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TRANSPORT BIOFUELS

Transport accounts for 25% of the UK's carbon dioxide (CO_2) emissions.[1] Low carbon fuels such as biofuels are expected to play a part in reducing CO_2 emissions from the transport sector. Biofuels are produced from biomass (plant or animal material). They are renewable and have typically lower lifecycle CO_2 emissions than petrol or diesel. 'Second generation' biofuels may offer even lower CO_2 emissions, but these are not yet commercially available. Although biofuels can provide carbon savings, some groups are concerned about the environmental and socio-economic impacts of biofuel feedstocks, especially in developing countries. This POSTnote examines the issues relating to current and future transport biofuels.

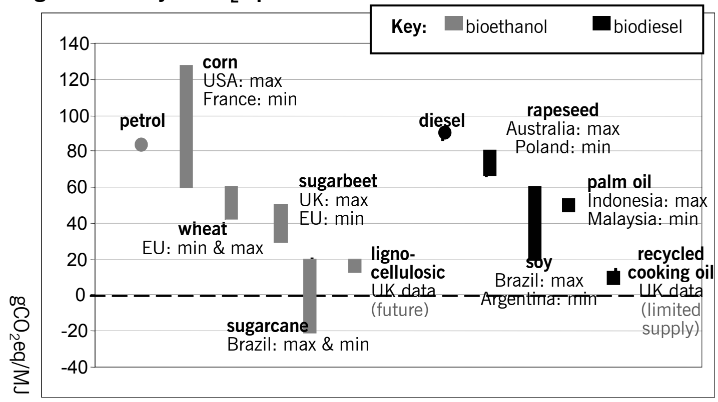
What are biofuels?

Biofuels are renewable liquid fuels produced from plant or animal material (biomass). Plants store their energy as sugar, starch or oil. These have a high-energy value and can be converted to liquid biofuels. Currently, the two main types of liquid biofuels are biodiesel, produced from plant oil and bioethanol, from plant derived sugar or starch. Biofuels can be directly substituted for, and blended with, conventional fossil fuels without the need for major modification of vehicles or refuelling infrastructures. However, current biofuels have lower energy contents than conventional fossil fuels which can reduce fuel economy, although low volume biofuel blends (10% or less) have a negligible effect (Box 1).

Life cycle CO_2 emissions from biofuels

Life cycle analyses show that biofuels can have 20% to 80% lower CO_2 emissions compared to fossil fuels.[2,3] Petrol and diesel fuels emit ~80-85gCO_2 equivalent per unit of energy (measured in megajoules, MJ) (Fig. 1). This compares to a range of 20 to 60gCO_2eq/MJ for most biofuels. The exception is corn derived bioethanol produced in the US, which has higher carbon emissions than fossil fuels. This range exists because biofuels have differing environmental benefits. Factors such as production, processing and transport of feedstock affect emissions. Biofuels are considered 'carbon-neutral' when burned, so that the CO_2 they release during vehicle use is equivalent to the CO_2 they absorbed during their growth. However, they are not 'carbon neutral' over their entire life cycle. Energy is input and CO_2 is emitted during each stage prior to vehicle use, from cultivation and fertilizer production, through to harvesting, transportation, processing and refining of the biomass into liquid biofuel. The greatest CO_2eq emissions often occur during the extraction and processing stage (~25-80% of total life cycle emissions), since this is where energy, usually from fossil fuel fired heat and electricity, must be input to convert the biomass into biofuels. However, emissions from fertilizer manufacture and cultivated soils can also be a large source of emissions (~5-60%).[3,4]

Figure 1. Life cycle CO_2eq emissions of fossil fuels and biofuels



Source: Values for all data from: Carbon reporting - default values and fuel chains, *E4Tech, 2007, except wheat:* Well-to-wheels analysis, *Concawe 2006, and cooking oil/lignocellulosic:* Carbon & energy balances, *Sheffield Hallam, 2003. (See refs 2 & 3)*

Life cycle emissions are measured as carbon dioxide equivalents (CO_2eq) to allow comparison between different greenhouse gases. Other greenhouse gases measured as CO_2eq are methane, (CH_4), and nitrous oxide, (N_2O). Although these gases are usually emitted in smaller amounts, their global warming potentials are greater than CO_2. For example, over 100 years, one tonne of methane is equivalent to 23 tonnes of CO_2.

Box 1 Characteristics of liquid biofuels

Fossil fuels and biofuels share similar properties and can be blended within limits. Up to 15% biofuel can be added to fossil fuel without modifying vehicles or fuel infrastructure. Fossil fuels have a higher energy content than biofuels. The energy content is measured in mega joules per litre (MJ/l). The more carbon atoms a fuel contains, the more energy it has. Diesel contains the most carbon, and delivers the most energy at 36MJ/l. Biodiesel has slightly less carbon and delivers 33MJ/l. Petrol has still less, delivering 32MJ/l, while ethanol has the least carbon, and so the least amount of energy, 21MJ/l. The energy content of bioethanol is one third lower than petrol, so vehicles running on a 10% blend of bioethanol, achieve 3% fewer kilometres per litre.

- **Biodiesel** can be produced from plant sources, for example, rapeseed, soybean, sunflower or palm, from animal fats such as beef or sheep tallow, and from used cooking oil. It has similar properties to conventional diesel so is used in diesel vehicles.
- **Bioethanol** is made from sugar and starch-rich plants such as sugar cane, sugar-beet, wheat and corn and can be substituted for petrol in vehicles.

Other biofuels

Biogas (methane) collected from landfill and animal manure, qualifies as a biofuel under the Renewable Transport Fuel Obligation (see Policy section), but its use as a transport fuel is not widespread in the UK. Biobutanol can be derived from the same feedstocks as bioethanol. It has a higher energy content than bioethanol, closer to that of petrol, so offers better fuel economy, however, the technology to produce it commercially is still being developed (see Issues).

This 'field-to-tank' (or 'well-to-wheel') life cycle assessment presented here includes only the CO_2eq emissions from the **production** of biofuels. It does not consider tailpipe emissions arising during vehicle use, as this would require adoption of an agreed set of vehicle performance factors, such as kilometres travelled per kilogram of biofuel consumed. The variability of these factors is too wide to address in this briefing.

Policy

Reducing transport emissions is an important part of the UK government's energy strategy, which aims to achieve a 20% reduction in carbon dioxide emissions by 2010. Promoting the use of transport biofuels in the UK is based on three objectives:[5]

- carbon savings compared to fossil fuels;
- diversity of energy supply, reducing 100% dependency on fossil fuels for transport;
- benefits for the rural economy such as diversification of agricultural markets.

There are two policy instruments driving the uptake of biofuels in the UK (Box 2):

- EU Biofuels Directive;
- UK Renewable Transport Fuel Obligation (RTFO).

Carbon and sustainability reporting

Under the RTFO, obligated companies will be required to submit reports on both the net greenhouse gas saving and sustainability of the biofuels they supply. Two draft frameworks, managed by the Low Carbon Vehicle Partnership (LowCVP), were published in June 2007:

Box 2 Biofuels policy

- **EU Policy:** The EU Biofuels Directive (2003/30/EC) was adopted in May 2003 to promote use of transport fuels from biomass.[6] It sets an EU wide target for biofuels to achieve 5.75% of the market share of transport fuels by 2010. The EU is far from this target, achieving only 1.4% across its member states in 2005.[7] In January 2007 the European Commission announced a new binding target of 10% biofuels by 2020 for all member states.
- **UK Policy:** There has been a 20 pence/litre duty reduction on biodiesel and bioethanol since 2002 and 2005 respectively. Despite this, penetration of biofuels into the UK remained low: in 2005, biofuel made up only 0.24% of total UK fuel sales. In 2004, the government proposed an 'obligation' to develop the UK biofuels market. The RTFO, which comes into effect in 2008, requires producers and suppliers of transport fuels to source 5% of their fuel from a renewable source by 2010. The estimated reduction in emissions equates to taking 1 million cars off the road.

The 5% target is the maximum biofuel content allowed by the EU Fuel Quality Directive, and without invalidating vehicle warranties. The RTFO is modelled on the Renewables Obligation (RO) scheme for the UK electricity industry.

- **Carbon Reporting** - a method to measure life cycle CO_2 emissions (by E4Tech);
- **Sustainability Reporting** - defining the sustainability criteria for biofuels (by Ecofys).

The government is now seeking views on the ease of providing this information to the RTFO administrator.

First generation biofuel technologies

'First generation' biofuels are produced using existing refining and fermenting technologies (Box 3). At present, biodiesel is the only biofuel produced in the UK, with over 30 companies operating production facilities. The first UK bioethanol production plant is being built in Norfolk by British Sugar, and is due to start operating in 2007. BP and ABF (Associated British Foods) jointly plan to build the UK's largest bioethanol plant near Hull, to start production in 2009.[8]

Biofuel yields and feedstocks

Biofuel yield varies widely depending on the feedstock, climate and the method of cultivation (use of fertilizer or irrigation). The energy yield of a biofuel is represented by an input to output ratio of energy that reflects the energy required to create the fuel, and the amount of energy the biofuel delivers as a fuel. For example, sugarcane, at a ratio of 1:8, yields eight units of energy for every one unit invested to grow, harvest and convert the cane into ethanol. Some analyses show that under certain conditions, it can take more energy to produce a biofuel than it finally delivers, (e.g. US corn-derived bioethanol).[9] In general, tropical crops such as sugar cane and oil-palm have higher energy yields than temperate crops such as sugarbeet and rape.

Second generation biofuel technologies

Second generation is the term used to describe 'lignocellulosic' biofuels which are made from the *whole* plant, not just from the sugar- or oil-rich components of

Box 3 How first generation biofuels are made[10]

Biodiesel

Plant-derived or waste-cooking oil is converted to biodiesel is through a chemical process called 'transesterification'. In this process, an alcohol is added which reacts with the oils. Application of heat and a catalyst induces a chemical reaction which results in two products: biodiesel (fatty acid alkyl ester), and glycerine (a by-product) which is removed, leaving the biodiesel.

Bioethanol

Two key reactions convert biomass to bioethanol:

- **Hydrolysis**, a chemical reaction that converts the starches in the raw feedstock to simple sugars. Acids and enzymes are used to catalyze this reaction.
- **Fermentation**, a series of chemical reactions that convert sugars to ethanol. Fermentation is caused by yeast or bacteria which feed on the sugars. Ethanol and carbon dioxide are produced.

After the oils and sugars in the biomass have been converted to biofuel, the by-products can be burned to produce electricity for the biomass-to-biofuel conversion process. The residual material from bioethanol production is known as distiller's dark grain and solubles (DDGS). It could be used to substitute other solid fuels (e.g. coal), but its main use is as animal feed.

food crops. Lignocellulosic biomass, is made up of complex sugars, which form the fibrous and generally inedible portions of plants. Biofuels produced from whole plants, can be derived from a variety of non-food feedstocks including wood, grasses like miscanthus, purpose grown energy crops such as poplar and willow and biomass wastes from urban, agricultural, and forestry sources. There are two main technologies to convert whole plant biomass to liquid biofuels: gasification and chemical conversion (Box 4).

Carbon savings from second generation biofuels

Second generation technologies deliver lower emissions than first generation processes over their life cycle. They achieve this by using by-products to power the biomass-to-liquid conversion process. For example, leftover plant fibres would be used in an onsite combined heat and power (CHP) plant to generate the heat and electricity needed to convert the biomass to liquid, either via gasification or chemical conversion. Second generation feedstocks require low energy inputs, with fewer fertilizers and pesticides, so emissions from the field during cultivation are lower. They are also higher yielding per hectare than food crops because the whole plant is used. Essentially, the energy conversion efficiency is higher for second generation processes.

However, first generation biofuels can also benefit from using by-products, such as the DDGS (Box 3), to power their processes. In Brazil, the life cycle CO_2eq emissions of bioethanol derived from sugarcane can be as low as those achieved for second generation lignocellulosic technologies. This is because the sugarcane bagasse, the fibrous cane material that remains after the sugar has been extracted, is used to provide the energy for the conversion process.

Box 4 How second generation biofuels are made

Gasification (biomass to liquid conversion)

When biomass is heated with little or no oxygen, it gasifies to a mixture of carbon monoxide and hydrogen known as syngas. A chemical catalyst is then added to convert the gas into liquid hydrocarbons (biofuels), a process known as Fischer-Tropsch (FT) synthesis.

Chemical (lignocellulosic) conversion

The conversion process begins by pre-treating the biomass to separate it into its primary components: cellulose, hemicellulose and lignin. Enzymes are added to the mixture to break down the cellulose into simpler sugars which are then fermented to create bioethanol.

Development of second generation technologies

There is not yet any commercial production of biofuel from second generation technologies. Despite the international interest that these fuels are generating, industrial and academic analysts estimate that the technology required to process the whole plant is currently 5-10 years away[11] (see Issues). Two Canadian companies, Iogen and SunOpta, operate demonstration (non-commercial) chemical conversion plants and are developing processes to break down lignocellulosic feedstocks. The first commercial scale biomass-to-bioethanol plant, is currently being constructed in Spain by Abengoa Bioenergy. Development of gasification technologies is also at the pilot and demonstration stages. Several companies are working to develop an integrated biomass-to-liquid (BTL) gasification process to produce biodiesel, including Choren in Germany, ECN/Shell in the Netherlands and Chemrec in Sweden.

Issues

The expansion of the global biofuel industry has raised concerns about the impacts of biofuels. The main issues are deforestation, biodiversity loss and carbon release due to land use change, the availability of land and feedstock, and competition between biofuels and food production.

Environmental sustainability of biofuels

Environment and development organisations agree that most biofuels can offer CO_2eq savings compared to fossil fuels. However, there is also some opposition to biofuels from these agencies. In March 2007, a group of UK-based NGOs including Oxfam, Friends of the Earth and Greenpeace, released a joint statement expressing concern that unregulated expansion of the biofuel industry could increase deforestation and so actually increase carbon dioxide emissions.

A number of schemes which aim to certify sustainable agriculture practices have been established for some dual purpose (food and fuel) crops. These include the Roundtable on Sustainable Palm Oil (RSPO) and the Basel criteria for responsible soy production. Crops such as sugar cane are not yet covered by a code of sustainable practice, but it is expected that standards will be developed in the future.

Carbon release due to land use change
Ploughing up grassland or forest for biofuels can have serious greenhouse gas consequences. Soil disturbance releases soil carbon and the change in land use reduces the organic carbon stored in the soil. Although this happens only once, the effect is large and long-lasting. The biofuels grown on the land do result in a CO_2 saving by replacing fossil fuels, but in terms of the total carbon budget, planting biofuels on grassland would not pay off for decades.[2]

Land and biomass feedstock availability
A report by the UK National Farmers' Union (NFU) estimates that there is sufficient domestic biomass feedstock and land availability in the UK to supply the 5% RTFO target in 2010.[12] This target would require 1.2 million hectares, (i.e. 20%), of the UK's **arable** land to be dedicated to biofuel crops. If the RTFO is extended beyond 2010 to require higher incorporation of biofuel, UK demand would need to be met by second generation and imported biofuels.[13]

Some environmental groups are concerned that limited land availability in the UK may see biofuel crops grown on 'set-aside' agricultural land which currently provides biodiversity benefits.[14] They warn that this pressure will extend to developing countries as more countries seek more land for biofuel crops. However, analysis by the International Energy Agency suggests that globally, there is a large amount of unused agricultural land available. At present, 1.5 billion ha of land is used worldwide for crops, but a further 2.8 billion ha is suitable for agriculture.[15]

Food versus fuel debate
A common objection to biofuels is that they may divert agricultural production away from food crops, threatening food supplies, especially in developing countries. Development agencies are concerned that biofuel companies may put pressure on local farmers to sell their land, or replace their food crops with energy crops. Limited knowledge of cultivation practices for these new crops might result in low yields and poor financial returns.[16] Biofuel companies investing in developing countries argue that non-food crops have the potential to reduce poverty and unemployment by giving farmers access to high-value energy crops without competing with food production. The biofuel can be used locally for transport and energy, and surplus can be exported to international markets. Yet, some plantations may still be established solely for export markets. Not all biofuel crops compete with arable land. One example is jatropha, an inedible plant which has a high oil content and can be grown on marginal land, reducing pressure on land for food crops. Jatropha plantations and refineries are now being established in India and southern Africa.[17]

Technical obstacles
One of the main problems hindering the development of new biofuels is the ability to scale up processes to produce commercial volumes. In 2006, British Sugar, together with BP and DuPont, announced it would convert an existing bioethanol plant to a biobutanol plant. Biobutanol has a higher energy content than bioethanol, so is more comparable to petrol. Although the plant was due to start operation in 2007, this has been delayed as the processing technology has so far yielded only sub-commercial quantities of biobutanol.

For second generation biofuels, a major obstacle to gasification is that the technology is not widespread. There are only five Fisher-Tropsch (FT) plants in operation worldwide, and experience in this process is focused on liquid fuels derived from coal or gas. There is little experience of gasifying biomass, or of linking it with the FT process. The main barrier to lignocellulosic bioethanol production is developing enzymes capable of efficiently breaking down the cellulose into simple sugars. The high cost of this technology means that currently, it is too expensive to be used on a commercial scale.[18]

Overview
- Most liquid biofuels have 20 to 80% less life cycle CO_2eq emissions than conventional fossil fuels.
- Using by-products (such as DDGS) to provide the energy to make first generation biofuels, could further reduce their life cycle emissions.
- Second generation biofuels do not require food crops and offer lower life cycle CO_2eq emissions, but commercial production is 5-10 years away.
- There are concerns that biofuel crops may have detrimental environmental impacts, unless effective sustainability criteria are established.

Endnotes

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