

Bio-fuels - A position paper by Roland Clift

Background

Bio-fuels are seen as attractive because they are “renewable”: carbon emitted to the atmosphere when they are burned is offset by carbon removed from the atmosphere by growing energy crops. Unlike other forms of renewable energy, their use is controllable and they can be stored. Looking behind these superficial features, there are problems to be addressed if bio-fuels become a major component of the energy economy. In brief, these are:

1. Competition for land use: if bio-fuels become major crops, they will be in competition for land with food. Projections of land required for bio-fuel production in Europe show that the current EU position, that over-producing food because we are cultivating too much land too intensively so that some must be “set aside”, will be rapidly reversed by development of energy crops.
2. While the carbon in bio-fuels may be renewable, other aspects of the fuel cycle can generate climate-forcing emissions (and other impacts). For climate change, the principle sources of these impacts are fuels used to transport biofuels and other inputs to fuel processing, and also emissions of other gases, primarily methane and nitrous oxide, from the cultivation of bio-fuels.

It is useful to distinguish between:

- (a) Ligno-cellulosic (“woody”) solid bio-fuels;
- (b) Liquid and gaseous bio-fuels.

Ligno-cellulosic Bio-fuels

Given that competition for land use will re-emerge, energy yield per cultivated area will become a major concern. In northern European latitudes, the highest yields are obtained with short-rotation coppice (SRC) cultivation of willow (*salix*) or with elephant grass (*miscanthus*), both perennials. They can be grown on land which is considered marginal for conventional agriculture. They are “non-domesticated” plants, and much effort is being devoted to developing “domesticated” strains of these and other crops (notably poplar) to give higher energy yields. Woody bio-fuel is already available as forest residues; materials, such as “thinnings”, removed during forest management; and even in urban areas from parks and transportation corridors. Some forms of agricultural wastes and residues, notably straw, can also be seen as lingo-cellulosic bio-fuels.

Woody bio-fuels have low mass and energy density. Therefore transport distances by road in particular have to be kept short. Ideally, woody bio-fuels are processed or used close to their source. However, if they are chipped or pelleted close to source, they can be shipped by sea without having a disastrous effect on the carbon balance. This lies behind the current international trade in wood chips and pellets, notably from Western Canada into Europe; the sea passage accounts for less carbon dioxide than moving the bio-fuel by road, for example from Bristol to Didcot where wood chips are co-fired with coal in a large generating station.

This leads to the conclusion that the preferred use for woody bio-fuels is in local heating or CHP plants. This approach has been followed in Austria, where bio-fuels have achieved the greatest penetration into the energy economy: about 15% of primary energy. The same approach is being followed in Germany, Denmark and Sweden. Some parts of UK Government and the UK Environment Agencies are also promoting this kind of use. Development has been inhibited so far by the lack of a market for solid bio-fuels; there is now recognition of this problem, and some evidence of will to remove barriers to the development of a market in the UK. Co-firing with coal in generating stations (e.g. Didcot, Drax, Ferrybridge) is being promoted as a means of stimulating development of the market but, if the sector develops as it potentially could, the Austrian approach is likely to be followed in the UK too. There are structural difficulties over the development of the biofuel sector. For SRC willow, at least five years is required from the decision to invest in the crop to the first harvest. This is much longer than the investment cycle for heat or CHP plants; imported wood chips are seen as a temporary measure to fill this gap. The lead time is shorter for *miscanthus*, and this may favour it over willow.

Where there is a demand for heat – primarily urban areas – woody biomass is likely to be used for local heating plants once the principle of heat distribution systems is accepted; this is already the pattern in the European countries mentioned above. Deployment of CHP plants, based on gasification of biomass to produce a fuel gas which is burned to drive a generator, is limited by scale: reliable plants are not available at a small enough scale.

Liquid and Gaseous Bio-fuels

The principal liquid bio-fuels are bio-diesel and bio-ethanol, both used primarily for transport.

Bio-diesel is probably the best established bio-fuel. It is my view that it has developed ahead of other bio-fuels because there was an existing market, dominated by companies such as Cargill who trade in agricultural liquids; because it can be blended into conventional diesel fuel up to certain limits to avoid engine modification; and for the perverse reason that some European countries realised that subsidising bio-diesel production is a way of circumventing the Common Agricultural Policy so that they could subsidise agriculture. Bio-diesel is usually produced from oilseed crops such as rape. (Bio-diesel from used cooking oils is a different matter, but will never be more than a niche market: it is a sensible thing to do with used cooking oils but not a solution to energy or climate change problems). Bio-diesel is by no means neutral in its effects on climate change: there are substantial emissions of non-CO₂ gases, primarily nitrous oxide; bio-diesel may possibly represent a small reduction in net climate-forcing compared to fossil transport fuels but even this is complicated and depends on what other products are replaced by the residual oilseed cake. Oilseed crops require different farming practices from other crop rotations, and this exacerbates competition for land use. Net energy yields per hectare are much lower than for ligno-cellulosic bio-fuels. Putting these together, the push for bio-diesel (and therefore the EU Bio- Fuels Directive) is a perverse short-term aberration which should be rectified once the reality is understood, the competition for land use

becomes clear, and the market for ligno-cellulosic bio-fuels has developed properly. In any case, the properties of bio-diesel do not make it attractive as an aircraft fuel.

Bio-ethanol, produced by fermentation of crops such as sugar and cereals, is also gaining ground. Like bio-diesel, some proportion can be blended into gasoline to avoid engine modifications. In northern Europe and the USA, yields per hectare are low. In Sweden, for example, initial enthusiasm for producing bio-ethanol has disappeared. However, the present economic conditions of cheap food and high energy prices make it attractive to convert crops such as cereals into bio-ethanol: revenues to the farm can be up to three times higher and the pay-back time on cheap inefficient fermentation plant can be less than a year. Early participants in this market are therefore set to be very profitable but this is likely to be a short-term “bubble”. There is some indication (early 2007) that the bubble may already be collapsing, with reduction in price of bio-ethanol. However, the demand for corn for bio-ethanol is blamed (Jan. 07) for a rise in the price of tortillas in Mexico.

Some estimates suggest that the EU target of 15% bio-fuels for transport would require more than two-thirds of the land under cultivation in Europe. The result would therefore be increased pressure to expand cultivated land area elsewhere in the world, for both food and energy crops. This is particularly annoying for companies in the edible oil business who are criticised for sourcing palm oil from land which was previously rain forest, and simultaneously for not promoting transport bio-fuels. This is the reason why Unilever are strongly opposed to bio-diesel, and why RWE recently announced that it was abandoning plans for a bio-diesel fired generating station.

The situation for bio-ethanol is different in tropical latitudes, where high yields per hectare can be obtained with sugar cane. Therefore this has developed more in some tropical countries, particularly in Brazil. Sugar is produced intensively in some parts of the country. To minimise parasitic losses in transport, the Brazilian approach is to disperse distilleries throughout the sugar-growing areas so that cane is transported no more than a few km before being processed into energy-dense ethanol. Ethanol is therefore the traded commodity, and is increasingly traded internationally. Carbon balances over the fuel supply chain are slightly more favourable than for biodiesel, especially where bagasse (the woody component of sugar cane) is used to provide the heat input for fermentation and purification and there is no other demand for the heat output. The energy input to purification is high because ethanol/water mixtures form a maximum boiling point azeotrope; to “break” the azeotrope and produce anhydrous ethanol, which is necessary if it is to be blended into conventional gasoline, requires extractive distillation which raises both the capital cost and energy use of the purification process. Bio-ethanol would become significantly more attractive on carbon-accounting grounds if internal combustion engines could run on the azeotrope.

There is discussion of producing liquid fuels (and even hydrogen) from ligno-cellulosic biomass by Fischer-Tropsch synthesis. It is difficult to see this as realistic: the technology is difficult and expensive and the efficiency of the fuel cycle will inevitably be low so that it is not a competitive use of bio-fuel, land or capital. The only past circumstances under which it has been attractive to convert solid fuels (usually coal) to liquid transport fuels have been dictated by political imperatives, not economics: Europe in the 1920s to 1940s, and South Africa in the 1970s and 1980s. Sasol (the South African company) quote costs for converting coal into synthetic

crude which many in the industry consider unrealistically low; nevertheless coal-to-liquids technology will, in effect, put a cap on the price of liquid hydrocarbon fuels. Much of the technological challenge in Fischer-Tropsch processing is in maintaining solids feed into the reactor. This is difficult enough with a consistent granular material like black coal; it is much harder with soft variable material like biomass. It is difficult to see how biomass could ever compete with coal as a feedstock for Fischer-Tropsch synthesis, even under circumstances where surplus lignocellulosic biomass is available after satisfying the demand for heat and power.

Other liquid fuels, including “talloil” which is a by-product from kraft pulping, will never be sufficiently abundant to expand beyond their present niche markets. Some companies (notably Volvo) advocate DME, a diesel-oil substitute produced from black liquor (which is a by-product from wood pulping). Even in parts of the world where there is a major pulping industry (Scandinavia and the Pacific North West of North America), this can never be more than a niche for reasons of availability, and because DME cannot be blended with conventional diesel so that it requires a separate supply system and vehicle fleet.

Another possibility, favoured in Sweden but largely ignored elsewhere, is biogas, usually produced by anaerobic digestion of organic wastes (including abattoir waste!) There are some “communes” (i.e. local authorities) in Sweden where all taxis and buses already run on biogas. This is a well established technology, but essentially still based on local systems of supply and use, with dedicated vehicle fleets.

Conclusions

1. Although bio-fuels are seen as “renewable” and therefore capable of contributing to reducing the carbon intensity of the economy, their carbon efficiency must be assessed over the whole fuel cycle. This contribution is real for woody biomass and close to its source for simple heat or CHP applications. However, the carbon emissions from production of liquid biofuels are in most cases so large that there is no significant net benefit.
2. Once markets have stabilised, bio-fuels will be dominated by ligno-cellulosics used locally. Fischer-Tropsch processing of biomass into liquid fuels is not a realistic proposition.
3. Bio-ethanol will continue to develop as a transport fuel produced in tropical latitudes and traded internationally, for use primarily as a gasoline additive. Bio-diesel should decline over time once the perverse incentives which have promoted it are removed.

Further Reading

Royal Commission on Environmental Pollution (2004) “Biomass as a renewable energy source” –

<http://www.rcep.org.uk/bioreport.htm>

Biomass Task Force report to Government (2006) –
<http://www.defra.gov.uk/farm/crops/industrial/energy/biomass-taskforce/pdf/btfreport-govresponse.pdf>

Carbon Trust (2006) “Biomass sector review for the Carbon Trust” –
<http://www.carbontrust.co.uk/Publications/publicationdetail.htm?productid=CTC512>

Energy for Sustainable Development, Volume X No 2, June 2006 “A review of life-cycle analysis studies on liquid biofuel systems for the transport sector”, Eric D. Larson

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