement biomass. Figure 1 shows the biomass is 'carbon neutral' cycle, which is often put forward by proponents of biomass.

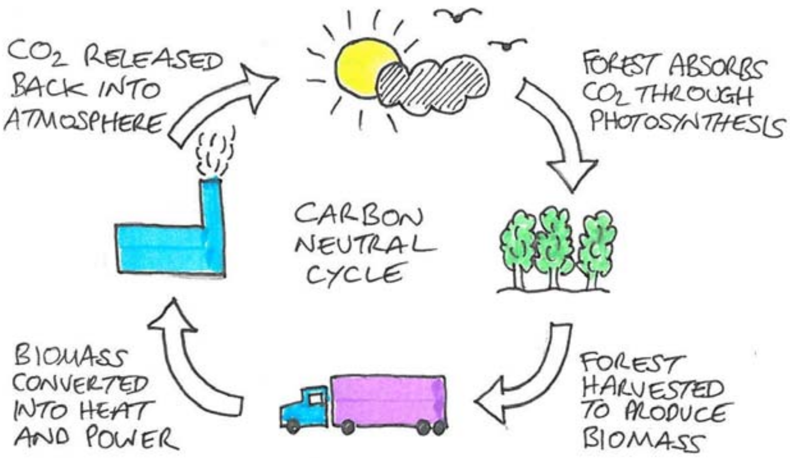


Fig 1 A biomass is carbon neutral diagram

The emissions factors from the *2012 Guidelines to DEFRA/ DECC's GHG Conversion Factors for Company Reporting*[1] are shown in Table 1. Biomass should really be classed as a low carbon fuel not a carbon neutral fuel because emissions occur during farming, harvesting, processing and delivering the fuel, which are shown as Scope 3 emissions in Table 1.

When wood based biomass is combusted it releases 75% more CO_2 per unit of fuel energy (0.35 kgCO_2e per kWh) than natural gas (0.2 kgCO_2e per kWh) because wood has a lower hydrogen content than fossil fuel. This difference increases further when the efficiency of converting the fuel energy into heat inside buildings is considered (biomass boiler efficiencies are typically 85% compared to gas boilers at 90%).

	Unit	kgCO_2e per unit			
		Scope 1	Scope 2	Scope 3	Outside scope
Wood logs	kg	0		0.08	1.44
Wood chips	kg	0		0.06	1.37
Wood pellets	kg	0		0.18	1.65
Biogas	kg	0		0.00	2.04
Wood logs	kWh	0		0.02	0.35
Wood chips	kWh	0		0.02	0.35
Wood pellets	kWh	0		0.04	0.35
Biogas	kWh	0		0	0.25

Scope 3 emissions include the production and transportation of the fuels.

The emissions outside of the scope are the CO_2 emissions released when the fuel is combusted and are roughly equivalent to the CO_2 absorbed in the growth of new feedstock (plants and trees) used to produce the fuel in the future.

The kWh for biomass are based on a Net Calorific Value (lower heating value) basis.

The biomass emissions factors do not account for the global warming contribution of black carbon. Refer to Information Paper 5 – Global warming due to black carbon for further discussion on this.

Table 1 **CO_2e emission factors by scope for biomass (source: DECC)**

Currently the world is consuming more timber than it replenishes (see box on page 4), therefore from a global perspective, more CO_2 is being released into the atmosphere from the consumption of timber than is being reabsorbed and fixed by the renewal of timber in new plantations and natural seeding. While biomass is renewable, should it be considered to be low carbon? Is planting new trees to absorb CO_2 from biomass combustion any different, from a carbon accounting perspective, to planting trees to offset CO_2 emissions due to air travel?

This is a complex argument and it depends on where the biomass is sourced from. Currently most wood chip/pellet in the UK is sourced from recycled wood, sawmill waste, forest residue (the bits that aren't useful for timber products and energy crops).[2] If the biomass is from these sources then assuming a low carbon emission factor is probably valid. But what about new plantations and energy crops?

The carbon neutral diagram (Figure 1) implies a closed loop system and that the source forest continues to take up carbon as rapidly as it is released by burning. But how quickly is the CO_2 reabsorbed from the atmosphere? Softwood plantations cultivated for energy production have a 15 year harvesting cycle. In comparison, short rotation willow coppice has a 3 year harvesting cycle. Cereal crops, such as rapeseed and sugar beet, grown for biofuel production have an annual cycle.

Figure 3 shows the processes and indicative timescales for wood pellets timescale to indicate when the emissions are released and absorbed.

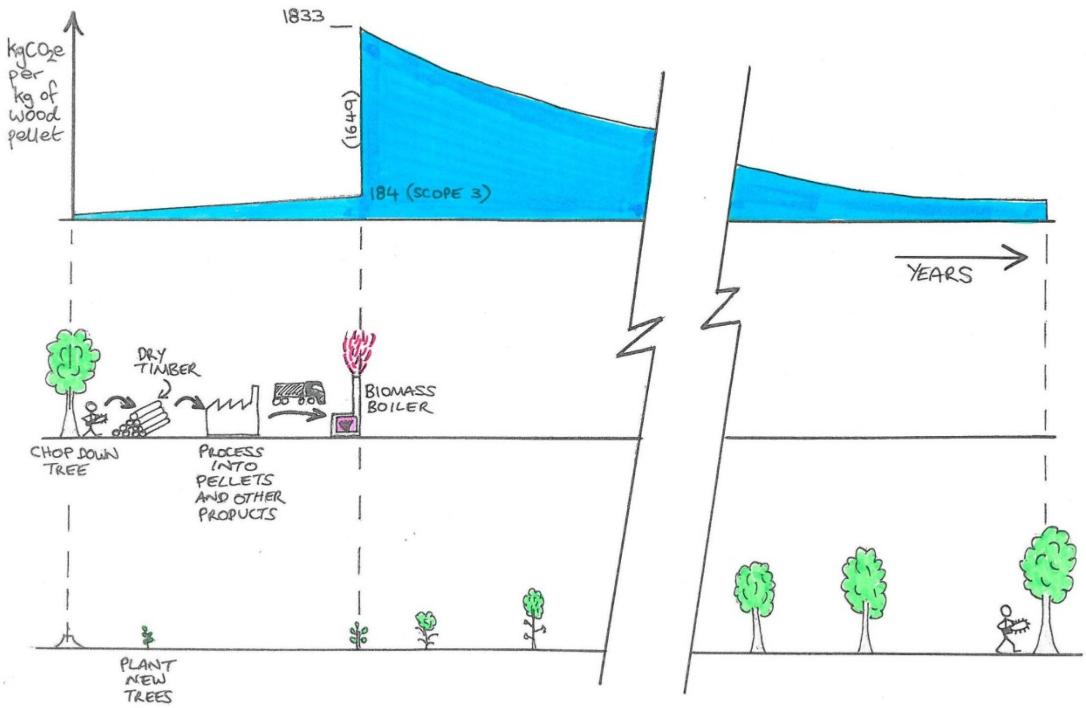


Fig 3 **Indicative CO_2 emissions and reabsorption timescales for wood pellets**

SUSTAINABLE GLOBAL FORESTRY?

The *Global Forest Resources Assessment 2010* published by the United Nations' Food And Agriculture Organization[3] states that:

- Around 13 million hectares of forest were converted to other uses or lost through natural causes each year in the last decade compared with 16 million hectares per year in the 1990s.
- Deforestation – mainly the conversion of tropical forest to agricultural land – shows signs of decreasing in several countries but continues at a high rate in others.
- The area of planted forest is increasing and now accounts for 7% of total forest area.
- 30% of the world's forests are primarily used for production of wood and non-wood forest products.

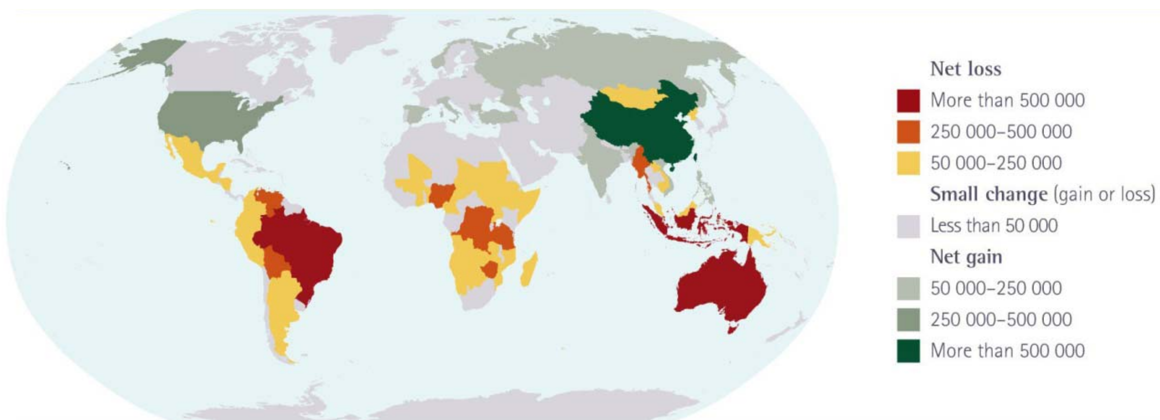


Fig 2 **Net change in forest area by country, 2005 – 2010 (ha/year) (source: UNFAO)**

What is the right emission factor to use?

We have a pressing need to start reducing global CO_2 emissions immediately, but burning biomass today will continue to increase the CO_2 concentration in the atmosphere. It is only when the replacement feedstock has fully grown that the CO_2 is fully reabsorbed.

So should we use a 'carbon neutral' emissions factor for wood pellets of 0.04 kgCO_2e/kWh (net CO_2e emissions assuming carbon sequestration) or 0.39 kgCO_2e/kWh (all emissions accrued at the point of consumption).

There is no simple answer to this – it depends on where the biomass is sourced from and what it would be used for otherwise. If it is left to decompose anaerobically, like landfill, then it produces methane which is a more potent greenhouse gas than burning it. To illustrate the impact this decision has on using wood based biomass as a low carbon fuel source, a 'CO_2 half –life' emissions factor could be considered:

- 'carbon neutral' emission factor 0.04 kgCO_2e/kWh
- 'CO_2 half-life' emission factor (0.04 + 0.35/2) 0.19 kgCO_2e/kWh

The half-life factor recognises that biomass has an immediate impact on greenhouse gas concentrations in the atmosphere while acknowledging that over time (assuming the forestry source is replanted) most of the CO_2 will be reabsorbed. By coincidence the half-life factor is similar to the emissions factor for natural gas – the fossil fuel that is often replaced by biomass for heating buildings. This shows how important it is to understand where the biomass is being sourced from and if the feedstock is from sustainable sources.

The emissions factors for different biomass fuels are shown in Table 2.

	Unit	kgCO_2e per unit	
		Carbon neutral	CO_2 half-life
Wood logs	kg	0.08	0.80
Wood chips	kg	0.06	0.75
Wood pellets	kg	0.18	1.01
Biogas	kg	0.00	n/a
Wood logs	kWh	0.02	0.19
Wood chips	kWh	0.02	0.19
Wood pellets	kWh	0.04	0.21
Biogas	kWh	0.00	n/a

Table 2 **CO_2e emissions factors for biomass including potential CO_2 half-life**

HARVESTING TREES VERSUS LEAVING THEM TO GROW?

In 2013 the UK Department for Climate Change noted that research shows that the use of harvested wood from UK managed forests *exclusively* for bioenergy (replacing fossil fuels) has higher relative CO_2e emissions than leaving the trees unharvested in the forest.[4] This suggests that on the basis of CO_2e emissions, there is not a strong case to produce bioenergy in this way.

However, DECC noted that such a scenario is very unlikely in the UK and that the research '*did not consider certain specialised forest types and management regimes dedicated exclusively for the production of bioenergy from harvested wood (e.g. short rotation forestry, short rotation coppice).*' While such practices are uncommon in the UK they do occur to some extent elsewhere, using different forestry practices to those employed in harvesting trees mainly for construction products.

DECC is currently undertaking more research to get better data on this issue.

How sustainable is importing biomass from overseas?

Many countries, such as the UK and Denmark, cannot currently produce enough biomass to meet demand and have to import it. How does importing biomass affect the embodied emissions? The component of emissions due to transport of biomass will of course vary depending on the distance travelled and the type of transport (road versus shipping).

To test this consider two scenarios: 1 tonne of wood chip produced locally in the UK versus wood chip imported from the Baltic. The simple calculation in Table 3 shows that the location of the biomass source can have a reasonable impact on the emission factor and sourcing locally is clearly better.

	Unit	Local	Overseas
Road distance	km	100	500
Shipping distance	km	0	1,500
Total distance	**km**	**100**	**2,000**
Road emissions	$kgCO_2e$/tonne	10.7	53.5
Shipping emissions	$kgCO_2e$/tonne	0	6
Total transport emissions	**$kgCO_2e$/tonne**	**10.7**	**59.5**
Energy content of 1 tonne of biomass	kWh/tonne	4,900	4,900
Transport emissions	**$kgCO_2e$/kWh**	**0.002**	**0.012**

The transport emissions factors are: [5]

Average diesel articulated lorry 0.107 $kgCO_2e$ per tonne.km

Average bulk carrier (shipping) 0.004 $kgCO_2e$ per tonne.km

Table 3 **Estimate of CO_2e emissions due to transporting biomass**

2. BIOFUELS

The emissions factors used in the book (shown in Table 3) are from the DEFRA guidelines. The CO_2 half -life factor is not considered applicable to biofuels as the crops grow rapidly (less than 1 year) and so the CO_2 released during combustion is quickly reabsorbed.

Fuel	Unit	kgCO_2e per unit				
		Total (scope 1 to 3)	Scope 1	Scope 2	Scope 3	Outside scope
Biodiesel	litres	**1.13**	0.02		1.11	2.49
Bioethanol	litres	**1.12**	0.35		0.77	1.30
Biomethane	kg	**1.33**	0.01		1.32	2.72
Biodiesel	kWh	**0.12**	0.00		0.12	0.27
Bioethanol	kWh	**0.16**	0.04		0.13	0.22
Biomethane	kWh	**0.10**	0.00		0.10	0.20

Notes

1. The direct emissions of CO_2 for biofuels are considered to be zero but the CH_4 and N_2O released is not reabsorbed by growing new crops and is therefore included in Scope 1.
2. Scope 3 emissions include the production and transportation of the fuels.
3. The emissions outside of the scope are the CO_2 emissions released when the fuel is combusted and are roughly equivalent to the CO_2 absorbed in the growth of new feedstock (plants and trees) used to produce the fuel in the future.
4. The kWh for biofuels are based on a Net Calorific Value (lower heating value) basis.
5. Bioethanol is usually blended with 15% petrol for use in typical engines.

Table 3 **CO_2e emission factors for biofuels (source: DEFRA)**

These are averages in the UK, however, the emissions from biofuels vary considerably depending on the type of fuel, the feedstock used, and the country of origin. In 2009 the UK Renewable Fuel Agency (RFA)[6] published default factors for a variety of fuels based on a methodology which considers farming inputs, processing and so on. Figure 4 shows an overview of the methodology used.

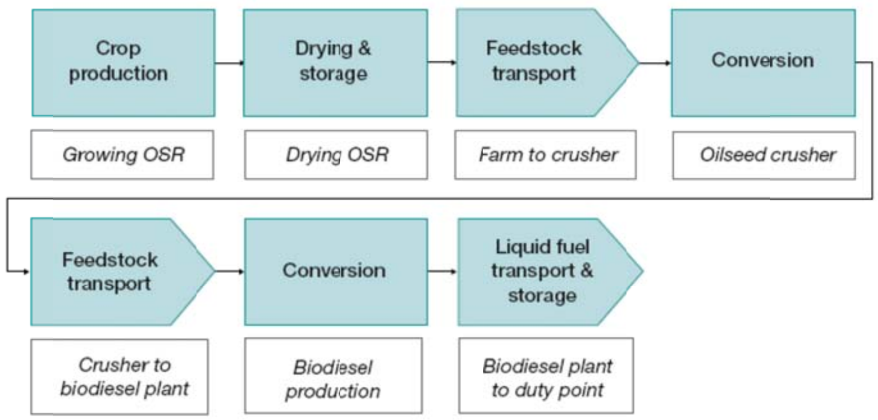
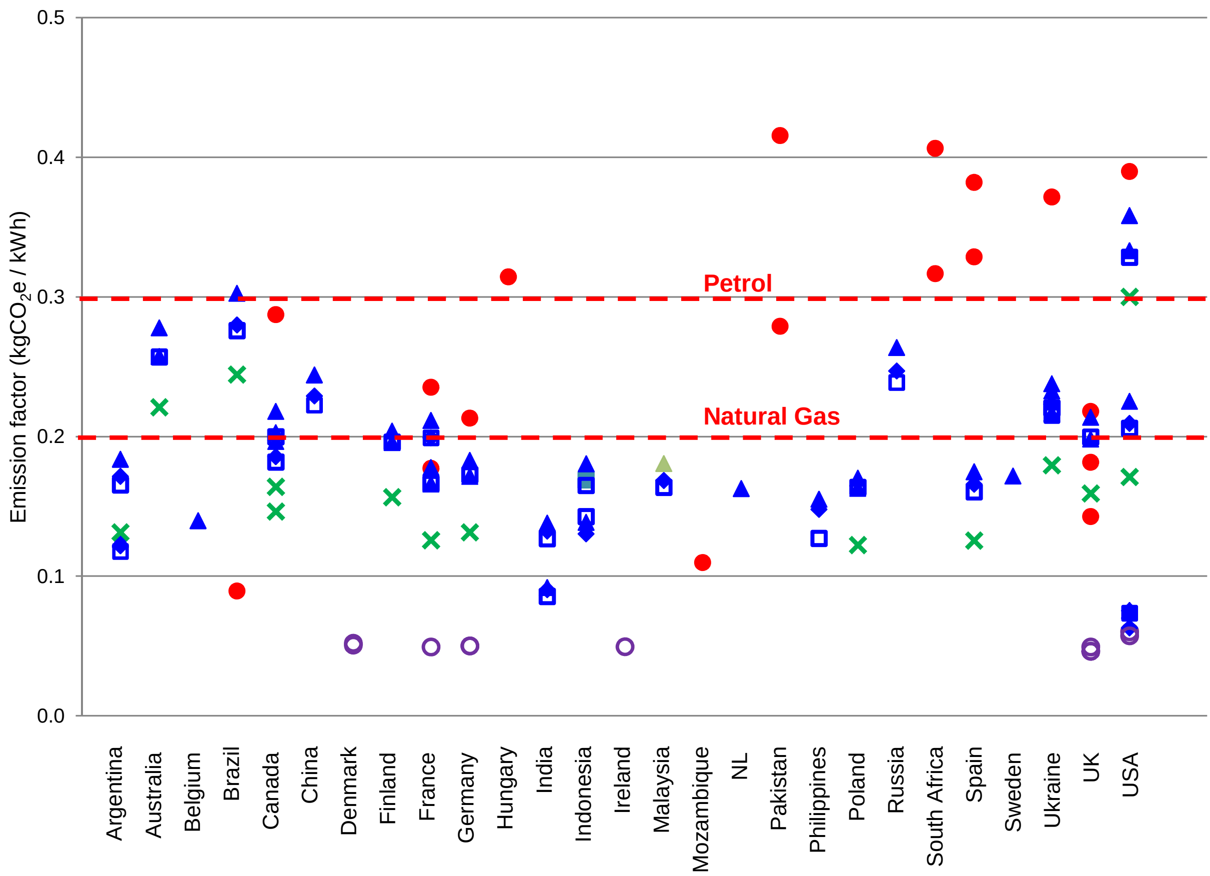


Fig 4 **Example fuel chain for oil seed rape (source: UK RFA)**

Figure 5 shows a summary of these emission factors, converted into kgCO_2e/kWh, for ethanol, biodiesel and pure plant oil produced in a variety of countries from different feed stocks.



	Fuel Type	Sources
●	Ethanol	Wheat, Barley, Sugar Beet, Sugar Cane, Molasses & Corn
◆	ME Biodiesel	Oil Seed Rape, Soy, Palm, Sunflower, Coconut, & Jatropha Corn (ME only)
▲	HVO Biodiesel	
□	CHVO Biodiesel	
×	Pure Plant Oil	Oil Seed Rape & Soy
○	Recycled Oil (biodiesel)	Cooking Oil & Tallow

Note: the kgCO_2/t emission factors from the RFA report were converted to kgCO_2e/kWh based on calorific values of 7.44 kWh/kg for ethanol, 10.33 kWh/kg for ME biodiesel, 12.22 kWh/kg for HVO biodiesel and 10.44 kWh/kg for pure plant oil.

Fig 5 **CO_2 emission factors for biofuels by type and country (source: data adapted from RFA, 2010)**

Of the 125 fuel emission factors shown in Figure 5, one quarter are higher than natural gas (0.2) and 10% are higher than petrol and diesel (0.3). The emissions factors do not include any carbon debt associated with clearing land or forest to create areas to grow the crops.

Only 15% of the fuels are below 0.1 kgCO_2/kWh, and these are primarily recycled oils from cooking oil and tallow. There is also a large variation in emission factors for the same feed stock –

Oil Seed Rape (OSR) used to make HVO Biodiesel in Poland (0.17) has emissions half that of the USA (0.36). Using OSR to make ME Diesel in Belgium is lower still (0.14).

Table 4 shows a comparison of the RFA factors to the DEFRA factors:

Fuel	Emissions factors ($kgCO_2e$ / kWh)			
	DEFRA factor	RFA factor range for UK produced fuels	RFA factor (lowest worldwide)	RFA factor (highest worldwide)
Ethanol (100%)	0.16	0.14 to 0.22	0.09	0.42
Biodiesel (100%)	0.12	0.05* to 0.20	0.05*	0.36
Pure plant oil	not stated	0.16	0.12	0.30

* - produced from cooking oil

Table 4 **Comparison of biofuel emission factors**

The DEFRA factors are within the lower third of factors calculated by the RFA. With such large ranges in emissions factors the importance of understanding where a particular biofuel is being sourced from cannot be understated.

A NOTE ON PURE PLANT OIL

Pure plant oil (PPO) is made from various vegetable oils (e.g. rapeseed, canola, palm, soya) and differs from biodiesel in that it doesn't go through a chemical process called transesterification (the separation of glycerine from the oil to leave methyl esters, the chemical name for biodiesel). Consequently it often has a lower carbon footprint than biodiesel although, in this emerging market, no one can seem to agree on what the emissions factor is.

Phoenix Fuels, who provided biofuel for a school CHP system in Nottingham in 2010 estimate a factor of 1.76 $kgCO_2$ per litre for rapeseed oil (1.03 $kgCO_2$ for the production of the oil and the rest for processing).[7] Assuming a calorific value of 37.6 MJ/litre gives an emissions factor of 0.17 $kgCO_2$/kWh which is similar to the RFA value in Table 4.

Elsbett, who make and convert engines to run on PPO, estimate that rape oil has an emissions factor of 0.87 $kgCO_2$ per litre, which is half the estimate of Phoneix Fuels, and is equivalent to 0.08 $kgCO_2$/kWh. This is half the value in Table 4.

Further research is required to confirm the emission factors to use for pure plant oil in the UK.

Notes

All websites were accessed on 15 June 2013 unless noted otherwise.

1. *2012 Guidelines to DEFRA / DECC's GHG Conversion Factors for Company Reporting*. The *2012 Methodology Paper for Emission Factors* provides background to how all the emissions factors were calculated. Values for methane (CH_4) and nitrous oxide (N_2O) are presented as CO_2 equivalents (CO_2e) using GWP factors from the IPCC 2nd assessment report (GWP for CH_4 = 21, GWP for N_2O = 310). Indirect emissions include extracting, processing and delivering energy and fuels to end users. www.gov.uk/government/publications/2012-greenhouse-gas-conversion-factors-for-company-reporting

2. Refer to Information paper 25 – Biomass and biofuel sources.

3. Global Forest Resources Assessment 2010. www.fao.org/forestry/fra/62219/en/

4. UK Bioenergy Strategy supplementary note: Carbon impacts of forest biomass, DECC, Nov 2012. www.gov.uk/government/uploads/system/uploads/attachment_data/file/65618/7014-bioenergy-strategy-supplementary-note-carbon-impac.pdf

5. Refer note 1

6. Carbon and Sustainability Reporting Within the Renewable Transport Fuel Obligation: Technical Guidance Part Two - Carbon Reporting – Default Values and Fuel Chains version 2.1 published in July 2010 by UK Renewable Fuel Agency. http://webarchive.nationalarchives.gov.uk/20110407094507/http:/www.renewablefuelsagency.gov.uk/sites/rfa/files/RFA%20CS%20TG%20Part%202%20v2.1.pdf

7. www.fwi.co.uk/Articles/2009/10/13/118301/Local-energy-projects-could-be-a-winner-for-OSR-growers.htm

8. *Pure Plant Oil - Is this a superior biofuel?* a presentation by James Scruby, Elsbett AG and Verdant Fuel Ltd at Biofuels Expo and Conference, 15th October 2008. www.slideshare.net/bioenergywm/pure-plant-oil-as-fuel-elsbett-ltd