Biofuels for Transport

Price 30p

Introduction

EU drivers are now using bio-fuel blends and President Bush launched a major programme to increase US bio-fuel use before leaving office. As far back as the late 1970s Brazil planned to power its vehicles exclusively on bio-fuels and though it hasn't yet fulfilled its aim much progress has been made. Bio-fuels are proven though still expensive. The remaining doubt is how much can sensibly be grown.

What are bio-fuels?

All organic matter contains carbon and hydrogen which can be converted to carbon dioxide and water, releasing energy. Fossil fuel, after all, starts life as plant material. Bio-fuels, whether they be landfill gas, sawdust or timber, can be burnt to provide heat or generate electricity but this note deals with transport. Bio-ethanol and bio-diesel are the most important fuels though bio-methane and butanol (which has a low freezing point and be used in aircraft) are of interest.

A Jatropha bush. The seeds (top) can yield 2 tonnes of fuel/ha/year. The bush grows on marginal land in hot countries

Bio-ethanol

Any vegetable starch can be converted to sugar, fermented and distilled to produce ethyl alcohol or ethanol (chemical formula C_2H_5OH) for use in 'petrol' engines. Many years ago synthetic alcohol was sold in the UK as Cleveland Discoll.

Currently almost 50 billion litres of ethanol are produced, 90% in America and Brazil. Indeed the US Clean Air Amendments Act of 1990 made the use of E10 mandatory when forecast levels of carbon monoxide in air were high and E20 fuel is now available from separate pumps in Minnesota. Bio-ethanol boosts low octane levels in US unleaded petrol and US farmers like it because it is a valued cash crop which, until recently, could be grown on surplus land.

Bio-diesel

Bio-diesel production in the US is much smaller, though growing. Over half (8.7 bn litres ex 16.1) is grown in the EU mostly in Germany and France. Bio-diesel is cleaner than fossil diesel because it contains less sulphur and, it is claimed, produces fewer particulates. It is biodegradable, so good in sensitive areas like waterways.

The Proalcool Project

Brazil, the first in the field, concentrated on producing bio-ethanol from surplus sugar cane. In the Proalcool project, begun in 1975, they encouraged the use of 100% hydrous ethanol in cars with converted engines. Unfortunately the market was badly organised. Supply failed to match demand, subsidies rose to £600M/year and had to be cut. The more secure blended market grew while the 'neat' one declined, but flexi-fuel engine management systems can now detect different fuels and 70% of new cars sold in Brazil can run on 100% bio-ethanol when available.

The Proalcool project hit two other problems. First the waste from distillation caused pollution and additional treatment had to be introduced. Second (a problem *fundamental* to the development of all bio-fuels) was the inefficiency of production in *energy* terms. Too much energy was used to produce fertilizers, grow, harvest and transport the crop and extract the fuel. The *net* energy gain was low.

Improving the energy yield

Much work has now been done to increase both the 'energy gain' and the economics. Both can be improved by finding uses for the waste material. For example 'waste' from oil seed rape can be sold as animal feed or incinerated in energy from waste plants. Fig 1 shows the kind of fossil fuel savings now possible. Straw is a waste product so the only fossil energy used is in transporting and processing. Oil seed rape (OSR) however would be grown specifically. The green in Fig 1 shows the net energy gain for the transport fuel alone. The blue figure is the *extra* energy from the waste. For OSR the net energy obtained could be 88% (53% + 25%). Put another way, a net 12 units of CO_2 are emitted to atmosphere instead of 100 using fossil fuel.

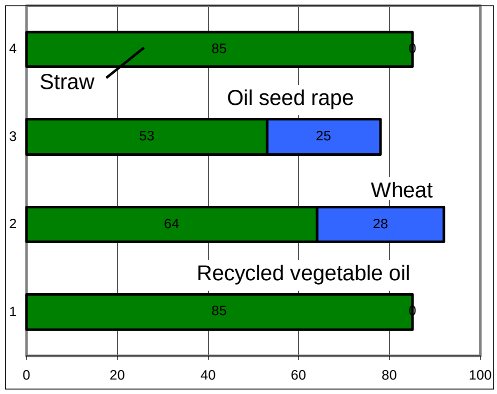

Fig 1. % CO_2 emissions savings. Blue % gives the CO_2 saved from burning the waste material.

This, however, is only the first part of the story. In the last 2 years it has been realised that the impact of 2 other greenhouse gases, methane and nitrous oxide, must be taken into account. Animal manure, unless digested first, will release methane, 21 times as dangerous as CO_2. Crops needing nitrogen fertilisers will release some nitrous oxide, 290 times as dangerous. So, for example, OSR may save 88% of CO_2 emissions but barely 10% of *total* greenhouse gas emissions because it uses a lot of fertilizer. Calculations also

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suggest US bio-ethanol production currently *increases* greenhouse gas emissions by 20% *more* than using fossil fuel!

The next problem is to account for the change of use of land. Forestry, grassland or fallow land will absorb carbon. If swamp or peaty soil is reclaimed or forest cut down huge carbon stores in the soil will be lost to the atmosphere. This is of great concern in Indonesia which is expanding into virgin forest to produce high yielding and lucrative palm oil.

The news is not all bad. Scientists have looked at waste products such as vegetable oil and wood chippings and realised that disposing of them takes energy. Converting them to bio-fuel saves this energy making the *effective* energy gain *more* than 100%. Converting vegetable oil to bio-diesel, for example, gives a net gain of almost 150%.

Land considerations

There is a global shortage of arable land although bio-fuel crops use barely 1% and the 2008 food shortages and riots were due much more to poor harvests in 2006/7 and 07/08 in Australia and elsewhere. Even so it is important to find high yielding crops. Pressure on land, from rising populations, more meat eating and now energy crops (for heat and electricity as well as fuel) is growing. In 2007 the USA, a grain exporter, diverted 85M tonnes of maize to bio-ethanol production compared to 15 Mt in 2000 showing the trend.

Source	Fuel	Yield GJ/ha
Wheat straw	Bio-ethanol	26
OSR	Bio-diesel	40
Wheat grain	Bio-ethanol	61
Sugar Beet	Bio-ethanol	117

Table 1. Productivity. 1 Giga Joule of energy = 47 litres bio-ethanol and 30 litres bio-diesel

Sources

In the UK bio-ethanol could be obtained from sugar beet, wheat grain, wheat straw, and wood chips, though sugar cane and maize are more important overseas. Bio-diesel locally only comes from recycled vegetable oil at present, but OSR and animal tallow could be used, and diesel derived from palm and jatropha oils imported. Maize (corn) is the main source in the USA but Brazil and Argentina are also using a GM soya. Jatropha is a good source because it can grow on poor quality land so does not compete for space with food crops and grows in hot, low rainfall climates where it can be used to resist desertification. As Table 1 shows, sugar beet gives the highest yield in the UK, producing 5500 litres of bio-ethanol/hectare (ha). A motorist growing his own fuel would need a 'garden' of 2000 m^2 size if driving 10,000 miles/year at 10 miles/litre.

Getting bio-fuels to market

The first EU bio-fuel directive set targets for 2% and 5.75% of fuel to be 'bio' by Dec 2005 and 2010 respectively. Austria and Germany were well advanced but at the time the UK used less than 0.5%. From 15th April 2008 however the UK's Renewable Transport Fuel Obligation (RTFO) requires companies to supply a minimum of 2.5% in the year 2008/9, 3.75% in 2009/10 and 5% in 2010/11. The duty on bio-fuel is 20p/litre less than on fossil fuels (not enough to offset their higher costs) but the RTFO demands a penalty of 15p for any litre not supplied (rising to 30p/litre in 2009/10) making the effective subsidies 35p and 50p/litre. This is a helpful though costly way to reduce CO_2 emissions.

In January 2008 the EU set a target of 10% bio-fuel by 2020 (though by also legislating for better fuel efficiency they hope this will be perhaps 7 or 8% of what is used now). To grow 10% locally would use up all the UK's former 'set aside' land and much good arable land besides. Some bio-fuel at least will have to be imported. British Sugar is one company keen to supply bio-ethanol and has a plant at Wissington, Suffolk.

Remaining technical and other problems

Bio-ethanol does not have the same chemical formulation as petrol nor bio-diesel as diesel. Indeed different crops produce bio-diesel with both higher and lower cetane (the diesel equivalent of petrol's octane) ratings. The route to market has been via blended fuel although manufacturers remain reluctant to extend warranties too far. The EU funded BioEthanol for Sustainable Transport (BEST) Project, where various bodies in Somerset including the County Council are leading UK players, are gathering data on performance. Using Ford Focus flexi fuel cars, early results show slightly better performance and no maintenance problems with E85 bio-ethanol though, unhappily, substantially worse (barely 3/4) fuel consumption.

The UK has had some problems establishing a robust bio-fuel supply chain. Farmers will not grow fuel crops nor companies build processing works if they are uncertain how the market will develop. However whereas new fuels such as hydrogen and compressed natural gas have to develop nationwide garage networks (perhaps starting with clusters around large cities) blended fuels are using existing forecourts and fuel tanks and, as noted above, separate pumps are already appearing in other countries. Some companies are already enhancing their green image. Tesco's 2000 distribution lorries, for example, use a 50% bio-diesel blend.

How much could be produced?

In 2007 the UK used 21.04 M. tonnes (about 25,000 M litres) of DERV (Diesel Engined Road Vehicle) diesel (other diesel and gas oil is used for heating and off road use, eg farm tractors) and 17.32 M tonnes (about 23,000 M litres) of petrol. If the diesel is produced from oil seed rape, yielding 1200 litres of bio-diesel/ha/year, over 20 M ha, more than all the UK's *total* 18 M ha of *both* arable and grazing land would be required. The EU target of 5.75% would take over 1M ha, which is more manageable, though another 0.24 M ha of sugar beet would be needed for the 5.75% of the petrol. Set aside payments have now ceased. Despite opportunities to import bio-fuels new sources must be found. Shell are trying to produce fuel from algae in Hawaii on land which cannot be used for crops.

Conclusion

Calculating the true benefit of 'growing' energy is complicated and still needs working out. In any case due to shortage of land the UK will be lucky to grow even half the 10% required by the EU by 2020 without inspired research including help perhaps from GM technology. Currently most UK biomass is best used to produce electricity. On the other hand bio-fuel technologies are developing fast and the need and the market is there. Crucially however every litre of bio-fuel must be produced in a certified sustainable way.