Next stop, hybrids

LCVs seem to be leading the way, in terms of hybrid technology in the CV world. But bus and coach operators are anticipating growing numbers of alternatives to conventionally-powered vehicles, reports John Challen

The Stern report, published in 2006, warned of a 'serious economic downturn unless prompt action was taken to reduce greenhouse gases'. Time will tell whether the recent recession could have been ameliorated, if society had acted sooner on combating that particular problem, but then-Prime Minister Tony Blair saw enough to warrant calling the document 'the most important report on the future I have received since becoming Prime Minister'.

Four years later and the response from the transport sector has been remarkably proactive. LCVs are trialling various technologies to lessen the impact of greenhouse gases, and the bus and coach sector, too, is looking for solutions. Figure 1 (below) shows a snapshot of where the industry stands with regards to available alternative fuels and technologies to deliver lower carbon vehicles.

So what's happening? One of the biggest deals is London's ambitious plan for hybridising its bus fleet. Of the 56 hybrid units currently running in the UK's capital (see panel on p20), 17 have been provided by Alexander Dennis. ADL hybrids programme manager Andrew Boulton is monitoring their progress carefully and comments that, so far, there have been advantages and disadvantages.

"In a series hybrid, the diesel engine is decoupled from the road wheels and can operate independently of speed. It can run in its most efficient operating range and is not subject to the rapid rpm changes that are prevalent in normal bus operations," he observes. Such a scenario allows the bus to achieve better fuel consumption, as well as reducing NOx and particulates emissions – again, a benefit of rpm being held within the engine's sweet spot.

"As the final drive is electric, there is no gearbox and, as such, no gear changing, so the drive is smooth and stepless," continues Boulton. "Also, since the engine tends to be operating in a narrow operating band, the unit tends to be quieter than the traditional diesel version."

However, Boulton believes bus operators shouldn't get too carried away just yet. "The weight of the battery, motor and generator are greater than the weight of the gearbox they replace," he warns. "Hybrid technology is also relatively new and, with trial vehicles currently at an early stage of development, there will be some early life issues as manufactures ramp up the learning curve."

There are also concerns about safety. While not stirring the same fear as hydrogen-fuelled transportation, the high voltage levels in bus depots leave some worried about hybrids' maintenance. "The systems themselves are inherently safe, but

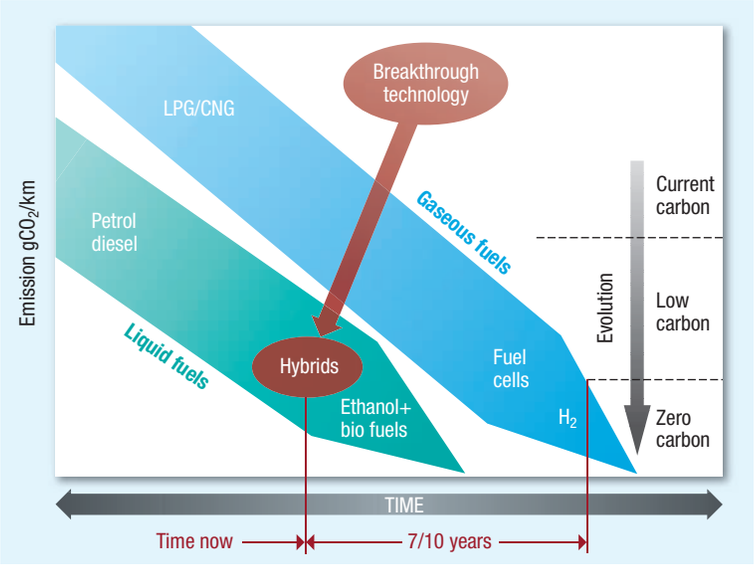

Figure 1: Illustration of the possible alternative fuel sources available now, and in the future

there are perceived concerns with high voltage safety," concedes Boulton. "As a result, there is a further training requirement for operators."

On the subject of power and range, key to getting hybrids right, he says, is to maximise brake energy recovery and, for this reason, the battery on ADL's hybrids has been selected for its ability to accept power. "The vehicle is configured so that it will start regenerative braking as soon as the throttle pedal is released," he explains. "In addition, the first inch or so of movement on the brake pedal is only for activation of regenerative braking. As such, the driver can control the vehicle without having to rely on the foundation brakes. Regenerative braking can slow the vehicle to a full stop."

Beyond that, the ADL hybrid is designed to be load following: it almost operates as a diesel-electric, with the batteries really only used to collect regenerative braking energy and to supply power to the vehicle in pulling away. Hence the battery charge swing is well managed, which results in a long service life – another key to success.

Options open at Optare

What about Optare? Development work on its Eco Drive hybrids is based on two technologies: a diesel-electric platform, from two well established companies, and a new mechanical technology. And, with 10 of its Tempo low-floor, heavy-duty, single-deck hybrid models now in service in London, Optare reckons it is gaining valuable real-world experience in diesel-electric hybrid technology.

Tempos use the Allison EP40 system, of which over 1,000 are now in service around the world. The main power unit is the Cummins 250hp ISBE Euro 5 engine and the system incorporates a dual power inverter. Six Panasonic nickel metal hydride batteries, as used in the Toyota Prius, are installed and can be replaced on a fixed price basis.

Table 1: Cost of ownership

ADL double deck hybrid life cycle cost calculator

Bus operating day	16	(hours)
Average speed	10	(mph)
Annual mileage	49,920	
Hybrid Fuel Consumption	6.89	(mpg)
ISBe Euro 4 fuel consumption	5.3	(mpg)
ISCe Euro 3 Fuel Consumption	5	(mpg)
Base diesel price	1	(£/litre)
Fuel Price (after Bus Operators Grant)	0.57	(£/litre)
Fuel Inflation	0	(%)
Average fuel cost (inc inflation)	0.57	(£/litre)
Bus Operators Grant (today)	0.4321	(£)
Bus Operators Grant Percentage	100	(%)
Hybrid Fuel Consumption Improvement	30	(%)
Urea consumption by fuel	5	(%)
Urea Price	0.3	(£/litre)
Lubricant cost (mineral)	0.45	(£/litre)
Hourly rate	20	(£/hour)
Time to complete oil change	0.5	(hours)
Oil Volumes Used / change		
ISBe4 6 cyl	20.5	(litres)
ISBe4 4cyl	15	(litres)
ISCe3 6cyl	23	(litres)
Oil Disposal Cost	0.4	(£/litre)
ISBe Euro 4 Filter Cost	18	(£)
ISCe Euro 3 Filter Cost	23	(£)
Oil change period		
ISBe4 6 cyl	16	(weeks)
ISBe4 hybrid 4 cyl	18	(weeks)
ISCe3 6cyl	12	(weeks)
Recon Engine Prices		
ISBe4 6 cyl	5,300	(£)
ISBe4 4cyl	3,800	(£)
ISCe3 6cyl	6,000	(£)
Operation assumed to be	6	(days per week)
Assumed Engine Life		
ISBe4 6 cyl	6	(years)
ISBe4 4cyl in hybrid	10	(years)
ISCe3 6cyl	7	(years)
Total Vehicle Life	12	(years)
Battery life	7	(years)
Battery cost	30,000	(£)
Brake disc life	3	(years)
Brake pad life	1	(years)
Brake disc cost (vehicle set)	600	(£)
Brake pad costs (vehicle set)	400	(£)
Brake life improvement with hybrid	50	(%)
Motor life	12	(years)
Motor service costs/year	100	(£)
Motor overhaul cost	3,000	(£)
PCS Replacement cost	2,500	(£)
Generator life	12	(years)
Generator service costs	150	(£)
Generator overhaul cost	1,800	(£)
Gearbox cost	6,000	(£)
Gearbox service costs per year	150	(£)
Gearbox life	8	(years)
Diesel bus price	190,000	(£)
Hybrid bus price	314,500	(£)

When London's red buses go green

Gearing up for the greenest Olympics ever gave London the opportunity to implement an ambitious plan to hybridise its red bus fleet. From when the first buses arrived on the fleet in December 2008, Transport for London (TfL) wanted to involve as many manufacturers as possible, who would trial as many hybrid offerings as they could.

"We split the 56 initial buses in the hybrid fleet among different operators in London to allow them to get experience and knowledge of hybrid buses," explains Mike Winter, fleet development manager at TfL. This meant seven operators running 10 routes, using buses from four OEMs. All the vehicles had different battery types, technologies and theories as to how a hybrid should work most effectively.

The results, says Winter, have not been without complications. "Battery and power supply are major factors," he says, confirming that it is most likely that lithium-ion will win out over gel lead acid batteries. "It was quite a task to keep them at the right state of charge and there were other issues, such as regulating them off and on the vehicle. The initial lead acid battery type has not proven to be the most successful, but manufacturers are modifying these vehicles to put in the latest lithium-ion battery packs."

Other problems have seen software systems replaced or upgraded to cope with London's operating conditions and brand new, smaller diesel engines put in the buses. Winter confirms that these alterations have been made by the bus manufacturers through their own development processes.

He also says that, throughout, electric motors have not given any serious problems. "We have series, parallel and blended hybrids on the fleet, but ultimately they are all driven by electric motors. Some are incorporated into a gearbox, which has a motor inside, but we have had no problems and none has been replaced through wear and tear."

Maintaining the new-look fleet

"We asked the manufacturers to provide vehicles that would fit into the standard maintenance systems we operate in each depot," explains Winter. "We have 8,500 buses in London and to introduce 56 more that had to be maintained in a different way, across a number of operators, could have led to headaches. So [the manufacturers] had to fit into our standard maintenance procedures and so far that's been working very well."

Hybrid buses are serviced alongside standard vehicles and general maintenance processes are roughly the same, he says – despite the differences, in terms of smaller engines and no gearbox. "They are different and are a change to what we are used to, but they have fitted in with the 28-day servicing periods we operate," continues Winter.

Obviously, when the service engineer visits the vehicle, there are different components to look at, compared with a standard bus. Manufacturers have assisted operators here, making sure they're aware of the changes and highlighting what technicians should be looking for during servicing. The biggest difference is dealing with higher voltages – 660V and 330V for double and single deckers respectively. Rest assured, the technicians have been trained in how to approach those voltages.

Winter is confident that hybrids will continue to make up an ever increasing percentage of the London fleet. Half a dozen more will take the hybrid fleet to 62 by the end of 2010, rising to 300 by 2011. By 2012, TfL has confirmed that all new models entering service will use hybrid technology.

Interestingly, EP40 also comes with a two-year warranty, extendable to five years.

Both the Optare Versa and Solo lightweight, low-floor models will be available shortly with the Siemens series hybrid drive, matched to the Mercedes-Benz OM904La Euro 5 engine. This system uses two drive motors, with a combined gearbox and a single generator, as in the Mercedes-Benz Cito. ISE super capacitor energy storage is employed, and the electrical system and engine cooling unit are roof-mounted.

How much for a hybrid?

Initial costs for all hybrid products are above those of standard diesel vehicles. For the field trial vehicles, we're talking about 65% extra for a double decker and 85% for a single decker. Over time, however, everyone expects demand and volumes to reduce costs – although maybe not dramatically.

That said, the issue is to assess the economics of hybrid bus operation and also to calculate the effects of emission reduction – and, for this, fleet managers need to look at whole life cost of the vehicle. Let's look at ADL's example of an Enviro400 hybrid, compared against the cost performance of a Euro 4 and Euro 3 diesel vehicle.

If we assume most subsystems remain the same, the only aspects likely to change cost of ownership are the engine, gearbox, motor, generator, battery and brakes. In this example, the engine is downsized from the six-cylinder ISBe and also its duty cycle will be lighter – meaning a longer life and oil drain interval.

Also, the hybrid vehicles are not fitted with automatic gearboxes, but do have a motor, generator, battery and PCS. Then again, the braking system of a hybrid is more lightly used, owing to the more efficient operation of regenerative braking compared with conventional retarders.

ADL provides a spreadsheet that calculates the difference in cost of ownership by assessing the annual cost of operating and maintaining a conventional vehicle, based on fuel oil and adblue, against that of a hybrid, including the cost of maintaining the transmission, hybrid system and batteries. Assumptions on unit life are all changeable, to allow for operators' experience and perceptions.

Table 1 – previous page – assumes that a vehicle operates 16 hours a day for six days a week at an

average speed of 10mph, covering around 50,000 miles a year. Calculating average fuel consumption and service life of the components, using the data supplied, the spreadsheet provides operators with the cost per annum to operate a Euro 4 and hybrid vehicle, benchmarked against a Euro 4 Trident.

In addition, the sheet calculates costs over the life of the vehicle, including or excluding major overhaul components, and CO_2 saved. Incidentally, the calculation takes into account fuel price rises and the percentage rebate for the BSOG (Bus Service Operators Grant), again programmable. Importantly, it shows that, if we keep the BSOG as it currently stands, then the hybrid saves nearly £60,000 over the life of the vehicle. However, if BSOG is discontinued, the result is nearer £130,000.

Clearly, there are engineering and fiscal challenges ahead for bus operators, not least of which are the performance of batteries and the extra mass from the electric motors and battery pack. But, looking at the UK as a whole, hybrid buses are likely to become the majority population before long.

Following the London experience, Oxford and Manchester have taken delivery of hybrid buses, which will enter service by August. With further developments likely in batteries and electric motors, as well as internal combustion engines, many more cities and towns are likely to follow suit soon. TE

For further information on technology and suppliers, visit www.transportengineer.org.uk

Preheating hots up hybrids

Heat exchange specialist Grayson Thermal Systems is one company working on a portfolio of projects for both hybrid drive and conventionally-powered buses and coaches.

Despite a great deal of investment in hybrid propulsion, this firm makes the point that large-scale replacement of existing fleets is not viable, so it is developing systems that can be retrofitted to minimise operators' outlay, yet still bring benefits.

Each is designed to help operators boost performance, cut energy costs and reduce emissions. For example, Grayson is developing a thermal resistor that removes the current requirement for diesel fuel heaters on hybrid drive vehicles (Transport Engineer, January 2010, page 14).

"We have been working with a major manufacturer of hybrid drive systems on a project to boost passenger and driver comfort in hybrid drive buses," reveals Grayson managing director Stuart Hateley.

Pre-production models are being evaluated in UK field trials and at Grayson's facility, with an expected production start date of July this year. "Our research indicates that using the thermal resistor will enable hybrid drive vehicles' diesel engines to warm up faster and to run more efficiently, leading to even lower fuel consumption," asserts Hateley.