Biogas beckons

Biodiesel may have its problems, but what about the various biogases on offer? Brian Tinham talks to engine and technology developers to assess the issues

There's a lot of talk in the industry about biofuels right now – just as there has been, on and off, for years. But how much do we really know about the alternatives, aimed at reducing our dependence on fossil fuels and cutting emissions? And, just as important, do we understand the implications of their sources, energy efficiency, the available infrastructure, costs and their requirements in terms of storage, treatment etc?

What about the engine modifications required, and the ancillary equipment and electronics being developed to run them efficiently? For that matter, what about all of the operational issues and the implications of different fuel types for maintenance and manufacturers' warranties? Ultimately, which fuels, and combinations of fuels, are likely to work best on what kinds of operations, and why?

Volvo Truck & Bus has publicly backed just two alternative biofuels for serious investment – having, just a few years ago, boasted of seven vehicles that were trialling seven fuels (see panel, page 12). Its preferred choices are now methane (natural gas from whatever source), in the dual-fuel arrangement with diesel, and DME (dimethyl ether) gas.

As Volvo director of public affairs Lennart Pilskog puts it: "We think that methane-diesel technology will work well in the European, Asian and American markets, and similarly DME, given the current plans for production in, for example, China, Japan and Iran. If you compare those fuels, methane has the advantage that it exists, although not everywhere, while DME has to be produced and distributed in separate channels. But DME offers as high an efficiency rating as a traditional diesel engine and at a lower noise level, with massively reduced climate change impact. So scaling up will be faster with methane-diesel than with DME, but DME provides a more optimal fuel for many transport operations."

So let's review those options. DME first, and a key point to note is that, while it can be produced from natural gas, it can also be processed from a variety of biomass sources – making it Bio-DME. Most important, the latter can claim a full 95% reduction in overall climate impact, compared with conventional diesel. But don't fall into the trap of assuming that means no tailpipe emissions – the savings there are more like 5%. However, DME also offers a fivefold improvement in transport kilometres per hectare of cultivated land, compared against first generation biodiesels.

Dimethyl ether

From a handling perspective, DME is a gas, but readily transforms into a liquid under low pressure (5bar, as per propane), which means it is not difficult to distribute or store – similar to LPG (liquefied petroleum gas), in fact. That does, however, mean pressurised fuel tanks.

Engine modifications to run DME are relatively minor. In 2005, Volvo trialled DME on an FM9 rigid two-axle truck, with a 9.4-litre D9 diesel engine, and that needed new electronic unit-injectors with the common-rail system. At the time, Transport Engineer speculated that Volvo was profiting from earlier work by Bosch on a common-rail system for a six-litre Cummins ISB engine to run on DME.

Needle and nozzle tolerances in common-rail injectors also had to be tightened, with higher grade materials used to minimise wear problems. Also, non-metallic seals in the fuel system had to be changed, as DME attacks plastics and rubbers

commonly used in most diesel engine fuel lines.

Today, Pilskog says simply: "We do change the injectors [which are from Delphi, not Bosch], the fuel pump, fuel lines, the electronic management system and, of course, the tanks." He also asserts that the reason for the change of injector has nothing to do with DME's poor lubricity, but is due to the "much lower pressures" required. "That is also the reason DME engines are so much quieter," he explains.

As for combustion itself, when vaporised inside the engine, DME has much in common with diesel. It's a compression-ignition fuel, so no spark plugs are needed and the resulting burn is quiet. Additionally, the fuel produces no particulates, which not only simplifies exhaust gas after-treatment, but also means that NOx emissions can be cut, using high EGR (exhaust gas recirculation) rates – making DME a natural for Euro 6.

Interestingly, DME also has a high cetane number (55–60, compared with diesel's 40–55), meaning that it ignites readily as cylinder pressure increases. Incidentally, because particulates are practically zero, the ECU doesn't have to reduce torque at standing start (as it does with diesel), so the engine effectively delivers higher starting torque values.

Volvo is currently involved in a significant project with the EU, the Swedish Energy Agency, Danish chemicals specialist Haldor Topsoe, fuel giants Total and Preem, and biofuel producer Chemrec, aimed at developing DME from black liquor – a by-product of the forestry industry. Alongside the Chemrec plant in Piteå, northern Sweden, construction has started on a facility for extracting DME from black liquor obtained from the nearby pulp plant. As part of the process energy rebalance, the cooking chemicals produced by gasification of the black liquor will be returned to the pulp plant, creating a closed loop that the team hopes will maximise 'well-to-wheel' energy efficiency.

However, there is nothing to prevent DME being produced from other sources – albeit not with the same energy efficiency. "As DME can be produced from all types of biomass, it may become viable even for countries without any major forestry industry," explains Per Salomonsson, DME project manager at Volvo Technology. "From the holistic

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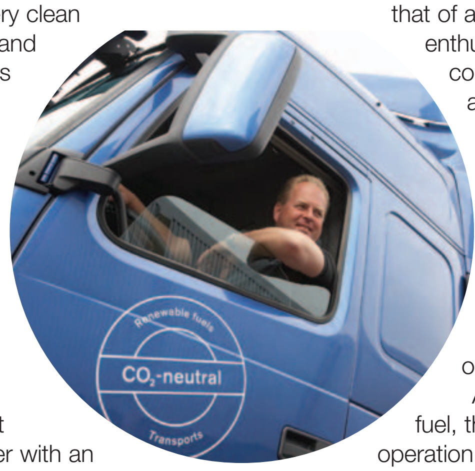
viewpoint, DME is one of the most promising second-generation biofuels," adds Lars Mårtensson, environmental affairs director at Volvo Trucks.

Currently, 14 test trucks are being built for use in field tests throughout Sweden, starting this summer. Preem is also building fuel stations, so the trucks can be used under normal operating conditions. Says Pilskog: "The field test is on Euro 5 engine trucks, but it's true that Euro 6 is within reach and probably easier with DME than diesel." However, don't expect a lurch to DME that quickly: he also points out that the development krone available for the massive Euro 6 diesel market far exceed those being applied to DME, which is still only at the early adopter phase.

Dual-fuel

So what about methane-diesel? Looking at methane (natural gas), its low carbon content means it also burns very clean – with negligible particulates – and Volvo's Mårtensson emphasises the point that it is by far the most accessible fuel realistically able to knock diesel off its perch. "There are larger reserves of natural gas than oil, but, above all, production of climate-neutral biogas is gaining momentum, which solves the most urgent problem – reducing CO_2 emissions," he says.



Volvo claimed in 2009 that it would "be the first manufacturer with an efficient diesel engine fuelled by a mix of methane gas and diesel". Field testing of its methane-diesel trucks would start in Sweden and the UK in 2010, it said – and indeed seven Swedish operators are now running with it commercially, and there are reports of biogas stations in the Nordics.

But that claim seems a little hasty, given the work already done by others – notably Clean Air Power back in 2006 and subsequently also rival Hardstaff, with its OIGI (oil ignition gas injection) technology (see page 19). Between them, they have enabled dual-fuel CNG/LNG (compressed natural gas/liquefied natural gas) and diesel conversions on Mercedes-Benz Actros and Axor tractor units, as well as on DAF CF85 in 4x2 and 6x2 configurations.

But there is a connection: Volvo concedes that, "to optimise and refine the technology, Volvo Trucks is collaborating with technology companies Clean Air Power, Hardstaff Group and Westport". With that explained, Mårtensson insists: "This technology allows us to combine the advantages of gas with the diesel engine's high efficiency, which is about 30–40% superior to spark ignition gas engines." His point is that dual-fuel trucks consume around 25% less energy than gas-only trucks. They also don't suffer their problem of restricted range (typically 150–200km). "Combining methane gas with diesel fuel, and using it in a diesel engine, increases range by over 50% and, when liquefied gas is used, that doubles again," he adds.

As for converting diesel engines for methane-diesel operation, this, too, appears to be a hurdle the engineers can get over. Volvo talks of adding special tanks for either LNG/LBG (the B signifying biogas) or CNG/CBG, and adding a separate fuel system with gas injectors for the inlet manifold, where mixing takes place. Then, in operation, a small amount of diesel is injected and ignited by the compression phase, which, in turn, ignites the methane gas/air mixture. Hence no spark plug and hence also the claimed ability to use already efficient diesel engine technology.

"Power and driveability are identical to that of a conventional diesel truck," enthuses Mårtensson. "Processors continuously calculate fuel ratio, according to the current driving pattern. The optimum [highest] proportion of gas is then achieved during smooth, stable driving," he adds. And he reassures operators currently contemplating the technology that, if the gas runs out, the truck can continue operating on diesel alone.

As for the greenness of dual-fuel, that depends on the truck operation, because the amount of gas injected has to change markedly as the engine moves through the demand cycle. "We expect to be able to run on up to 80% methane gas, once the technology has been refined and tested," claims Mats Franzén, who manages engine strategy and planning at Volvo Trucks.

"Our field tests will start with a mixture containing up to 70% methane; the remainder will consist of bio-mix diesel [fossil diesel mixed with diesel produced from renewables]," he adds.

Given a fair wind, Franzén reckons that, in the long term, the technology could cut CO_2 emissions by up to 80% from 'well-to-wheel', compared to diesel – assuming that biogas and 100% second-generation biodiesel are used. He also suggests that low methane prices and strict environmental regulations in many towns and cities will force the pace of demand for what amount to gas-powered trucks on steroids. "Methane gas is currently a relatively cheap fuel in many markets. For example, Volvo Trucks' technology already offers a profitable fuel option for trucks undertaking long daily transport jobs and returning to the same filling station," he says. TE

Gas and diesel on steroids

Mercedes-Benz's experience of methane-diesel operations and engine conversions sheds useful light on the dual-fuel story. The company's interest goes back a few years to the time when US-based Clean Air Power – then one of the leaders in CNG/LNG and diesel technology for diesel engines – was working with Kingston-on-Soar-based Hardstaff Haulage, which had itself been doing pioneering work with natural gas-powered heavy transport.

Clean Air Power and Hardstaff went their own ways – the former with its Genesis system and Hardstaff on its OIGI (oil ignition gas injection) alternative, developed with help from Loughborough University, which reputedly harnessed aerospace technology for the job (Transport Engineer, April 2009, page 18). Although both use diesel compression to propagate ignition of the gas and both use a box of electronics to enable variable gas intake to match engine demand, that's where the similarity ends.

Nick Blake, sales engineering manger for Mercedes-Benz vans and trucks, explains that his organisation went with Hardstaff, partly because of Hardstaff Haulage's clear commitment to gas-powered heavy-duty operations in its own truck fleet and partly because Mercedes felt the OIGI approach had an edge.

"There were several factors," says Blake. "Hardstaff's system for treating methane slip [across the inlet and outlet ports] seemed better and they introduced a high-temperature catalyst methane trap in the exhaust." That matters, because methane emissions are orders of magnitude worse than CO_2 in terms of climate change potential. "But the equipment also delivers slightly better methane substitution and it works completely independently of our engine management system," he adds.

Mercedes-Benz has worked with Hardstaff for around two years, and also has several converted Actros and Axor tractor units in operation with other customers. Blake cites Howard Tenens and Newark Haulage on heavyweight operations, and Plaxton on Midibuses in Lincolnshire. Late last year, Optare announced a separate deal with Hardstaff, also using Mercedes engines, and Blake mentions "orders for over 60 vehicles to be converted".

"Broadly, Hardstaff inserts a sandwich plate between the cylinder head and inlet manifold, and manages sequential injections of the gas into the manifold, not the cylinder itself, to get a good gas-air mixture before it hits the combustion chamber," says Blake. "Because we maintain a flow of diesel through the injectors, lubricity is not a problem and there aren't the issues with lubricant dilution in the bottom half of the engine, as with biodiesel," he adds.

Loughborough University optimised injector design and electronics for the gas management system, and the result is a system that substitutes gas for diesel, while also managing injection timing, without interfering with the ECU or the CANbus. Few details are available, but Hardstaff's OIGI apparently intercepts the signal from the ECU to the diesel injectors, and uses that to control gas injection and cut diesel volume. It does so without causing problems for the vehicle's other functions, such as the auto transmission, which needs to believe fuel is flowing in line with the demand signal. And it uses a lambda oxygen sensor in the exhaust to gauge combustion efficiency and adjust the diesel/gas ratio accordingly.

As for vehicle conversion costs, Hardstaff quotes from £13,000 for a single-cylinder CNG on a Euro 3 vehicle, to £25,000 for a three-cylinder CNG system on a Euro 5 truck. Clean Air Power says simply that £22,000 is an average cost. Blake says payback is only going to be within two years, if your operation involves high horsepower double- or triple-shifting, with some serious mileage and returning to base for regular refuelling. So it's not ideal for low mileage trunking, but can work for municipal vehicle operations where duty cycles equate to high fuel consumption.

For Mercedes, the issues of gas/diesel dual-fuel are no longer technical; it's all about the CNG/CBG supply infrastructure. Sainsbury's experience, with its dual-fuel Axor tractors on Clean Air Power's Genesis, makes the point eloquently. In its case, LBG comes from Gasrec's anaerobic digester at a landfill site in Albury, Surrey – so it's carbon neutral. But then it's carried by tanker to a Chive Fuels LNG station at Severn View, close to Sainsbury's distribution depot in Bristol – so it's no longer carbon neutral. The day that biogas is connected to the grid and integrated into filling stations is the day it can really score.