



Environmentally friendly cars are about more than just horsepower

Developments in biofuel-powered vehicles

by **Phil Thane**

The EU's ambitious energy and climate plan was unveiled in January 2007 and since then the EU has consistently said that 10% of all vehicle fuel by 2020 would come from biofuels. Then in July this year energy ministers meeting in Saint-Cloud, France, announced that they had discovered that this was not necessarily true. 'The member states realised that the Commission's plan specifies that 10% of transport needs must come from renewable energy, not 10% from biofuels,' Jean-

Louis Borloo, the French environment and energy minister said, at the end of the three day conference.

But back in the real world, it does not seem likely that electric trains powered by wind turbines are going to make much impact, and hydrogen fuelled economy is a long way off, so increasing the ratio of biofuels to petroleum in more or less conventional vehicles seems the only real way to meet European targets.

In the US the Energy Policy Act of 2005 created the Renewable Fuel Standard (RFS) programme which

aimed to increase the volume of renewable fuel required to be blended into petroleum to 7.5 billion gallons by 2012.

This was revised upwards by the Energy Independence and Security Act of 2007 to 36 billion gallons. To achieve this a revised RFS is published annually. For 2008 it is set at 7.76%. This should lead to the use of 9 billion gallons of renewable fuel in the US this year.

Optimum blends

Providing both the petroleum and biofuels meet the

relevant standards companies can blend in any ratio, but will struggle to sell it unless the major motor companies endorse it.

At present most countries require oil companies to blend biodiesel at around 5% and ethanol anywhere between 2-5%, but stronger blends are available. B30 (30% biodiesel) is becoming common in Europe; E85 (85% ethanol) is already common in Brazil and becoming more so in the US.

Many diesel engines especially the heavier ones used in trucks, farm and construction machinery can

run on B100, though 1% petroleum diesel is usually added to retard mould growth. New Holland, maker of agricultural equipment, announced last year that it approves the use of B100 in all its engines, which is good news for farmers who can now grow their own fuel. For lighter, faster engines used in cars, vans and light trucks the different ignition properties of biodiesel – that it ignites earlier and burns longer producing slightly less power – are more significant. B30 is about the limit for these engines in standard form.

Ethanol has a lower energy density than petrol but contains some oxygen, requiring a richer fuel/air ratio to be delivered into the engine. Modern electronic engine management systems

can adjust automatically to cope with low ratios around 5% but beyond that most require a firmware upgrade at the very least. Flexfuel vehicles (FFVs) are designed to run on a wide range of petrol/ethanol blends from pure petrol to E85, enabling them to take advantage of high ethanol content fuel when it is available.

Hydrous ethanol

Ethanol forms an azeotropic mixture with water at 96.4% purity. Conventional distilling cannot make it purer. At this level the ethanol and water are so tightly bound that they evaporate and condense together.

This is unfortunate since standards for fuel ethanol normally require it to have a

much lower water content. The ASTM standard is 1% while in Europe the EN standard has recently been reduced from 0.3 to 0.2%. These levels are difficult and expensive to achieve, and once achieved the fuel has to be stored very carefully since it naturally attracts water and can easily go over the acceptable level.

The reason why so-called anhydrous ethanol is specified for fuel use is that at low concentrations hydrous ethanol can separate from petrol forming a distinct layer in the tank. This is obviously a problem for terminals which would find it hard to deliver fuel to the required specification and might lead to corrosion problems in some vehicles.

HE Blends and the Process

Design Centre (PDC) of Breda in the Netherlands have demonstrated that this is not a problem with blends containing higher proportions of ethanol. Their research shows that blends at E15 and higher are able to remain correctly mixed even when the ethanol contains 4% water. Tests show that eliminating the dehydration stage results in an energy saving of between 10-45% during processing and a 4% product volume increase.

Not only is this fuel cheaper and more energy efficient to produce, it gives higher mileage too. Hans Keuken, MD of HE Blends, points out that the heat of vapourisation of water and alcohols is substantially higher than that of hydrocarbons. Vapourisation

Motor manufacturers' recommendations

PSA Group's (Peugeot and Citroën) diesel cars can run on blends up to B30, provided that the biodiesel used meets EN14214. The group's petrol engines can run on blends up to E10 without making any changes. In Brazil, 80% of PSA Group's cars sold have flexfuel engines capable of running between E20 to pure ethanol. From 2007, the Group will launch FFVs (Flex Fuel Vehicles) operating on a blend of up to E85 in the European market.

Ford has been selling FFVs in Europe since 2005, and introduced four FFV models in the US in 2006. Ford UK has supplied 165 Ford Focus FFVs, mainly to fleets located close to the country's 14 bioethanol pumps such as Avon & Somerset Police, the Environment Agency and National Farmers' Union. Ford's FFV vehicles are priced the same as their petrol-only equivalents.

To help raise the profile of ethanol the team behind the Formula Ford championship has evaluated it in its single seater racing cars. Trials have shown that ethanol is suitable for racing and they expect Formula Ford to become the first junior motor sport category to go green later this year.

Ford is less enthusiastic about biodiesel. It is happy to let drivers fill up with B2 or B5, but does not recommend

anything else. Ford US is working with Michigan State University on improving biodiesel production methods and quality control, with the long term aim of enabling its vehicles to run on higher ratio blends.

Volkswagen-Audi approves the use of B5 in its new generation of vehicles for the US market including the Jetta TDI. Next year it will extend this to the Touareg V6 TDI. In Europe the Volkswagen Group approved its diesel engines to run on B100 until 2004, but then changed its policy over concerns about the sensitivity of the latest-generation of fuel injection systems.

Steve Keyes, director of PR for VW America, says the latest information from the Research and Technical teams in Germany suggests that VW will be recommending up to B7 in the near future.

Considering an Audi R10 TDI won the Le Mans 24 hours race on a mixture of Shell V-Power Gas-To-Liquid (GTL) racing diesel and a newly designed Biomass-to-Diesel (BTL) fuel in June this year, the group's attitude to biofuels in road cars seems rather conservative.

Honda has developed an FFV system that enables engines to operate on either 100% ethanol or a wide range of ethanol-petrol fuel mixtures. Since late 2006 Honda has been selling flex-fuel Fit sub-compacts and Civic sedans in Brazil,

where ethanol blends are widely available.

Honda's R&D team, together with Kyoto-based Research Institute of Innovative Technology for the Earth (RITE), have developed a new technology to produce ethanol from soft-biomass.

Converting cellulosic biomass by traditional fermentation yields only very low levels of ethanol due to fermentation inhibitors, formed during the process of separating cellulose and hemicellulose from soft-biomass, interfering with the function of the micro-organisms that convert sugar into alcohol. The new process uses a micro-organism developed by RITE that increases production by reducing the fermentation interference.

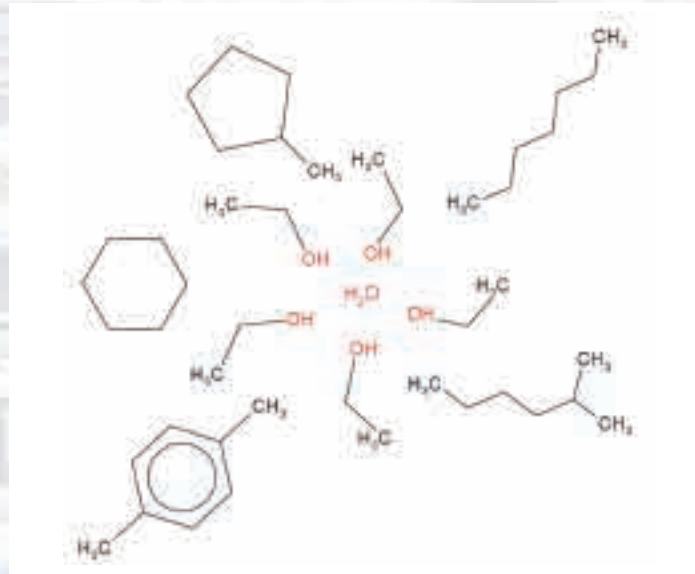
Honda's research unit plans to set up a pilot plant to test the technology on a larger scale.

All **Daimler-Benz** Jeep Grand Cherokee diesel vehicles sold in the US leave the factory with an initial filling of B5 biodiesel and the company is committed to creating the technologies that will enable its vehicles to run on B10 and E10 fuels. Daimler-Benz is a member of the Alliance for Synthetic Fuels Europe (ASFE), founded in 2006 by car makers and oil companies to promote the use of synthetic fuels and is heavily involved in the development

of liquids with a higher heat of vapourisation (during combustion in the engine) leads to vapours with lower temperature. This leads to improved engine performance, which can be even further enhanced by tuning the engine.

HE Blends have patented this type of fuel and tests have been performed by independent labs: SGS Drive Technology Centre in Austria and TNO Automotive in the Netherlands, in conjunction with Shell and Volkswagen.

Vehicle manufacturers are wary of any fuels containing water, but Jo Sijben, senior consultant at PDC points out that hydrous ethanol has been widely used in Brazil for many years. He adds: 'Due to the polarity of the various molecules present in



When hydrous ethanol is blended with petrol, it appears that each water molecule is surrounded by ethanol, isolating it from the petrol and preventing it causing corrosion

a blend of petrol and hydrous ethanol, water molecules are surrounded predominantly

by ethanol molecules, which accommodate it in the hydrocarbon-rich mixture.

'As a result the water activity is much lower than one would expect on the basis on its concentration and less active in a chemical sense. Its tendency to be corrosive is much reduced.'

In June this year the governor of Louisiana authorised the use of hydrous ethanol blends of E10, E20, E30 and E85 in motor vehicles for test purposes until January 1, 2012.

Fuel of this type does not conform to current standards, but that does not prevent its sale providing the customer is made aware of what he or she is buying. HE Blends has entered into an agreement with Berkman Energie Service to sell the fuel in the Netherlands under the brand name hE15 Biosuper. The first forecourt selling



A hydrogen-powered BMW at a rare hydrogen filling station in Berlin

of biomass-to-liquid (BTL) fuels.

Daimler-Benz is involved, along with VW, in Choren Industries, producers of BTL SunDiesel and intends to fill the tanks of all new vehicles leaving its European production plants with SunDiesel as soon as an adequate supply of the fuel is available.

Toyota expressed concern about the sustainability issues around first

generation biofuels and the pressure their use may be putting on food prices. The company's current strategy is to support low biofuels blends in Europe (E10 and B5) as a first step, moving to higher biofuels blends in the future if the criteria of availability, sustainability, and high quality are met.

All Toyota and Lexus petrol vehicles sold on the European market today

can run on E10, while all European Toyota and Lexus diesel models can run on B5. Toyota does not promote the introduction of FFVs in Europe.

Toyota is currently involved in research on second-generation biofuels made from non-food sources, and is investigating the use of hydrogenated vegetable oil for biofuel.

BMW is not pursuing the biofuel path at all. The company's long-term strategy is to implement hydrogen-powered vehicles, but for the mid-term it is looking at hybrid technology and electric vehicles.

All **General Motors'** vehicles built since the late 1970s are capable of running on E10 and there are currently more than 3 million GM FFVs on the road in the US. In Brazil about 95% of GM vehicles are FlexPower and can run on E25 or E100, a decision typically made by customers depending on the price of the fuel. In Sweden, all Saab vehicles are capable of running on E85.

GM has been researching biofuels for 25 years and earlier this year announced alliances with two next-generation biofuel start-ups, Coskata and Mascoma, to develop cellulosic ethanol. GM researchers also work with the national laboratories and many universities on fuel developments. They intend to make half their annual production FFVs by 2012.

this was officially opened in Voorburg by the Netherlands' Environment minister Jacqueline Cramer on 7 July.

Furanics

As many motor manufacturers are demanding that biofuels become more sustainable before they will promote their use, technological developments are more important than ever.

Avantium is a spin-off from Shell specialising in catalysis and crystallisation. In addition to offering R&D services, Avantium also initiates product and process development of biofuels and bio-based chemicals.

Avantium's biofuels are manufactured by reacting a glucose-containing starting material with an alcohol in the presence of an acid catalyst. Hydroxymethylfurfural (HMF) has previously been made by the conversion of sugars such as fructose in the presence of an acid catalyst, but fructose is undesirable given its high price compared to other sugars. So far, no process for the synthesis of HMF has been developed on an industrial scale.

Avantium's researchers have discovered how to convert glucose-containing starting material derived from biomass into HMF derivatives. Furanics is the company's preferred term for the whole group of products under development. A promising molecule for fuel use is ethoxymethylfurfural (EMF) but no decision has yet been taken on a brand name.

The energy density of EMF is 8.7 kWh/L, comparable to regular petrol (8.8 kWh/L), nearly as good diesel (9.7 kWh/L) and significantly higher than ethanol (6.1 kWh/L), so with a full tank of Furanics drivers can drive almost as far as with a full tank of traditional fuels.

Avantium employed the Intertek labs, in Geleen, the Netherlands to carry out engine tests to demonstrate the potential of these fuels

prior to announcing them last October. The tests were carried out using a Citroën Berlingo with a regular diesel engine running on blends between 5-17% Furanics. The engine ran smoothly for several hours and exhaust analysis showed a significant reduction in particulates. A further benefit is that Furanics do not contain any sulphur.

Ed de Jong, director of the catalytic biomass conversion programme within Avantium, explains how testing has progressed since then: 'We have continued testing using ratios up to 40% Furanics in the Berlingo, and results are completely in-line with the earlier tests with no surprises at all. We are now in discussions with vehicle manufacturers about conducting more rigorous long-term testing.'

To enable extended road tests Avantium is in the process of setting up a pilot plant to produce sufficient fuel, and this will also generate useful data on managing the production process on a large scale. Avantium has already begun talks with the standards bodies and will be involving them in the testing process. If everything goes according to plan the new fuel should be ready for large scale use by 2012-15.

Talking about pricing, Ed de Jong says: 'A lot depends on how the oil market develops. We don't expect oil to fall below \$100 (€70) and we are confident we can compete with that.'

'It's not a simple calculation. We are already seeing interaction between oil prices and biomass prices. Higher oil prices are reflected in our raw material prices, and even if oil fell to \$60 we could still be competitive because our raw material prices would also fall.'

Vehicle politics

So far the drive to use more biofuels has focused on producing fuels very similar to standard petrol and diesel. This has been convenient for both the vehicle makers who



Test results from an engine running on Furanics show a significant reduction in particulates

have not had to change their models, and oil companies who have been able to use their normal channels of distribution.

It has been a good start, but it is not the long term answer. Without subsidies from government it is not yet economic, and the subsidies are contributing to distortion of the agricultural industry in favour of fuel and to the detriment of food production.

To meet targets on carbon emissions new fuels will be needed, and soon, but the hydrous ethanol story illustrates the problem. It appears to work very well, and has been used for years in Brazil, but getting ethanol into petrol in the US and EU meant getting the oil companies and car makers on side in drawing up standards. They were understandably nervous of water so tight limits were set.

Now there is a new political

problem; HE Blends and Berkman Energie's work suggests that hydrous ethanol is perfectly safe in petrol but allowing it in standard blends will not be popular with all those producers that have invested huge sums in de-hydration systems, and are relying on the premium price they get for anhydrous ethanol to pay the bills. Should governments underwrite their losses?

Similar arguments about quality, cost, profit and subsidy will probably dog Avantium's push to get Furanics accepted as an alternative to petroleum diesel and FAME. All they can hope for is that the oil companies, vehicle makers, standards bodies and politicians can agree to approve new fuels quickly, and be prepared to change standards as the technology develops. ●