Second-generation biofuels

Driving on organic waste

Biofuels for cars can help reduce CO2 emissions, but there are drawbacks. The large areas of land needed to grow biofuel crops could threaten food production. Or nature will have to make way. The second generation of biofuels now in the pipeline are claimed to overcome these problems, but not all scientists are convinced.

By **Koos Dijksterhuis**

The carbon dioxide emitted by cars is one of the main causes of climate change. The biofuels that are being promoted as alternatives to fossil fuels have been in use for decades. Brazil and the United States are major producers and users of biofuels, especially bioethanol. But environmental concerns, the growing scarcity of oil and the desire to reduce the dependency on oil-producing countries in the Middle East and Russia, have caused a rush of research to develop new and more efficient technologies, leading to what is called the 'second generation' of biofuels.

At present, biofuels are made from biomass – plant material, in other words. Although biofuel crops such as sugarcane and maize absorb CO_2 as they grow, thus removing it from the atmosphere, they release some CO_2 when they are burned. Nevertheless, the net emissions of these 'first-generation' biofuels are about half those of fossil fuels. But more efficient fermentation processes are being developed whereby not only the sugars contained in fruit, seeds and root crops are used to make fuel, but also the fibrous parts of plants and organic waste. These second-generation biofuels could reduce greenhouse gas emissions by 90% relative to fossil fuels, and would also reduce the demand for land to grow biofuel crops.

Recent policy measures in Europe and the United States have given a new impetus to the development of new biofuel technologies. The use of biodiesel is rising rapidly, particularly in Germany, where it remains duty free. Some 210,000 cars were already running on pure biodiesel in 2000, which is now available at 1600 German filling stations.

While biogas – methane – can be used as fuel for cars (see box), it is generally used to generate electricity. In the Netherlands, some farmers already ferment animal dung and use the methane released in the process to heat their cattle sheds. Orgaworld, a company in Lelystad, is using biogas from organic waste to generate 'green' electricity, and composts the fermented residue. In Nepal, the Biogas Sector Partnership, an NGO, is promoting the use of this process. Over 150,000 Nepalese households now have a biogas plant – an airtight container that can digest half a cubic metre of buffalo dung. The methane released is used for cooking and in gas lamps, and the residue is returned to the fields.

Bioethanol, biodiesel and biogas

There are three sorts of biofuel for cars, equivalent to petrol, diesel and LPG:

Bioethanol is alcohol that is produced during the fermentation of sugars. Maize, sugarcane and rapeseed are the main raw materials. As in brewing, yeasts covert the sugars into alcohol, which is then distilled and purified before it is ready to use in the petrol tank.

Biodiesel is similar to fossil diesel. It consists of methyl esters made from oils pressed from rapeseed, peanuts, sunflower seeds and soya. Even animal fats such as old cooking oil are suitable.

Biogas is made by fermenting organic material in an airtight container. Anaerobic bacteria break down the material, releasing methane (CH_4) and CO_2. With just a few engine modifications, LPG cars can run on compressed methane.

Source: SenterNovem. http://gave.novem.nl/gave

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Tortilla crisis

In 2005 half a billion litres of biofuel were used to fill European cars. The aim is to increase this tenfold by 2011. But the growing demand for biofuels is creating an increasingly serious problem: growing sufficient fuel crops will require enormous areas of land, resulting in competition with food crops, food shortages and thus higher prices in developing countries and the rest of the world. Cultivating fuel crops can also be detrimental to natural areas.

In their *Agricultural Outlook 2007–2016,* the Organisation for Economic Cooperation and Development (OECD) and the UN Food and Agriculture Organization (FAO) expect that the world prices of agricultural produce will rise, due to the growing demand for food and for biofuels. At present (mid-2007), the world market price of maize is more than 50% higher than the average price between 2001 and 2005. In Mexico this has already led to what became known as the 'tortilla crisis', when the price of maize used to make this staple food quadrupled.

'Fuel for the rich or food for the poor?' was how Rudy Rabbinge, professor of sustainable development at Wageningen University, put this dilemma at a debate on biomass from developing countries in The Hague in March 2007. Rabbinge believes that biofuel and food are incompatible. In his opinion, only unused plant remains should be used to generate energy, provided that it meets the sustainability criteria set out by the Cramer Commission, chaired by Professor Jacqueline Cramer of the University of Utrecht, now the Dutch environment minister. In other words, biofuel production must not involve the loss of agricultural land, and it must not threaten food production, biodiversity, or the welfare of workers. Above all, it must have a positive impact on CO_2 emissions, according to a life-cycle analysis.

Rabbinge believes that biofuels are unlikely to help reduce CO_2 emissions to a significant extent. 'You need artificial fertilizer to grow potatoes', he explained in a telephone interview, 'and it takes energy to grow and transport the elements of the fertilizer. So the net reduction in CO_2 emissions from converting starch to ethanol is very small'. He believes that the United States is investing heavily in biofuel production both to reduce the country's dependence on Arab states and Russia for its fuel, and to support American farmers. If biofuel crops were to displace food crops, the US can simply import food from far more countries than just the few oil producers.

A simple calculation may clarify the problem. One hectare of rape produces 4500 kilograms of seed, which can be used to produce 1400 litres of oil. A car needs some 700 litres of fuel to drive 10,000 kilometres per year. So one car can run on the biofuel produced from half a hectare of rapeseed. This means that in the Netherlands, with 7 million cars, 3.5 million hectares of land would need to be permanently available to fuel them. Almost the entire country would have to be given over to rapeseed or sugar beet production.

At the European level, however, there is agricultural land to spare. Europe has a maize surplus of 12 billion kilos and, according to the European Commission, there is enough fallow land for Europe to grow 80% of its own biofuels by 2020. 'That is possible', Rabbinge agrees, 'but you could also have wildlife on that land. You have to choose. If you're looking to reduce emissions, solar collectors and fuel-efficient cars are more effective than biofuels'. But that does not solve the car fuel problem – while solar collectors may capture more of the sun's energy than biofuel crops, it is not possible to use it to make petrol, diesel or LPG for cars.

Second-generation resources

Great hopes are now being pinned on the second-generation biofuels now being developed in research projects such as those under way at the Kluyver Centre for Genomics of Industrial >

Fermentation, which is affiliated to Delft University of Technology (see box). To avoid competition with food production or the natural environment, the researchers are seeking ways of making biofuels from inedible materials such as agricultural waste and cellulosic (woody) material.

Besides making better use of plant waste, another way to avoid competition for land for food and biofuel crops would be to use marginal land that is unsuitable for food production anyway. This includes silted up areas, saline soils or impoverished land where little grows apart from some fibrous grass species that are ideal for the brewer's yeast process. Both Asia and the United States have large tracts of such land, for example. Researchers around the world are now searching for new techniques to convert the plants that can grow in these areas into biofuels.

In Mozambique, for example, TU Delft lecturer Wouter van Winden is researching the production of biodiesel from algae. Together with colleague Bram van Beek, he set up a field laboratory for growing algae, which has been in operation since late 2006. The lab, part of Eduardo Mondlane University in Maputo, consists of nine shallow ponds 40 cm deep, so that sunlight can penetrate to the bottom, allowing the algae to proliferate. To ensure maximum algal growth rates, paddle wheels keep the water moving constantly. The ponds are fed by a river that flows through a silted up, unusable area where only salt-tolerant algae thrive. These algae are now being studied to establish whether they contain enough oil for biodiesel, which fuel-poor Mozambique desperately needs.

In the United States, David Tilman, professor of ecology at the University of Minnesota, has found that three times as much grass can grow on poor prairie soils if several types are sown together, rather than the usual monoculture. Based on trials in which he harvested enough biomass to produce 2000 litres of fuel per hectare, his call for increased use of grasses for biofuels has generated considerable debate in academic journals.

Erik Heeres, professor of chemical toxicology at the University of Groningen, is a great fan of jatropha (*Jatropha curcas*), a hardy shrub that produces seeds with up to 40% oil content. Jatropha can survive in relatively dry, poor soils and is regarded as a weed, so growing it on marginal land would not threaten food production. Working with a researcher from the Institut Teknologi in Bandung, Indonesia, Heeres produced sufficient pure jatropha oil to drive his jeep 3000 km. As well as oil, jatropha seeds also contain sugars that can be used to make ethanol. But Heeres warns that the fact that jatropha can grow on poor soils does not mean that it will only be grown there, as it does much better on moist, fertile agricultural land or in forest soils. So if they can earn money with jatropha, farmers will prefer to grow it on better land.


Hollandse Hoogte

The intestines of Indian elephants

The cellulose that keeps plant stems and tree trunks upright is tough stuff. While brewer's yeast (*Saccharomyces cerevisiae*) can easily break down the sugars in maize, sugar cane and potatoes, converting it to ethanol in the process, it is not at all keen on cellulose and hemicellulose, which make up a large proportion of plants. 'We've found a way of getting it to ferment', says Jack Pronk, director of the Kluyver Centre. He explains how cellulose and hemicellulose, which are polymers – chains of sugars – are first separated into individual sugars using enzymes. But because brewer's yeast can not digest two of the sugars released – xylose and arabinose – the team set about modifying the yeast to enable it to break down the sugars to produce ethanol.

'We established how we could influence the yeast's metabolism to get it to convert xylose', Pronk says. 'Then we were lucky enough to find that scientists in Nijmegen were researching how a fungus, *Piromyces*, isolated from the intestines of Indian elephants helps them digest woody food'. In this fungus the Nijmegen team found precisely the gene that Pronk and his fellow researchers had failed to find in brewer's yeast, which enables the fungus to break down xylose. Similarly, a lactic acid bacterium from dairy products provided the Delft team with the gene they needed to convert arabinose. www.kluyvercentre.nl

This criticism of the second-generation biodiesel crops is echoed by Prem Bindraban, team leader with Plant Research International at Wageningen University. They can be grown on marginal land, but they need a lot of water and artificial fertilizer to give adequate yields, he says, so that 'biofuels are a problem rather than a solution'. He, like Rabbinge, highlights the indirect competition between biofuel crops and food crops or nature. According to Bindraban, US farmers are already switching from soya to maize, so more soya has to be imported from Brazil for cattle feed – with disastrous consequences for the Amazon rainforest.

But Jack Pronk of the Kluyver Centre argues that the problem does not lie in the switch from soya to maize, but in how these food crops are used. If they are fed to animals, as most maize is, they lose 90% of their nutritional value. That is just as wasteful as turning plants into fuel.

Proponents and sceptics do agree on one thing, however. Organic waste that would otherwise be burned can be converted into fuel with no negative effects. But will we be able to produce enough organic waste to meet the growing demand for fuel? ■

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A longer version of this article, with notes and references, can be found at www.thebrokeronline.eu.