Understanding bio-economics

By Martin Patel

Posted 1 March 2008 5:00 am GMT

New plants for production of bio-based fuels, chemicals or plastics are being set up at an accelerating pace. However, this transition towards bio-based fuels, feedstocks and chemicals has not come without consequences. Increased demand has pushed up prices of key agricultural products such as maize and corn with the result that consumers - especially those in low income areas - have reacted with concern and protest.

At the same time, environmental research institutes and lobby groups - and now some policy makers - have expressed concern about the effectiveness of this path in reducing fossil fuel use and greenhouse gas (GHG) emissions, about the availability of biomass (and the land required to produce it), and the consequences for biodiversity, deforestation and social relations.

The European Commission this year released a proposal for a directive covering the promotion of renewable energy. This proposes that overall greenhouse gas emission savings from biofuels must be at least 35%. Other efforts are underway to develop sustainability certification for biofuels. These initiatives mark the beginning of a new phase for bio-based products, one in which they will be assessed in a far more strict and comprehensive manner.

Against this background it is reasonable to ask: Is it is better to use biomass for producing chemicals or biofuels? This article will attempt to answer that question for one key compound in polymer production - ethanol - and for simplicity will consider non-renewable energy use and greenhouse gas emissions.

Life cycle analysis (LCA) does not allow a direct comparison of diverse incomparable products - such as a biofuel and a biochemical - because the purpose (in LCA terminology the "functional unit") differs.

However, it is possible to make a comparison in an indirect manner, by first comparing the biofuel with petrol derived from fossil resources and then, secondly, comparing the bio-based chemical or polymer with its petrochemical counterpart. The two differences can then be compared with each other.

In the chart below, a method is applied to enable comparison of the use of ethanol as a fuel and as a chemical. The comparison refers to one tonne of ethanol produced from cereals (such as maize or wheat) which typically require around 0.36 hectares of land for cultivation. The calorific value of one tonne of ethanol is around 30GJ (the higher of the heating values in the first bar in the chart). This is the amount of energy that is available for combustion in a car.

Production of one tonne of ethanol by this route still requires considerable amounts of non-renewable fossil fuel energy - 22.5 GJ (shown in the lower part of the first bar). The difference between this value and the total heating value of ethanol (30 GJ/t) is the effective energy from the biofeedstock (7.5 GJ).

The second bar shows the situation for traditional petrol. To ensure equivalence, it is assumed that 30 GJ of energy is available for the car. Only a relatively small amount of energy is required for exploitation, transport and refining this fuel, adding around 7% or 2 GJ of fossil fuels to result in a total of approximately 32 GJ. By subtracting from this value the non-renewable energy use for bioethanol (22.5 GJ) it is possible to determine the amount of non-renewable energy saved as 9.5GJ (represented by the double-headed arrow).

Translated into simple terms, the production of bioethanol requires approximately 30% less non-renewable energy than the petroleum-based production chain (32GJ). This example is not too far from the provisional EU policy target of 35% (percentages for non-renewable energy and greenhouse gas emissions can be expected to be quite similar).

The same comparison can be applied to ethanol for chemical use. As shown in the last bar in the chart, 60GJ of non-renewable energy is required to produce one tonne of petrochemical ethanol. The reason for this high value is because it includes both the calorific content (30 GJ/t) and a substantial amount of processing energy for naphtha production, steam cracking (the largest contribution) and hydration.

However, it has been established above that only 22.5GJ of non-renewable energy is needed to make one tonne of bioethanol. And so the difference between the first bar and the last bar represents the savings offered by the use of bioethanol as a chemical as 37.5GJ (represented by the double-sided arrow next to the last bar in the chart.

This simple analysis shows the savings in non-renewable energy use amount to: 9.5 GJ/tonne of ethanol if bioethanol is used as automotive fuel replacing petrol; or 37.5 GJ/tonne of ethanol if bioethanol is used as chemical replacing petrochemical ethanol. The savings differ by a factor of four.

Production of bio-based ethanol also requires agricultural land, obviously not the case for petrochemical ethanol. So the difference in agricultural land use is identical with the amount of land needed to make bioethanol - 0.36ha. Dividing the non-renewable energy savings mentioned above by this value gives: a saving of 26 GJ non-renewable energy per hectare of land per year if bioethanol is used as automotive fuel; savings of 105 GJ non-renewable energy per hectare of land per year if bioethanol is used as a chemical.

The BREW study of biotechnologically produced chemicals (www.chem.uu.nl/brew) looked at 21 compounds in depth. It showed that the effectiveness of land use efficiency for saving non-renewable energy is beyond 100 GJ/ha for efficiently produced chemicals.

This analysis looked at ethanol production from starch-containing crops, generally considered to be a "first generation" route to bioethanol. The transition to "second generation" technologies which use lignocellulosics such as straw or wood would increase the efficiency of production and would reduce the amount of non-renewable energy needed. However, this is also likely to be applied for bio-based chemicals and is unlikely to change the overall finding.

Across the world, governments and NGOs are becoming more and more aware of the limited availability of sustainably produced biomass for non-food purposes. The limits to growth once put forward by the Club of Rome seem to manifest themselves equally in rising prices for fossil fuels and agricultural products, as well as certain ores and metals. The struggle to find and implement the optimum way of producing and using biomass - alongside managing fossil energy use and greenhouse gas emissions - is the critical element in the thought process required to make the change for industrial production, private consumption and economic growth.

The analysis in this example is a strong indication that, in a world of scarce agricultural land and forest resources, it is more effective to use biomass for production of chemicals compared to use for biofuels.

However, while ambitious policy goals and substantial public funding - in the form of tax exemptions - have been set for biofuels, no comparable measures exist for bio-based chemicals and polymers. The latter has been selected as a product area for the European Commission's lead market initiative but this has so far represented symbolic value rather than tangible government support.

This imbalance should be corrected and the EC's proposal to set a minimum of 35% greenhouse gas (GHG) savings for biofuels over petroleum equivalents may be the first step in that direction.